The interventions of physical education by using augmented reality based mobile learning can significantly improve gross motor skills in elementary school students

Las intervenciones de educación física mediante el uso de aprendizaje móvil basado en realidad aumentada pueden mejorar significativamente las habilidades motoras gruesas en estudiantes de primaria

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Abstract

Introduction: Physical education interventions outside of school that use augmented reality mobile learning can be an effective method to improve students' gross motor skills in primary school. The novelty of this study, learning media is packaged into an application that runs on a mobile device.
Objective: The aims of the study was to prove that interventions of physical education by using augmented reality based mobile learning can significantly improve gross motor skills in elementary school students.
Methodology: The study examined the effects of physical education by using augmented reality based mobile learning. This study used 60 participants who were divided into two groups: the intervention group and the control group. The instrument used was the Test of Gross Motor Development Second Edition (TGMD-2) to evaluate the growth pattern of gross motor skills. The data analysis techniques used were normality test, influence test, and independent samples t-test.
Results: The results showed that interventions of physical education by using augmented reality based mobile learning, provided a greater improvement in gross motor skills. The control group showed the least change.
Discussion: The interventions of physical education by using augmented reality based mobile learning can significantly improve gross motor skills in elementary school students.
Conclusions: These findings may guide options for those looking for effective ways to improve gross motor skills especially for early childhood. The interventions of physical education by using augmented reality based mobile learning can significantly improve gross motor skills in elementary school students.

Keywords

Augmented reality; mobile learning; motor skills; physical education; students.

Resumen

Introducción: Las intervenciones de educación física fuera de la escuela que utilizan el aprendizaje móvil con realidad aumentada pueden ser un método eficaz para mejorar las habilidades motoras gruesas de los estudiantes en la escuela primaria. La novedad de este estudio es que los medios de aprendizaje están empaquetados en una aplicación que se ejecuta en un dispositivo móvil.
Objetivo: El objetivo del estudio fue demostrar que las intervenciones de educación física mediante el uso de aprendizaje móvil basado en realidad aumentada pueden mejorar significativamente las habilidades motoras gruesas en estudiantes de escuela primaria.
Metodología: El estudio examinó los efectos de la educación física mediante el uso de aprendizaje móvil basado en realidad aumentada. Este estudio utilizó 60 participantes que se dividieron en dos grupos: el grupo de intervención y el grupo de control. El instrumento utilizado fue el Test of Gross Motor Development Second Edition (TGMD-2) para evaluar el patrón de crecimiento de la motricidad gruesa. Las técnicas de análisis de datos utilizadas fueron la prueba de normalidad, la prueba de influencia y la prueba t para muestras independientes.
Resultados: Los resultados mostraron que las intervenciones de educación física mediante el uso de aprendizaje móvil basado en realidad aumentada proporcionaron una mayor mejora en las habilidades motoras gruesas. El grupo de control mostró el menor cambio.
Discusión: Las intervenciones de educación física mediante el uso de aprendizaje móvil basado en realidad aumentada pueden mejorar significativamente las habilidades motoras gruesas en estudiantes de primaria.
Conclusiones: Estos hallazgos pueden orientar opciones para quienes buscan formas efectivas de mejorar las habilidades motoras gruesas, especialmente en la primera infancia. Las intervenciones de educación física mediante el uso de aprendizaje móvil basado en realidad aumentada pueden mejorar significativamente las habilidades motoras gruesas en estudiantes de primaria.

Palabras clave

Realidad aumentada; aprendizaje móvil; habilidades motoras; educación física; estudiantes.

Introduction

Basic motor skills in children are divided into three categories: locomotor, non-locomotor, and manipulative movements. Manipulative skills fall under the category of gross motor, as they involve the use of large muscles of the body (Ferriz-Valero et al., 2020). Motor science focuses on the study of movement. It is important to provide learning about motor science to children from an early age so that they can develop their movement skills optimally (Mokmin & Rassy, 2024). A child's motor skills can be a significant indicator, as bones, muscles, and the nervous system play an important role in movement. There is a close relationship between gross and basic motor skills in children (Wang et al., 2020).

The decline in gross motor skills in early childhood has been the focus of various studies. In the modern era, this decline in skills is often influenced by a variety of factors, including changes in lifestyle, environment, and parenting patterns (Calabuig-Moreno et al., 2020). The increase in sedentary lifestyle, which is characterized by the habit of sitting for long periods of time at home as well as at school, causes children to be less involved in physical activity that is essential for the development of their gross motor skills (Lizandra et al., 2020). One of the efforts to intervene in the decline of gross motor skills in early childhood is by providing physical education learning that has been carried out in schools (Mata et al., 2021).

To improve children's motor skills, students need resources for sports education that facilitate physical activity at school and outside of school (home). However, research shows that primary schools often lack complete facilities and infrastructure for effective sports learning (Guindos-Sanchez et al., 2020). In addition, the frequency of students only doing physical education learning only once a week. During the implementation of learning plans at school and at home, a study shows that 100% of physical education learning is carried out in schools (Liang et al., 2023). This shows that physical education is only applied in schools and is not implemented at home with the guidance of parents or guardians (Rey et al., 2020).

The problem is that physical education learning in conventional schools is considered less effective in improving gross motor skills in early childhood is crucial. Physical education learning provided in schools only has a very limited learning time, only done once per week (Cocca et al., 2020). It can be concluded that this short duration is not enough to provide continuous and effective gross motor stimulation (Freitas da Silva et al., 2020).

Based on this problem, innovations are needed in physical education learning media outside of school which is additional learning as a preventive measure to prevent the decline of gross motor skills in early childhood (Sutapa et al., 2021). The rapid development of the times and the significant impact of advanced technology encourage professionals in the field of education to conduct in-depth research and develop educational technology, from planning to application and evaluation in the learning process (Aye et al., 2023). The use of digital-based physical education learning media is believed to be able to adapt to the progress of this modern era (Samodra et al., 2023).

Prevention efforts can be made by teachers by providing additional physical activities for students that can be done at school (Criollo et al., 2021). The research conducted by (Botagariyev et al., 2024), creating a web-based physical education learning media that presents e-modules on physical education learning for students can significantly increase student learning motivation. However, the limitation of web-based physical education learning media is that the material provided is less real and not interactive (Martínez-Rico et al., 2022).

Physical education is essential for fostering lifelong health and wellness in people of all ages. As society becomes more inactive, high-quality physical education programs are crucial for addressing increasing rates of obesity, heart disease, and other health-related problems (Junior et al., 2022). Recently, technological advancements have created promising avenues to improve the effectiveness of physical education and boost student engagement (Botagariyev et al., 2024). One notable innovation is the Augmented Reality Exercise Monitoring System (AREMS), which provides real-time feedback and personalized coaching to enhance exercise performance and learning results. Traditional methods of teaching physical education often depend on instructor-led demonstrations and verbal instructions to convey exercise techniques and track student progress (Sundawan et al., 2023). Nonetheless, these

approaches may lack accuracy and timely feedback, which can hinder their effectiveness in meeting individual learning needs and facilitating skill development.

The emergence of digital technologies has profoundly changed the educational environment, introducing innovative teaching methods that address the varied learning needs of today's students. One notable technology is Augmented Reality (AR), which effectively combines the real world with virtual components, resulting in immersive learning experiences that boost engagement and motivation across different fields, including sports education. Recent research has pointed out AR's ability to enhance learning outcomes by offering interactive and contextual learning settings that encourage students to connect more deeply with the material (Fuentes-Nieto et al., 2022).

Previous research explained that physical education interventions based on the Augmented Reality Exercise Monitoring System (AREMS) can significantly increase the motivation of adolescent students in physical education (Criollo et al., 2021). Technology-based physical education can significantly improve physical education learning outcomes in adolescent students because learning is flexible and can be done anywhere. The research was conducted by (Martínez-Rico et al., 2022) creating an innovation in physical education learning media inspired by online fitness coaching. The results of the study show that physical education learning media intervention based on the Augmented Reality Exercise Monitoring System (AREMS) can significantly increase the level of physical activity in adolescent students. Physical education based on the Augmented Reality Exercise Monitoring System (AREMS) can be applied outside of school, so students can do it anytime and anywhere (Junior et al., 2022).

Based on previous research, it was stated that physical education learning media based on the Augmented Reality Exercise Monitoring System (AREMS) media is very useful for improving physical education learning outcomes. Previous research was only limited to examining the intervention of physical education learning media based on the Augmented Reality Exercise Monitoring System (AREMS) media on motivation, learning outcomes, and physical activity levels in adolescent students who are used to using technology, while in the early age student group has not been widely discussed. The novelty of this study, the application of physical education learning outside of school using augmented reality based mobile learning in early age students. Learning media is packaged into an application that runs on a mobile device.

Augmented reality-based mobile learning applications in physical education learning are designed to help children recognize various movements that can increase physical potential and motor literacy (Dhar et al., 2021). In addition, this augmented reality-based mobile learning program will also provide complete information about the physical education curriculum to parents or guardians of students, so that it can increase the active participation of students at home with the assistance of parents or guardians (Liang et al., 2023). The application of augmented reality-based mobile learning applications involves collaboration between teachers, children and parents so that it can increase parents' awareness of the importance of gross motor development, so that children's physical activity becomes a priority (Sucipto et al., 2021).

This study aims to provide learning media innovations in physical education using augmented reality based mobile learning applications that can be done outside of school to improve early childhood gross motor skills. The design of augmented reality-based mobile learning physical education for the elementary school level is made based on findings in the field through curriculum planning, implementation, and evaluation. This program aims to support teachers, students, and parents in the process of planning, implementing, and assessing physical education learning, so that it can connect activities at school and at home, and help improve students' gross motor skills. The augmented reality based mobile learning physical education program is presented through application-based digital media, which provides information about teaching planning, learning implementation, learning media, and evaluation (Mokmin & Rassy, 2024). The program can be accessed online by parents and students from home, and allows them to provide feedback to teachers regarding the material and the implementation of physical education learning at home.

Method

Study design

This study applies an experimental method involving two groups, namely the control group and the intervention group. The research design used is pre-test and post test design. A total of 60 students became participants who were divided into two groups for this study, participants consisted of 48% female students and 52% male students. A total of 30 participants joined a group that was given additional learning interventions in physical education using augmented reality-based mobile learning applications outside of school. Meanwhile, as many as 30 other participants were incorporated into a group which was a control group (no intervention was given). The intervention was given for eight weeks involving collaboration between teachers, students, and parents. The program can be accessed online by parents and students from home, and allows them to provide feedback to teachers regarding the material and implementation of physical education learning at home.

Table 1. Analysis of the quality of physical education learning media by using virtual reality-based mobile learning

Media quality analysis procedure	Details
Identify the problem	The researcher made additional observations to find out the media used in physical education learning. The media used are tools used in direct learning, such as cones, balls, and mats. However, not all students have access to the media used by teachers during learning through the zoom platform or other online applications such as Google Meet or WhatsApp Group. After identifying these problems, the researcher formulated the idea to develop virtual reality-based mobile learning learning media in physical education, with the aim of increasing the active participation of students in accordance with the curriculum.
Describe the purpose	The general purpose of this study is to design and develop learning media that can overcome or provide solutions to the problem of declining gross motor skills. This additional learning is carried out entirely online from each other's homes, to make it easier for children and parents to learn together. Thus, this research aims to develop virtual reality-based mobile learning learning media that is integrated in physical education learning in accordance with the curriculum.
Product design and development	The design and development stage of this virtual reality-based mobile learning product follows the ADDIE development model (analysis, design, development, implementation, evaluation). The process begins with an analysis of the problems that arise in distance learning and online. This includes an analysis of the achievement of indicators to set limits on application materials, as well as an analysis of the software and hardware used to create the learning media. After that, the design stage was carried out by compiling the Media Program Outline (GBPM) and storyboard. In the development stage, researchers collected images from Google, edited with Adobe Illustrator software, and made a prototype of a virtual reality-based mobile learning application. In the implementation phase, the researcher applies the media that has been developed to the predetermined research subjects. The last stage is evaluation, which aims to assess the efficiency and effectiveness of learning media through instruments and validity tests by media and material experts.
Field trials of developed products	The prototype that has been made then undergoes an assessment by experts through an expert judgment process. This assessment is also known as a limited initial trial to validate the product before it is tested in the field. The field trial involves testing the product directly to users, namely teachers, students, and parents/guardians of SD Labschool Unesa. This stage of testing aims to identify deficiencies in the developed product. After the trial, the defects found will be used as a guide for the next stage of development, in order to make improvements and provide input on the products that have been created.
Evaluation of test results	Evaluation of field trial activities is the fifth step in design and development research. The purpose of this evaluation is to identify any deficiencies that arise during the trial, which will be used as a basis for improvement and decision-making in subsequent product development. The evaluation process was carried out by distributing questionnaires and conducting interviews to collect data related to the use of virtual reality-based mobile learning.
Communicate test results	After completing the previous stages, at this stage the results of data analysis will be presented in the form of a written report which will then be presented in the dissertation session. The results of this research are expected to provide benefits for the learning process, increase knowledge insights in the institution, and provide new ideas for the next researcher.

Research steps

The app can be run on a mobile phone and installed on a parent's or guardian's phone by following the instructions that appear during the installation process. After that, parents/guardians can open the application by clicking the start button. Next, the camera will automatically be activated to scan images used as a medium to display moving objects, as if looking directly at objects in the real world. The moving object can be seen from various angles by rotating the scanned drawing paper. This augmented reality media is interesting to develop, because it can motivate students to move according to the movements shown by augmented reality media.

Table 2. Physical education content using augmented reality-based mobile learning

Content items	Content details
Student bio	The student's name, date of birth, grade, and body mass index, and the name of the student's parents.
Parent attendance list	as a sign that parents accompany students during physical activity tutorial activities.
Student attendance list	as a sign that students follow physical activity tutorials consistently and continuously.
Exercise content	Exercise week-one (basic athletics: sprinting, relay running, long jump, and throwing a ball) Exercise week-two (small ball game: hitting, catching, and throwing activities. Examples of badminton games, caste games, and table tennis) 3. Exercise week-three (big ball games: football, volleyball, basketball) Exercise week-four (physical fitness activity: coordination, strength, and flexibility exercises through simple exercises) Exercise week-five (basic gymnastics: floor gymnastics activities such as front rolls, back rolls, candle postures) Exercise week-six (gymnastics activity: students imitate the video tutorial of rhythmic movement activities) Exercise week-seven (traditional games: games such as hide and seek, congklak, bangkiak, and other traditional Indonesian games) Exercise week-eight (water activities: basic teaching such as floating, and playing in the water safely)
Log book	A practical tutorial notebook for physical activities is a document that serves to record various activities, events, or important information in detail and structured in chronological order. Students can report tutorial activities in the form of photos or videos of practice activities.
Student feedback	Students' responses to the activities/activities given, for example "I am very happy and can follow well the tutorial of the activities given".
Parent feedback	Parents' responses as companions to the physical activity tutorial given, for example "my child does the physical activity tutorial well"

The intervention was carried out for eight weeks consisting of eight main materials. The intervention process lasted for eight weeks, starting from the end of January to the beginning of April 2024. Every week students get varied materials/exercises. Table 2 displays the content of physical education by using augmented reality based mobile learning. The content contains physical activity tutorials that are presented interactively using video media. The presentation of the video physical activity tutorial makes it easier for students to practice the physical activities given. Students are required to practice tutorials at least three times a week. Student participation can be known from filling out the tutorial practice log book, and synchronization in the aspect of monitoring the attendance list of students and parents, monitoring student and parent feedback. Students are declared dropped out as participants if they do not practice tutorials less than three times a week. In this study, all participants were declared worthy of being research subjects because they followed the intervention in accordance with the regulations.

Research instruments

The tool used in this study is the Test of Gross Motor Development Second Edition (TGMD-2) to evaluate the growth pattern of gross motor skills in children aged 3 to 13 years (Rey et al., 2020). The test is divided into two categories: object control skills and locomotor skills. TGMD-2 was recognized as a legitimate and credible instrument for evaluating gross motor development in children. This tool was specifically designed to assess gross motor skills in the context of specific physical activities (Aye et al., 2023).

Locomotor skills include activities such as running, jumping, stepping, gliding, jumping on one leg, and jumping forward. Meanwhile, object control skills include activities such as throwing, catching, kicking, hitting, and dribbling. By utilizing TGMD-2, researchers can assess student development before and after the intervention. The measurement steps are that all participants are measured locomotor skills and object controll skills, followed by raw scores from the locomotor and locomotor skills test. Next, the raw score is converted to a standard score, then the standard score is added between the locomotor and object control skills tests so that the final result is a gross motor quotient (GMQ) score (Aye et al., 2023).

Use the following categories to interpret the results, a score of ≥130 is Very Superior, a score of 120-129 is Superior, a score of 110-119 is Above Average, a score of 90-109 is Average, a score of 80-89 is Below Average, a score of 70-79 is Inferior, and a score of ≤ 69 is Very Inferior. Thus, it can be ensured that this instrument meets the standards of gross motor skills assessment that are valid and reliable among children in Indonesia (Sutapa et al., 2021).

Data analysis techniques

The research used was a parametric study, which used a normality test, an influence test to test the effects of the intervention given, and an independent samples t-test to test the difference. All statistical analyzes were carried out using the SPSS version 21 application for Windows 10.

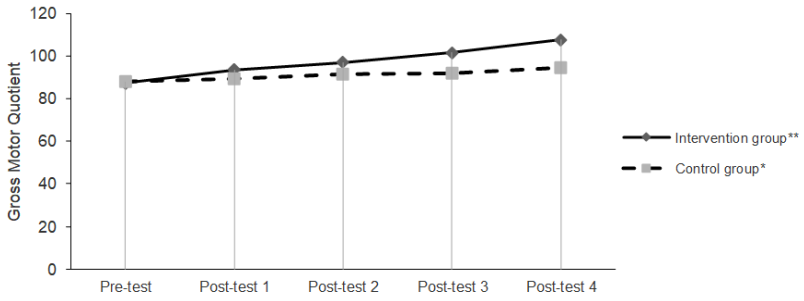
Results

The results of the analysis of participant characteristics are presented in Table 3. Based on Table 3, there were no significant differences in participant characteristics including age, weight, height and body mass index (all $p < 0.05$).

Table 3. Participant characteristics

Parameters	Mean ± SD		p-value
	Intervention group	Control group	independent samples t-test
Age (years)	9.10±4.70	9.18±3.30	0.921
Height (cm)	1.36±0.02	1.37±0.05	0.875
Weight (kg)	39.60±5.20	40.30±4.40	0.794
Body Mass Indeks (kg/m)	21.52 ± 2.81	21.55 ± 2.12	0.998

Figure 1. The effect of the intervention on gross motor quotient of intervention group and control group



Description: post-test 1: conducted in week two during the intervention, post-test 2: conducted in week four during the intervention, post-test 3: conducted in week six during the intervention, and post-test 4: is the final post-test conducted after 8 weeks of the intervention. *: the intervention given was not significant, **: This shows that the intervention given has the highest improvement in gross motor skills compared to other interventions ($p<0.05$).

Table 4. The difference test between the intervention group and the control group

Gross Motor Quotient	Intervention group	Control group	p-value independent samples t-test
Pre-test	87.30 ± 2.10	88.10± 1.90	0.820
Post-test 1	93.60 ± 1.80**	89.40 ± 1.10	0.001
Post-test 2	97.10 ± 1.20**	91.50 ± 2.30	0.001
Post-test 3	101.70 ± 1.30**	92.10 ± 1.50	0.001

Description: post-test 1: conducted in week two during the intervention, post-test 2: conducted in week four during the intervention, post-test 3: conducted in week six during the intervention, and post-test 4: is the final post-test conducted after 8 weeks of the intervention. **: This shows that the intervention given has the highest improvement in gross motor skills compared to other interventions ($p<0.05$).

Discussion

Digital-based learning media innovation for physical education subjects can be a creative solution in improving children's gross motor skills. These digital media can be designed to offer an interactive, fun, and educational experience, which optimally supports children's gross motor development (Pérez-Muñoz et al., 2024). The findings of the study showed that the intervention of physical education learning media innovation using mobile learning applications carried out outside of school can significantly improve early childhood gross motor skills.

Physical education interventions that utilize augmented reality (AR)-based mobile learning are an innovation with great potential in improving students' gross motor skills at the primary school level (Mokmin & Rassy, 2024). Augmented Reality (AR) allows students to interact with virtual objects in a real environment, making learning activities more engaging and actively engaging students (Susanto et al., 2022). Learning that utilizes technology is usually more attractive to students, especially for the generation that has become accustomed to mobile devices (Koryahin et al., 2020). AR can display live demonstrations of gross motor movements such as running, jumping, or catching through virtual avatars that serve as guides. AR applications can also provide a real-time assessment of the accuracy of students' movements, helping them improve their skills independently thanks to feedback provided in real time (Mata et al., 2021).

Intervention in physical education through the use of augmented reality (AR)-based mobile learning is an innovative learning medium to improve gross motor skills among elementary school students (Lizandra et al., 2020). AR technology integrates virtual elements with real environments, allowing students to interact with digital objects in fun and educational physical activities (Yang et al., 2021). In physical education, AR can offer an immersive experience that supports students in understanding and executing gross motor movements such as running, jumping, throwing, and catching through realistic visual simulations (Qi, 2021). This learning method is not only interesting for students, but it also provides a step-by-step guide that makes it easier for them to understand movement techniques correctly (Pérez-Pueyo et al., 2021). In addition, this learning is arranged so that the level of difficulty is in accordance with the ability of each student, so that the learning process becomes more personal and effective. AR supports students in developing gross motor skills gradually, from basic mastery to more complex levels (Vega-Ramírez et al., 2020).

Research shows that the use of AR in physical education can increase students' motivation to participate in physical activity. Students feel more interested because the digital media used resembles a game, making the learning process a fun and challenging experience (Wibowo, 2024). Additionally, AR allows for the integration of various learning elements, such as interactive animations, level-based challenges, and game simulations, which encourages active participation from students (Blavt et al., 2023). As a result, students' gross motor coordination, balance, and endurance can experience significant improvements, thanks to repetitive but still regular physical exercises (Dhar et al., 2021).

However, the use of AR in physical education faces several obstacles, such as limited access to technology and the need for training for teachers. Not all students have AR-enabled mobile devices, and not all teachers have knowledge of this technology, thus becoming an obstacle in this study. Nonetheless, the great potential of AR to improve gross motor skills through interactive and technology-based learning makes it a relevant and innovative tool to support students' physical development at the primary school level.

Physical education interventions that utilize mobile learning and augmented reality (AR) have great potential to impact the global community, particularly in improving gross motor skills in primary school students (Liang et al., 2023). This technology offers innovative solutions that can be applied in different countries and educational environments to address global problems such as declining physical activity, childhood obesity, and lack of access to quality physical education resources (Sucipto et al., 2021). The use of AR in physical education provides a more equitable opportunity to access gross motor learning programs around the world, including in areas with limited sports facilities or instructors (Mokmin & Rassy, 2024). Mobile-based applications can be easily downloaded and used on a variety of devices, making them a flexible and affordable technology to implement in developing and developed countries. With the help of AR, students can practice and learn physical skills independently, albeit in a limited environment, without the need for complete sports facilities (Calabuig-Moreno et al., 2020).

These interventions help the global community in dealing with widespread health challenges, such as the increased sedentary lifestyle due to children's use of digital devices. This new approach is changing the way children interact with technology, from passive consumption to interactive and rewarding physical activity (Pérez-Muñoz et al., 2024). Children are invited to move actively through AR-based simulations that are designed in a fun and educational way, so that they can reduce the negative impact of modern lifestyles. The use of Augmented Reality (AR) in physical education also creates opportunities for international collaboration in program research and development(Ferriz-Valero et al., 2020).

Academics, technology developers, and education practitioners from different countries can work together to produce innovative and globally relevant AR content (Vega-Ramírez et al., 2020). This collaboration has the potential to create more effective solutions in improving gross motor skills and physical health of children around the world, while promoting the creation of healthier and more active communities (Liang et al., 2023). Overall, AR-based physical education interventions not only contribute to the improvement of individual gross motor skills, but also have a positive impact on the global community (Guindos-Sanchez et al., 2020). These technologies drive inclusivity, equity, and innovation in physical education, and prepare future generations to face global health challenges in smarter and more sustainable ways (Lizandra et al., 2020).

Conclusions

The interventions of physical education by using augmented reality based mobile learning can significantly improve gross motor skills in elementary school students. This finding is relevant for the development of digital-based physical education learning media that is presented interactively. Practically, the results of this research can be used to design a motor skill improvement program that is more effective, accessible, and flexible because it can be practiced outside of school. With the right adjustments, these results have the potential to have a positive impact on improving gross motor skills, especially for elementary students.

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