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B. S. ARYMBEKOV [1], S. K. KODANOVA [1], K. FEDUS [2],*
Y.R. TURSANOVA [3], M.TURDALYULY [3], N. SUPRAPTO [4]

[1]Al-Farabi Kazakh National University (Almaty.Kazakhstan),
[2]Nicolaus Copernicus University (Toruń, Poland),
[3]Kazakh National Research Technical University (Almaty, Kazakhstan)
[4]Surabaya State University, (Surabaya, Indonesia)
e-mail: beckemn@gmail.com

STUDY OF COGNITIVE SKILLS IN PHYSICS LESSON WITH AUGMENTED REALITY

Abstract

According to statistics, using augmented reality in high schools in Kazakhstan is growingly higher than any other CIS countries, giving the initially promising picture of immersive technologies in Kazakhstani education; however, there is a significant underrepresentation of AR users in high schools yet. As a result, a persistent dominance of traditional teaching in the Kazakhstani schools contrasts Japanese fully metaverse high schools.

The study considers the initial physical skills of pupils as a determinant of their learning and cognitive abilities. Employing a laboratory experiment with a quantitative approach, the research sampled 175 randomly chosen 9th-grade high school students. Data collection involved administering a cognitive learning skills test during a physics lesson, with results analyzed using statistical tests like normality and Linkert tests.

The primary objective of this study is to assess the efficacy of augmented reality in enhancing cognitive learning skills during physics lessons among high school students in the Ili district. Notably, the improvement in cognitive learning skills is more pronounced among students with higher initial physical abilities. This underscores the potential of augmented reality in augmenting cognitive learning skills within the realm of physics education.

This research contributes valuable insights to the evolving understanding of augmented reality's effectiveness in fostering pupils' cognitive learning skills, particularly within physics education. The findings indicate that the use of augmented reality yields positive outcomes in enhancing students' cognitive learning during physics lessons compared to traditional teaching methods.

Keywords: education, physics, augmented reality, critical thinking, cognitive skills

Introduction. Physics is a subject that requires pupils to visualize correctly, analyze data, and make predictions based on visualization. By engaging in the process of solving physics problems, pupils can develop their cognitive learning skills (Ozdamli, et al., 2017). Physics often deals with abstract concepts and phenomena that cannot be directly observed. Therefore, students need to develop the ability to visualize these concepts accurately in their minds (Kaur, et al., 2020:881). This involves mentally representing physical processes, structures, and relationships, which is crucial for understanding and problem-solving in physics (Chen, et al., 2020). Physics is deeply rooted in empirical evidence and experimentation. Students must learn to collect, analyze, and interpret data obtained from experiments, observations, or theoretical models (Moro, et al., 2021:680). This process involves identifying patterns, relationships, and trends within the data to draw meaningful conclusions about the physical world (Chou, et al., 2021). Physics enables students to make predictions about future events or outcomes based on their understanding of underlying principles and observed patterns (Chang, et al., 2020). By applying their knowledge and reasoning skills, students can anticipate the behavior of physical systems or phenomena under different conditions, facilitating the formulation of hypotheses and the design of experiments (Demitriadou, et al., 2020). Physics education often revolves around solving problems that require critical thinking, logical reasoning, and mathematical skills (Zhang, et al., 2020). Through the process of tackling physics problems, students learn to apply theoretical concepts to real-world situations, break down complex problems into manageable steps, and formulate systematic approaches to finding solutions (Huang, et al., 2021). Engaging in physics problem-solving activities helps students develop various cognitive skills, including analytical thinking, spatial reasoning, memory retention, and pattern recognition (Chin, et al., 2021). These skills are not only valuable in the context of physics education but also have broader applications across disciplines and in everyday life (Buchner, 2021). The statement underscores the importance of active engagement and hands-on learning in physics education, as well as the role of visualization, data analysis, prediction, and problem-solving in fostering students' cognitive development and understanding of the physical world (Arymbekov, et al., 2023). In addition, having strong cognitive learning skills can lead to better academic performance, as pupils are able to understand and apply concepts more effectively. It can also lead to better problem-solving skills, which are important in study of physics (Cai, et al., 2021). Therefore, it is important for physics teachers to prioritize the development of cognitive learning skills in their pupils, and to provide opportunities for pupils to engage in activities that promote critical thinking, such as problem-based learning, inquiry-based learning, and collaborative learning (Garzón, et al., 2020).

Main part. Research on cognitive skills in physics lessons with augmented reality aims to investigate the impact of utilizing augmented reality technology in enhancing cognitive skills among students during physics lessons. This research delves into how augmented reality, as an innovative educational tool, influences the development of cognitive skills such as critical thinking, problem-solving, and spatial reasoning in the context of physics education. Research on cognitive skills in physics lessons focuses on understanding how students develop and apply cognitive abilities during their physics education. This field of study investigates various aspects of cognition, such as problem-solving, critical thinking, spatial reasoning, and conceptual understanding, within the context of physics learning. Researchers employ diverse methodologies to explore cognitive skills in physics lessons, including experimental designs, quantitative analysis of learning outcomes, qualitative assessments of student understanding, and observations of classroom interactions. These studies aim to uncover the cognitive processes involved in physics learning, identify effective instructional strategies, and enhance students' cognitive development in the subject. Through empirical investigations, theoretical frameworks, and educational interventions, research on cognitive skills in physics lessons seeks to advance our understanding of how students acquire and apply knowledge in the domain of physics. By elucidating the cognitive mechanisms underlying learning, this research informs the design of curriculum, teaching practices, and educational technologies aimed at promoting effective physics instruction and fostering cognitive growth among students. The study employs various methodologies, including experimental designs, quantitative analysis, and assessments of cognitive learning outcomes. It examines the effectiveness of augmented reality applications in comparison to traditional teaching methods, focusing on factors such as engagement, comprehension, and knowledge retention. By exploring the relationship between augmented reality and cognitive skill development in physics education, this research contributes valuable insights into the potential benefits and challenges of integrating emerging technologies into the classroom. It sheds light on the opportunities for optimizing learning experiences and improving educational outcomes through innovative approaches to instruction.

Literature review. Augmented reality has the potential to enhance the learning experience by providing a more immersive environment for pupils (Thees, et al., 2020). By combining real-world situations with virtual objects, pupils can better visualize and understand abstract concepts, leading to improved learning outcomes (Eldokhny, et al., 2021). Augmented reality technology offers a unique opportunity to revolutionize the learning experience by blending digital content with the real-world environment (Arymbekov, 2023). We study elaboration on how AR can enhance the learning process. AR creates an immersive learning environment where virtual objects are seamlessly integrated into the physical world (Guntur, et al., 2021). By superimposing digital content onto real-world objects or scenes, AR allows students to interact with and manipulate virtual elements as if they were part of their immediate surroundings (Marini, et al., 2022). This immersive experience captivates students' attention and fosters active engagement in the learning process. Many scientific concepts, particularly in subjects like physics, can be abstract and difficult for students to grasp through traditional teaching methods alone (Hsieh, 2021). AR technology enables students to visualize these abstract concepts in a tangible way by overlaying virtual models, simulations, or animations onto physical objects or environments (Sahin, et al., 2020). For example, students can explore the structure of atoms, observe the motion of celestial bodies, or interact with complex machinery through AR applications (Lee, et al., 2021). By combining real-world situations with virtual objects, AR facilitates a deeper understanding of complex concepts. Students can manipulate virtual objects, conduct experiments, and observe simulations in real-time, allowing them to explore cause-and-effect relationships and visualize the consequences of their actions (Christopoulos, et al., 2021). This hands-on approach promotes active learning and encourages students to actively construct their knowledge. Research has shown that integrating AR technology into educational settings can lead to improved learning outcomes. AR enhances students' motivation, engagement, and retention of information by making learning more interactive, personalized, and enjoyable (Wahyu, et al., 2020). Additionally, AR provides immediate feedback and scaffolding support, enabling students to learn at their own pace and receive tailored assistance when needed. AR experiences often leverage multiple senses, including visual, auditory, and tactile feedback, to create a rich and multisensory learning environment (Alqarni, 2021). By engaging multiple senses simultaneously, AR stimulates different areas of the brain and enhances information processing, memory formation, and knowledge retention (Arymbekov, et al., 2023). This multisensory approach accommodates diverse learning styles and preferences, making learning more inclusive and accessible to all students. augmented reality holds immense potential to transform education by offering immersive, interactive, and personalized learning experiences (Nurbekova, 2020). By bridging the gap between the physical and digital worlds, AR empowers students to explore, experiment, and discover in ways that were previously unimaginable, ultimately leading to enhanced learning outcomes and a deeper understanding of complex concepts (Elmira, et al., 2022). The use of augmented reality in education can provide a more engaging learning experience, which can help to maintain pupil motivation in the subject matter. This can be particularly beneficial in physics where pupils may struggle with understanding (Arymbekov, 2023). Furthermore, the use of augmented reality can help to overcome the limitations of traditional classroom-based learning, such as limited resources and access to real-world scenarios (Afnan, et al., 2021). With augmented reality, pupils expose to a wider range of scenarios and experiences that would otherwise be difficult or impossible to recreate in the classroom (Weng, et al., 2020). The use of augmented reality in education offers numerous benefits, including the skills to provide an interactive and immersive learning experience that can improve pupils' understanding of abstract concepts (Arymbekov, 2023). Augmented reality can also help to build pupils' interest in learning by creating a more engaging and interactive environment (Sugandi, et al., 2022). Moreover, augmented reality provides a medium for educators to communicate with pupils, providing feedback and distributing messages that can help to facilitate an effective and efficient learning process (Arymbekov, et al., 2023).

The use of augmented reality in education has the potential to transform the learning experience by providing a more engaging, immersive and interactive environment that can enhance pupils' understanding, motivation, and interest in the subject matter (Saitnabieva, et al., 2023). Augmented reality can help to enhance pupils' cognitive learning skills by providing an interactive learning environment. This research studies have focused on the application of augmented reality in learning, including identifying its potential for introducing building objects and serving as a learning medium (Suhaizal, et al., 2023) . In addition, research has been conducted on the relationship between problem-based learning models and cognitive learning skills, as well as the development of cognitive learning questions based on local wisdom (Eldokhny, et al., 2021). Therefore, it is important to examine the improvement of pupils' cognitive learning skills during physics lessons using augmented reality. By using augmented reality media, pupils can engage in an interactive and immersive learning experience that can enhance their cognitive learning skills. This allows pupils to visualize 3D objects, which can help to reinforce their understanding of abstract concepts of problem-solving abilities. Overall, the use of augmented reality in education has the potential to improve pupils' cognitive learning skills in physics lesson (Aviandari, et al., 2023).

Research materials and methods. The research method is described a physics laboratory experiment with nonequivalent control group design. The study aims to investigate the effect of using mobile augmented reality application with Unity3D on the cognitive learning skills of ninth-grade pupils in three high schools. The study compares experiment group, who receive the mobile augmented reality application, with the control group, who receive pupil worksheets. This research design allows for an investigation into the effect of mobile augmented reality application on cognitive learning skills in a controlled setting, while also considering the influence of initial physical skills. By comparing the experimental group to the control group, the study aims to determine whether the use of mobile augmented reality application is an effective method for improving cognitive learning skills in physics lessons.

Motion in a vertical circle refers to the movement of an object along a circular path in a vertical plane, such as a roller coaster or a pendulum swinging back and forth. This type of motion involves changes in both speed and direction as the object moves around the circle. In order to keep an object moving in a circular path, there must be a force directed towards the center of the circle. This force is known as the centripetal force. In the case of motion in a vertical circle, gravity provides the centripetal force necessary to keep the object moving in a circular path. For objects connected to a string or rope that moves in a vertical circle, tension in the string plays a crucial role. At the top of the circle, tension must be greater than gravity to prevent the object from falling. At the bottom of the circle, tension decreases as gravity assists in providing the centripetal force.

Due to changes in speed and direction, objects in vertical circular motion experience acceleration. At the top of the circle, the object experiences centripetal acceleration directed downwards, while at the bottom, it experiences centripetal acceleration directed upwards. As the object moves up and down the vertical circle, its kinetic energy (due to motion) and potential energy (due to height) change. The total mechanical energy (sum of kinetic and potential energy) remains constant if only conservative forces, like gravity, are acting on the object. Understanding motion in a vertical circle involves analyzing the forces acting on the object, including gravity, tension, and centripetal force, and applying principles of kinematics and dynamics to describe the object's motion accurately (Figure 1).

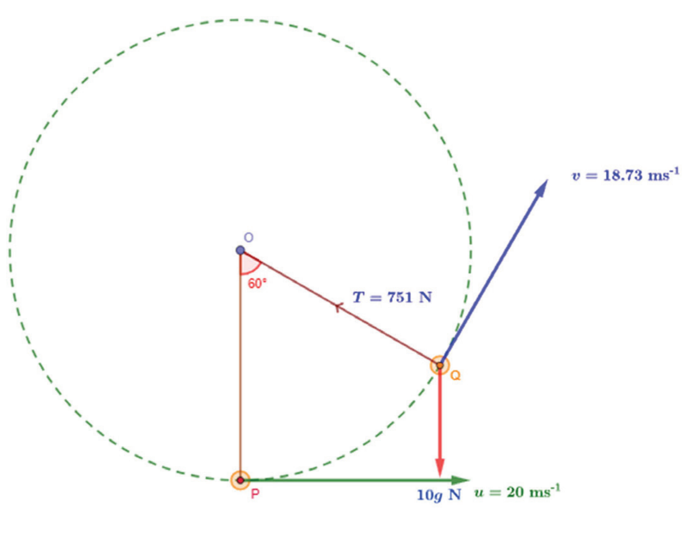

Figure 1. Motion in a vertical circle

The use of a validated test, as well as statistical analysis, increases the validity and reliskills of the study results. Overall, this research design is a rigorous and systematic approach to investigating the impact of mobile augmented reality application on cognitive learning skills.

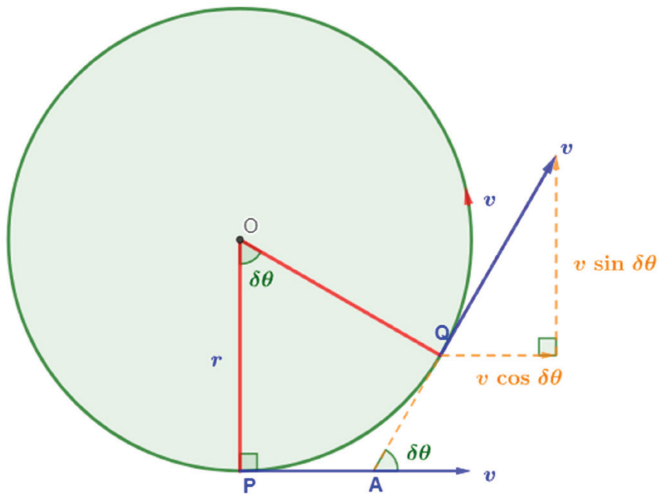

Figure 2. The acceleration of a part moving on a circular path

When a body moves with uniform motion on a circular path, it experiences centripetal acceleration. Centripetal acceleration is the acceleration directed towards the center of the circular path, which keeps the object moving in a curved trajectory instead of a straight line (Figure 2.). In uniform circular motion, the speed of the object remains constant, but its direction changes continuously. Therefore, the magnitude of the velocity remains constant, and only the direction changes. As a result, the centripetal acceleration it remains constant in magnitude but continuously changes in direction, always pointing towards the center of the circular path. It is important to note that centripetal acceleration is not a velocity; it is an acceleration. It represents the rate of change of velocity (in direction) of an object moving in a circular path.

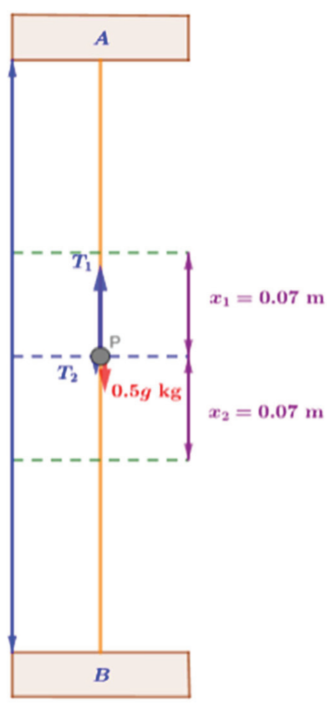

Figure 3. Hooke's law with more than one string

Using Hooke's law with more than one elastic string involves applying the principle of superposition (Figure 3). Hooke's law states that the force required to extend or compress a spring is directly proportional to the displacement of the spring from its equilibrium position. x is the displacement from the equilibrium position. When dealing with multiple elastic strings, each string obeys Hooke's law independently. Therefore, to determine the total force exerted by multiple springs, you simply sum up the forces from each spring individually. It is important to note that this approach assumes that the springs are connected in parallel or series, depending on the setup. If they are connected differently, such as in a complex network, the analysis would involve considering the specific arrangement of the springs and their interactions.

Augmented reality has been increasingly used in education to enhance learning experiences. AR technology involves overlaying digital information, such as 3D images, videos, and sounds, onto the real-world environment, creating an immersive and interactive experience for learners. There has been a growing body of research on using AR in lessons, and the results have been largely positive (Table 1).

Table 1. *Expected reseach area in this study*

#	Learning Indicator	Assumted Reseach Results
1	Increased engagement	AR can make learning more engaging and interesting by providing a more interactive and immersive experience
2	Improved understanding	AR can help learners visualize abstract concepts or complex topics, making it easier to understand and retain information
3	Personalized learning	AR can be tailored to individual learners' needs, allowing them to learn at their own pace and level
4	Enhanced creativity	AR can encourage learners to be more creative and innovative, as they explore and experiment with digital content in a real-world context

Science and engineering: AR can be used to visualize scientific concepts, such as the structure of atoms or the movement of the solar system. It can also be used to simulate engineering projects, allowing learners to test and refine designs in a virtual environment. History and geography: AR can bring historical events and landmarks to life, allowing learners to explore and interact with them in a more meaningful way. It can also be used to simulate virtual field trips to different parts of the world. AR can be used to create immersive language learning experiences, allowing learners to practice their skills in a real-world context. Research suggests that AR has great potential to enhance learning experiences and improve learning outcomes. However, it is important to consider factors such as accessibility, cost, and technical requirements when implementing AR in education.

Results. This study aims to examine, describe, and compare the differences in the improvement of cognitive learning during the physics lesson skills between pupils who receive learning using augmented reality media with Unity3D and Vuforia and conventional learning based on pupils' initial physical abilities. Initial physical skills of pupils consists of three categories, namely: high category, medium category, and low category. The following is the distribution of the research sample (Table 2).

Table 2. *The Data Distribution of Research Results*

IMA	Conventional Learning	Experiment with Augmented Reality	Amount
High	15	15	30
Medim	15	15	30
Low	15	15	30
Total	45	45	90

The summary statistics presented in the table provide information about the distribution of pupils' initial physical abilities based on their previous learning outcomes. The mean is the average score of all the pupils, while the standard deviation is a measure of the variskills or spread of the scores around the mean. The minimum and maximum values represent the lowest and highest scores, respectively. By analyzing the descriptive statistics, we can get an idea of how the pupils are distributed across the different categories of initial physical skills. If the mean is high and the standard deviation is low, then it indicates that most pupils have similar scores and are clustered around the mean. On the other hand, if the mean is low and the standard deviation is high, then it indicates that the pupils have widely varying scores. The descriptive statistics provide a useful summary of the distribution of pupils' initial physical abilities, which can be used to analyze the results of subsequent statistical tests (Table 3).

Table 3. *The Data Description of Pupil Initial Physical Skills*

Descriptive Statistics	Control	Experiment
N	15	15
X	81,52	80,45
Sd	6,64	6,12
Maximum	98	100
Minimum	64	65

In the table above, the normality test results for both the control class and the physics Laboratory experiment class show that the value is greater than 0.09, indicating that the data is normally distributed. Therefore, the test is used to test the equivalence of the initial physical abilities between the two learning groups. However, the homogeneity of variance test using the Linkert test showed that the p-value is less than 0.09, indicating that the variance of the initial physical skills data is not equal between the two groups. As a result, the test, which is a modification of the t-test that takes into account unequal variances, is used to test the equivalence of the initial physical abilities between the two learning groups (Table 4).

Table 4. *Normality Test of Pupil Initial Physical Skills*

Kolmogorov	Control	Experiment
N	73	79
TP	0,51	0,71

In the table 3 above, it shows that the probskills value of the data on conventional learning and augmented reality media with Unity3D and Vuforia is more than 0.09. This means that H_0 is accepted, so it can be concluded that the sample data for the two groups came from a normally distributed population. Furthermore, the homogeneity of the variance of the initial physical skills of the two groups will be tested using Levene's test. The results of the homogeneity test of the data for the initial physical skills of pupils in the two learning groups are presented in the following table (Table 5).

Table 5. *The Test of Pupil Initial Physical Skills*

Levene-test	Data	Criteria
N	30	H_0
DR	0,19	Accepted

In the table above, it shows that the probskills value (sig.) of the data is greater than 0.05. This means that H_0 is accepted, so it can be concluded that the data variance of the two groups is homogeneous. Furthermore, the equality of the initial physical skills data will be tested using the t-test. The results of the data equivalence test of pupils' initial physical abilities based on learning are presented in the following table (Table 6).

Table 6. *The Equivalence Test of Pupil Initial Physical Skills*

t-test	Data	Criteria
N	370	H_0
DR	0,51	Accepted

In the table above, it shows that the probskills value is greater than 0.05, so H0 is accepted. Thus, there is no difference in skills between pupils who receive learning using augmented reality media with Unity3D and Vuforia and pupils who receive conventional learning. This further strengthens the statement in the previous table 2 that, overall, there is no significant difference in the description of the initial physical skills of the control class and the physics Laboratory experiment class. Then to see the difference in increasing cognitive learning during the physics lesson skills of pupils who receive learning using Augmented reality media with Unity3D and Vuforia based on pupils' initial physical abilities, a prpbskills test will be carried out. In order to obtain an overview of the quality of cognitive learning during the physics lesson skills of the two groups of pupils, the data were analyzed descriptively so that the mean, standard deviation, minimum value, and maximum value could be known. The summary of the results of the descriptive analysis of pupils' cognitive learning during the physics lesson skills data in the two lessons is presented in the following table (Table 7).

Table 7. *The Description of Data Pupils' Cognitive Skills*

Learning	Skills	Mean	SD
Augmented reality	Extraordinary	0.71	0.15
	Mediocre	0.62	0.11
	Squat	0.99	0.19
Traditional	Extraordinary	0.74	0.15
	Mediocre	0.93	0.07
	Squat	0.90	0.09

In the table above we have provided a description of a research study on the comparison of cognitive learning during a physics lesson between pupils who received conventional learning and those who received learning using augmented reality media with Unity 3D and Vuforia. The results of the data analysis suggest that the cognitive learning skills of pupils who received learning using augmented reality media with Unity 3D and Vuforia was better than those who received conventional learning based on initial physical skills. Before testing the average difference, the data normality and homogeneity of variance were tested. The Kolmogorov test was used to test the normality of the data. However, you have not provided the results of the normality test for the cognitive learning during the physics lesson skills data for the two learning groups. Please provide the results of the normality test so that I can help you further in following table (Table 8).

Table 8. *The Normality Test of Data Gain Pupils' Cognitive learning Physical Skills*

Kolmogorov-Smirnov	Control	Experiment
N	91	79
TY	0,11	0,33

From the table above, it shows that the significance value of the cognitive learning during the physics lesson skills of the two learning groups is greater than 0.05. This means that the null hypothesis is accepted. That is, the data on pupils' cognitive learning during the physics lesson skills for both the control class and the physics Laboratory experiment class is normally distributed. Furthermore, the homogeneity of the variance of cognitive learning skills of the two sample groups will be tested using Linkert's test. The results of the homogeneity test of the data variance of pupils' cognitive learning during the physics lesson abilities in the two learning groups are presented in the following table (Table 9).

Table 9. *The Homogeneity Test of Data Gain Pupils' Cognitive learning Physical Skills*

Linkert-test	Data	Criteria
N	75	H_0
TY	3,07	Accepted

From the table above, it seems that the results of the homogeneity test of the data variance goes up. Skills of pupils who received learning using augmented reality with Unity3D and Vuforia and conventional learning showed a significant value greater than 0.07, indicating that the null hypothesis is accepted and the variance is homogeneous. Since the data meet the assumptions of normality variance, the next step is to test thesignificant difference between the average cognitive learning during the physics lesson. Skills of pupils who received learning using augmented reality media with Unity3D and Vuforia and pupils who received conventional learning and whether there is an effect of the interaction between the learning used and the initial physical skills on pupils' cognitive learning during the physics lesson skills. This will be tested using two-way probskills. However, we have not provided the calculation results for the probskills with the following table (Table 10).

Table 10. *The probskills test of Data Pupils' Cognitive learning Skills*

Indicator	Total	Dk	Average square	F	ERR	H_0
Learning	1642,80	1	1642,80	54,69	0,003	Rejected
IFT	7942,06	2	3971,03	132,22	0,005	Rejected

Table 11. *The skills test of Data Pupils' Cognitive learning*

Indicator	Total	Dk	Average square	F	ERR	H_0
Interaction	300,20	2	150,10	4,99	0,01	Rejected
Error	720,80	24	30,03			
Total	125678,00	30				

From the table above (Table 11), it shows that the initial physical skills factor used by each learning group has a significant influence on pupils' cognitive learning during the physics lesson skills. This can be seen from the significance value obtained at 0.00,7 which is smaller than 0.09. It seems that your statement is discussing the findings of a study on the use of augmented reality in physics education. The study revealed that the use of augmented reality, specifically using Unity3D and Vuforia, has a significant impact on pupils' cognitive learning skills during physics lessons compared to conventional learning methods. The use of augmented reality has several advantages, including the skills to visualize 3D models and create new experiences for users. The study shows that augmented reality has great potential and benefits in the learning process, and its use in education has been proven to have a positive impact on pupils' cognitive learning skills.

Discussion. This statement suggests that augmented reality can be an effective tool in enhancing physics education and improving pupils' learning outcomes. The following is the process of implementing and answering pupil test results in the experiment class. Additional information about the indicators of cognitive learning skills used in the study. The study found that pupils who received learning using augmented reality media with Unity3D and Vuforia had better cognitive learning skills during the physics lesson compared to pupils who received conventional learning based on their initial physical abilities. The study also found that the use of augmented reality in learning has several advantages, such as creating 3D models that are difficult to visualize in traditional classrooms, on computers, or in the minds of pupils. Augmented reality also has great potential and benefits in the learning process. The study provides evidence that augmented reality can have a significant influence on increasing pupils' cognitive learning during the physics lesson skills based on their initial physical abilities. It also highlights the importance of identifying relevant information, formulating problems into physical models, and using principles to deduce conclusions in developing cognitive learning skills. It can be concluded that learning using augmented reality media with Unity3D and Vuforia has a positive effect on pupils' cognitive learning during the physics lesson skills, especially on flat-shaped material. The use of augmented reality in learning provides several advantages, such as the skills to create 3D models that may be difficult to visualize in the classroom, on a computer, or in the minds of pupils, and the potential to create a new and exciting learning experience for pupils. However, there are still some challenges to be addressed in the implementation of augmented reality in the classroom. The transition process for pupils to feel comfortable with the augmented reality media format and platform is still considered new to the school, and some pupils may be rigid in using the application at the beginning of learning. Additionally, some types of cellphones may not be able to install augmented reality applications, and pupils may experience application errors. The study shows that augmented reality has the potential to improve pupils' cognitive learning during the physics lesson skills, and further research can explore the use of this technology in other subjects and contexts. The challenges in the implementation of this technology in the classroom should also be addressed to ensure its effective use in supporting pupils' learning. The use of augmented reality media in the classroom has been shown to be beneficial in improving cognitive learning skills and enhancing the learning experience of pupils. By merging the real and virtual worlds, providing an interactive and real-time experience, and incorporating three-dimensional objects, augmented reality can engage and captivate pupils, leading to more focused and regulated learning. Augmented reality can be particularly helpful in teaching complex concepts, such as atomic physics, where visual aids and interactive tools can aid in understanding. Additionally, the study suggests that gender should be taken into account when implementing augmented reality in the classroom, as male pupils may be more enthusiastic about using augmented reality and may benefit more from its use in developing cognitive learning abilities. It is important to note that while augmented reality can be a valuable tool in education, it should not be used as a replacement for traditional teaching methods. Instead, it should be used as a supplementary tool to enhance the learning experience and provide pupils with a more engaging and interactive way of learning.

Conclusions. Based on the findings presented in the article, it can be concluded that the use of augmented reality media with Unity3D and Vuforia in physics lessons leads to better improvement in cognitive learning skills compared to conventional learning methods, especially for pupils with different initial physical abilities. However, it is important to note that the magnitude of improvement may vary among individual pupils, and further investigation is needed to determine the effectiveness of this approach for developing higher-order thinking skills beyond cognitive learning in physics lessons. We suggest that the implementation of augmented reality (AR) technology, specifically utilizing platforms like Unity3D and Vuforia, in physics education offers several advantages over traditional teaching methods. AR technology overlays digital content onto the real world, providing an interactive and immersive learning experience for students. In the context of physics lessons, this means that students can visualize and interact with virtual objects and phenomena in a more engaging manner. Unity3D is a popular game development platform known for its versatility and ease of use, while Vuforia is a software development kit (SDK) for creating AR applications. By leveraging these tools, educators can create customized AR experiences tailored to their physics curriculum. The use of AR media in physics education has been shown to enhance cognitive learning skills among students. This includes abilities such as problem-solving, critical thinking, spatial reasoning, and visualization. AR allows students to interact with complex physics concepts in a hands-on way, facilitating deeper understanding and retention. The research suggests that AR-based learning outperforms traditional teaching methods in terms of improving cognitive learning skills. This could be attributed to the immersive nature of AR, which actively engages students and provides them with opportunities for experiential learning. Importantly, the benefits of AR in physics education extend to students with varying initial levels of proficiency or physical abilities. AR can accommodate different learning styles and preferences, making it accessible and inclusive for all students. Overall, the findings indicate that integrating augmented reality media, particularly through platforms like Unity3D and Vuforia, into physics lessons holds great promise for enhancing learning outcomes and catering to diverse student needs in the classroom. Overall, the results suggest that augmented reality learning media with Unity3D can be a valuable tool for enhancing the quality of physics education and promoting pupils' cognitive development.

Recommendations. Based on the insights gleaned from the study, we have developed suggestions for integrating AR into physics education: Here are some recommendations for integrating augmented reality (AR) into physics lessons:

1) Ensure that the AR experiences are closely aligned with the learning objectives of the physics curriculum. Identify specific concepts or topics where AR can enhance understanding and provide meaningful learning experiences.

2) Use AR to create interactive simulations that allow students to manipulate virtual objects, conduct experiments, and observe phenomena in real-time. Provide opportunities for students to explore cause-and-effect relationships and make predictions based on their observations.

3) Integrate AR experiences that contextualize physics concepts within real-world environments. For example, use AR apps to overlay physics principles onto familiar objects or situations, such as motion tracking in sports or understanding the physics of roller coasters at an amusement park.

4) Foster a spirit of exploration and inquiry by giving students the freedom to explore AR content at their own pace. Encourage them to ask questions, make hypotheses, and test their ideas within the AR environment.

5) Promote collaborative learning experiences by incorporating multiplayer AR activities where students can work together to solve physics problems or complete challenges. Encourage communication, teamwork, and peer-to-peer support within the AR environment.

6) Leverage the interactive nature of AR to provide immediate feedback to students as they engage with the content. Use features like virtual annotations, tooltips, or pop-up explanations to reinforce correct concepts or provide guidance when students encounter misconceptions.

7) Use AR to differentiate instruction and cater to the diverse learning needs of students. Provide multiple entry points and levels of challenge within AR activities, allowing students to choose paths that align with their abilities and interests.

8) Use AR as a formative assessment tool to gauge students' understanding of physics concepts in real-time. Design AR activities that require students to demonstrate their knowledge through problem-solving, data analysis, or hypothesis testing.

9) Encourage students to reflect on their learning experiences with AR and engage in metacognitive processes such as thinking about their thinking. Provide opportunities for students to articulate their strategies, identify areas of growth, and set goals for further exploration.

10) Stay informed about the latest AR technologies, apps, and resources available for physics education. Explore online platforms, educational app stores, and professional development opportunities to discover new ways to integrate AR into your lessons effectively.

By following these recommendations, educators can leverage the immersive and interactive nature of augmented reality to create engaging and impactful learning experiences for students in physics lessons.

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