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Research Article

Cooperative model, digital game, and augmented reality-based learning to enhance students' critical thinking skills and learning motivation

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Low levels of critical thinking skills and learning motivation, particularly in physics learning, pose significant challenges that must be promptly addressed to ensure students' future success. To tackle this issue, the present study endeavors to develop a Cooperative Model, Digital Game, and Augmented Reality (CAP)-based learning, which is both valid and practical, to enhance these crucial aspects effectively. This study used Educational Design Research through a non-equivalent control group design in the data collection process. Using purposive sampling method, 54 high school students were divided into two classes were involved. The data collection period was from July to August 2022. The research instruments used include syllabus, lesson plan, Adventuring Physics media, critical thinking test instrument, motivation questionnaire, student response questionnaire, validation questionnaire, and observation sheet. Statistical tests used include descriptive, paired, and independent t-tests. The results reveal that the learning products and instruments exhibit strong validity and reliability, alongside a high degree of practicality in their implementation. The experimental group demonstrated a notable improvement both in critical thinking skills and learning motivation. Additionally, students' feedback regarding this learning approach has been overwhelmingly positive. Consequently, this research highlights the importance of fostering more engaging and enjoyable innovations through digital learning in physics education to achieve optimal learning outcomes and enhance 21st-century skills.

Keywords: Cooperative learning; Adventure game; Augmented reality; Critical thinking skills; Learning motivation

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1. Introduction

Game-based learning has become a worldwide researcher's interest (Chen et al., 2022). The utilization of game-based teaching methodologies has been shown to enhance students'

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performance as well as motivation (Byusa et al., 2022; Krouska et al., 2022). In line with this, the trend of using Augmented Reality (AR) in learning has increased in the last few decades (Hidajat, 2023; Prahanı et al., 2022). Academic innovation via technological advances, including mobile games, will offer an innovative setting for learners to enjoy while studying. Mobile phones are currently utilized in classrooms for various academic reasons, particularly physics subjects with many abstract materials (Rizal et al., 2020; Wirjawan et al., 2020). Android-based games might be used as an educational instrument to help learners grasp physics. These games are up-to-date learning materials with technological improvements (Rahayu et al., 2021). The utilization of Android-based games is anticipated to ease students' receipt and comprehension of learning content while also simplifying teachers' providing teaching material (Ismara et al., 2021; Nadeem et al., 2022; Wardoyo et al., 2021).

However, one of the main issues in physics learning is low critical thinking skills. This low level of critical thinking proficiency hampers their ability to analyze complex issues, make informed judgments, and effectively solve problems (Mahanal et al., 2019). Consequently, they do not know what they are studying and the relation of the concepts they learn to everyday life. This certainly impacts the quality of human resources in the future, and it was confirmed by several researchers who revealed that students' critical thinking skills were still low (Neswary & Prahani, 2022; H. V. Saphira et al., 2022). Addressing this challenge and implementing strategies to enhance students' critical thinking skills is crucial for their academic growth and future success because the skills are commonly used and needed in workplace, where evaluating information and making rational decisions is highly valuable (Xhomara, 2022).

Apart from critical thinking skills, learning motivation in physics lessons has a tendency to be low, which is confirmed by (Jufrida et al., 2019; Keller et al., 2017; Marshman & Singh, 2015). Based on the preliminary study by the researchers held at two different schools in Sidoarjo, Indonesia, from March to August 2022, with 115 students, 67.82% or 78 students acknowledged a lack of enthusiasm to learn physics. Furthermore, 63.47% (73 students) said their experience with physics was monotonous. This problem can negatively impact students' retention and comprehension of physics concepts. When students are not motivated to explore and understand the subject actively, they may rely on surface-level learning strategies or formula-memorization techniques rather than deep comprehension and critical thinking (Nolen, 1988). Another issue is that some physics substances, such as the magnetic field subject, frequently become misunderstandings owing to the difficulty of abstract thinking, visualization, and complexity (Bestiantono et al., 2019; Mandagi et al., 2021). Furthermore, based on our preliminary study findings, 78.26% or 90 students stated that it was challenging to comprehend abstract and microscopic items since they could not be easily seen and were challenging to envision.

In line with this, Suliyanah et al.'s (2021) literature review showed that game media might also be a way to raise interest among pupils in specific courses, including mathematical concepts that are comparable to formulae and tough to understand. Educational media that are proven to be fruitful can be transformed into Android-based forms so it can be accessible by learners easily. Furthermore, the research by Saphira and Prahani (2022), showed that the use of AR is predicted to increase the capacity for critical thinking skills in physics materials. The use of games and AR in learning should also be supported by a cooperative model so that students can work together to accomplish missions contained in the game, understand abstract concepts through AR-based learning that focuses on themselves, and discuss in groups to develop their critical thinking skills (Warsah et al., 2021).

Previous research stated that implementing cooperative learning methods was effective in increasing learning motivation (Tran, 2019), academic achievement (Gull & Shehzad, 2015), and conceptual understanding (Eymur & Geban, 2017) because when students work cooperatively in groups, the more knowledgeable students are able to help the less ones students understand new concepts, and high-achieving students benefit because they are verbalizing their ideas and actually teaching others (Mendo-Lázaro et al., 2022). On the other hand, digital games and AR provide benefits that include enhanced engagement, improved information retention, engagement, motivation, the development of cognitive (Nadeem et al., 2023), critical thinking, and problem-solving skills (Yang & Chang, 2013). If these pedagogical approaches and immersive technologies are combined, it can potentially boost learners' enthusiasm and motivation for learning physics as well as their critical thinking skill. With respect to that, it seems that no research has been carried out.

Therefore, this research developed a cooperative model, digital game, and AR-based learning in physics subjects to promote their critical thinking skill and learning motivation. The game used in this study belongs to the adventure genre, while the AR technology utilized is marker-based AR. These two technologies are integrated into a mobile application called Adventuring Physics (Rizki et al., 2023), thus giving rise to the Cooperative and Adventuring Physics (CAP)-based learning model. Through this innovative learning approach, students are actively engaged in collaborative learning, benefit from an enhanced understanding of the subject matter through sophisticated visualizations, and gain new and immersive learning experiences (Suprapto et al., 2021). Referring to Nieveen (1999), this research aims to develop a valid, practical, and effective CAP-based learning model to improve students' critical thinking skills and learning motivation. By fulfilling these three criteria, the CAP-based learning model ensures that it is not only theoretically sound but also practically applicable and effective in real-world educational settings. The contributions of this research to the literature are helping to improve the quality of teaching activity and enhances the students' critical thinking skills and learning motivation.

2. Method

This research uses Educational Design Research (EDR) to develop CAP-based learning instruments that fulfill valid, practical, and effective criteria (McKenney & Reeves, 2014; Nieveen, 1999). The sample used in this study consisted of 54 students from a high school in Sidoarjo Regency, Indonesia, with 28 students in the experimental class and 26 students in the control class. The research was conducted between July and August 2022. Purposive sampling was employed as the sampling technique by adjusting all teaching materials developed with the curriculum applicable at the school. Since human participants were involved, ethical considerations were taken into account, including obtaining permission from the school principal to conduct the research and ensuring that the students were aware of their participation as research subjects. Additionally, the research methodology underwent evaluation by two reviewers from the Indonesian Ministry of Education.

2.1. Instruments

2.1. Lesson plan

The lesson plans were developed based on the school curriculum and relevant materials derived from analyzing problems and needs. The specific topic addressed in this study was the magnetic field. The learning activities were structured using a cooperative model with the following components: 1) conveying goals and motivations; 2) presenting information; 3) organizing students; 4) guiding study groups; 5) evaluation; and 6) recognition (Arends, 2011), as shown in Table 1. The teacher gives initial motivation to students by stating that there will be a reward at the end of learning. Then, through the Adventuring Physics application, the teacher gives a challenge that the group that is the fastest in completing the mission will be rewarded. Finally, groups of students will compete to meet the challenge. The lesson plan also included teaching materials that could activate AR and student worksheets, facilitating students' learning process.

2.1.2. Adventuring physics media

This media is in .apk format, which can be installed on Android phones and downloaded on Google Play Store, and has a file size of 125 MB. The application does not require internet access to

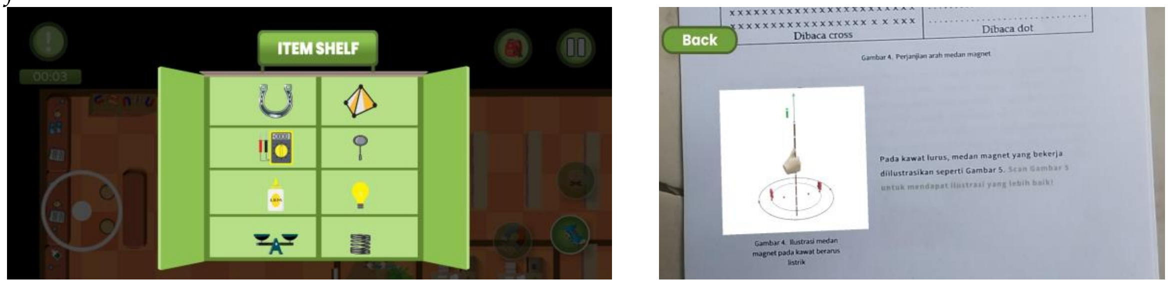
[Insert Table 1 Here]

Table 1
Learning Activity with CAP-based learning in the experiment group

Syntax	*Activity*		*Critical Thinking Indicator(s)*	*Learning Motivation Indicator(s)*
	Teacher	*Student*		
Delivering objective and motivation	Convey learning objectives and provide perception and motivation	Listening to the instruction from the teacher	E	SE, PG, AG
Presenting information	Stimulate and display contextual videos	Receiving the stimulation and paying attention to the video	E, A	ALS
Organizing students	Ask students to group and identify relevant problems	Students group and identify problems	A	SLE
Guiding learning groups	Guide students to collect data through the Adventuring Physics application and reading literature, processing and interpreting data	Students collect data through the Adventuring Physics application and read literature in groups	A, S, F(S), F(V)	ALS, SLE
Evaluation	Ask each group for a presentation and give an evaluation	Presenting the discussion result and receiving feedback	S, F(S), F(V)	PLV
Recognition	Reward the winning group	Receiving reward (only for group champion)	-	SE, AG

Note: E = Evaluating; A = Analyzing; S = Synthesizing; F(S) = Forming Arguments (Structure); F(V) = Forming Arguments (Validity); SE = Self-efficacy; PG = Performance Goals; AG = Achievement Goals; ALS = Active Learning Strategies; SLE = Stimulation of the Learning Environment; PLV = Physics Learning Values function. The concept of this application revolves around utilizing games with a strategy genre. Users are tasked with assembling magnetic field-based weapons accurately to defeat enemies using specific components like batteries and coils. Each component has a different magnitude, requiring careful evaluation and analysis for proper selection. If a faulty part is chosen, the player will lose. Through this game, students' critical thinking skills are honed as they strategize to complete missions within the game. This application also has an AR feature that can visualize magnetic field concepts that tend to be abstract, making them easy to understand. The appearance of this application is depicted in Figure 1 (Rizki et al., 2023).

Figure 1
Appearance of Adventuring Physics app: (a) students are required to find relevant items and (b) the AR feature



2.1.3. Critical thinking and learning motivation test instruments

The instrument used to measure critical thinking ability is a test instrument consisting of five questions in accordance with the indicators of achievement of syllabus competence and indicators of critical thinking skill by Reynders et al. (2020), which consists of evaluating, analyzing, synthesizing, and forming arguments (structure & validity). The critical thinking test is 30 minutes. Meanwhile, for learning motivation measured by the Student Motivation Toward Science Learning questionnaire that has been modified from Tuan et al. (2005), indicators of learning motivation are physics learning values, self-efficacy, achievement goals, active learning strategies, performance goals, and stimulation of the learning environment.

2.1.4. Student's response questionnaire

This questionnaire aims to gather students' feedback after implementing CAP-based learning. It consists of 10 questions that are designed to assess various aspects such as learning objectives, media involvement, affective perceptions, and future plans. The researchers themselves developed the items in the questionnaire by considering the learning activities carried out. The questionnaire has also met the validity and reliability tests based on expert assessments. The questionnaire is administered exclusively to the experimental classes that have received CAP-based learning treatment.

2.1.5. Expert validation questionnaire

Validity assessment to determine the feasibility of the instruments that have been developed is the purpose of this questionnaire. The validation process was carried out by three experts in physics education and educational technology targeting the constructs and content of instruments. In this context, the validity of CAP-based learning instruments were determined based on the average assessment by experts, as presented in Table 2 (Hariadi et al., 2022; Limatahu et al., 2018). These assessment results were also utilized to establish the instrument's reliability using Cronbach's Alpha (α) coefficient, ensuring that all instruments have internal consistency. The instrument is considered reliable if the coefficient value exceeds 0.7 (Taber, 2018). Ultimately, expert opinions were used to revise and improve the quality of all research instruments.

Table 2
Measurement of validity and practicality criteria

Validity Criteria		*Practicality Criteria*	
3.25 < V ≤ 4.00	Very Valid	3.25 < P ≤ 4.00	Very Practical
2.50 < V ≤ 3.25	Valid	2.50 < P ≤ 3.25	Practical
1.75 < V ≤ 2.50	Less Valid	1.75 < P ≤ 2.50	Less Practical
1.00 ≤ V ≤ 1.75	Invalid	1.00 ≤ P ≤ 1.75	Impractical

2.1.6. Observation sheet

An implementation sheet measures the correlation between the implementation process of CAP-based learning and the prepared lesson plan. The sheet employs a Likert scale construct ranging from 1 to 4 to assess the implementation of learning activities, thereby determining the practicality of the learning process. This sheet was used by two observers: an in-service physics teacher and a pre-service physics teacher, since the practicality of CAP-based learning is evaluated through observations of the learning implementation. The average scores provided by two observers are adjusted according to the practicality criteria outlined in Table 2. The reliability of the observations is also measured using the Cronbach-α coefficient.

2.2. Implementation Process

The research procedure begins with the assessment of instrument validity, which typically takes at least two weeks for the experts to conduct. The validity of the CAP-based teaching materials can be observed in Table 3, which indicates that all instruments exhibit high validity and good reliability. The experts suggest that the learning materials are feasible for use after minor revisions. These revisions were conducted to enhance the quality of the materials, transforming them into a final product suitable for implementation with students.

Table 3
Result of validity assessment

Instrument	*Validity Score*	r_α	*Validity Criteria*	α	*Reliability*
Syllabus	3.50	0.80	Very Valid	0.93	Reliable
Lesson Plan	3.50	0.73	Very Valid	0.90	Reliable
Teaching Material	3.33	0.88	Very Valid	0.97	Reliable
Student’s Worksheet	3.31	0.85	Very Valid	0.96	Reliable
Test Instrument	3.33	0.85	Very Valid	0.94	Reliable
Student’s Questionnaire	3.52	0.83	Very Valid	0.94	Reliable

Note: r_α = Corrected item-total correlation; α = Cronbach’s alpha.

Valid and reliable instruments can be considered effective tools in the teaching and learning process, suggesting that they are well-designed and aligned with their intended purposes. They also effectively measure or support different aspects of teaching and learning. Additionally, while the values are generally reliable, it is worth noting that the lesson plan has a slightly lower reliability coefficient compared to the others. However, there is no significant difference in internal consistency because it still meets the established reliability criteria.

Valid and reliable instruments can be considered effective tools in the teaching and learning process (Biasutti & Frate, 2018; Cook & Beckman, 2006; Rink, 2013; Türel, 2011), suggesting that they are well-designed and aligned with their intended purposes. They also effectively measure or support different aspects of teaching and learning. Additionally, while the values are generally reliable, it's worth noting that the lesson plan has a slightly lower reliability coefficient compared to the others. However, there is no significant difference in internal consistency because it still meets the established reliability criteria. After receiving validation results and being deemed valid by the experts, the next step is to conduct trials to determine practicality and effectiveness concurrently.

Practicality refers to the degree of compatibility between the implementation of CAP-based learning and the lesson plans. During the trial process, the level of practicality of CAP-based learning is measured through observation activities conducted by two observers: An in-service physics teacher and a pre-service physics teacher. They observe the implementation of CAP-based learning by the researchers. The practicality and learning evaluation results, as presented in Table 4, demonstrate that all the syntax components meet the criteria for practicality and reliability. Specifically, the syntax related to delivering objectives and motivation, presenting information, guiding learning groups, and evaluation exhibits a convenient level of implementation. However, the recognition syntax receives a slightly lower practicality score compared to the others. This discrepancy arises from a minor deviation in the teacher's initial plan to reward three groups. Nonetheless, due to time constraints and limitations in the class schedule, only one group was ultimately recognized for their exemplary performance in explaining their discussion outcomes and problem-solving processes. The inability to provide rewards to the other groups resulted from practical constraints rather than a reflection of the learning model itself.

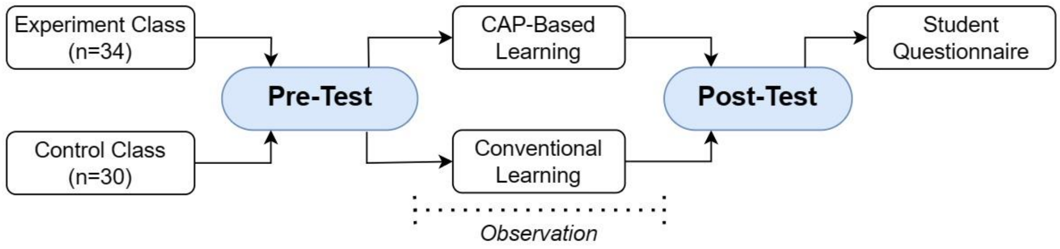
Table 4
Result of practicality assessment

Syntax	*Practicality Score*	*Practicality Criteria*	*a*	*Reliability*
Delivering Objectives and Motivation	3.50	Very Practical	0.90	Reliable
Presenting Information	3.75	Very Practical	0.90	Reliable
Organizing Students	3.25	Practical	0.90	Reliable
Guiding Learning Groups	4.00	Very Practical	0.97	Reliable
Evaluation	3.50	Very Practical	0.90	Reliable
Recognition	3.00	Practical	0.94	Reliable

The practical criteria imply that this learning can be tested to improve students' critical thinking skills and learning motivation. This means that the learning materials, strategies, and activities have been designed with practical considerations in mind, taking into account the available resources, constraints, and conditions of the educational environment (Siswanto et al., 2018). As a result, piloting CAP-based learning is more likely to be successful and sustainable in schools or classrooms. If a learning model is practical, it aligns with the educational environment's available resources, constraints, and conditions. This enhances the chances of successful implementation and reduces the likelihood of logistical challenges or disruptions (Brown et al., 2014; Siswanto et al., 2018; Wilson et al., 2016). Practical learning models are adaptable and flexible to accommodate diverse learning needs and contexts, ensuring that the learning model remains relevant and effective in various educational scenarios (Imran et al., 2023; Shraim, 2020). In line with Auliya & Munasiah (2019); Setiani et al. (2019) research that practical learning models and AR media can improve students' concept understanding and learning motivation proficiently.

Simultaneously, learning effectiveness is evaluated using a non-equivalent control group design, with an experimental and control group. Initially, both groups are given a pre-test to assess critical thinking and learning motivation using similar question types. Subsequently, the experiment group receives CAP-based learning treatment, while the control group undergoes conventional learning, which involves material explanation, structured tasks, and a question-and-answer session. The control variables for both groups include the lesson duration (4 × 45 minutes), a male pre-service physics teacher, the use of the school's operational curriculum, and magnetic field learning materials. The only difference lies in the learning processes and activities. Finally, both groups underwent a post-test to assess critical thinking and learning motivation to measure improvement. Following the post-test, the experimental group is given a student response questionnaire. The data collection procedure is depicted in Figure 2.

Figure 2
Data collection of practicality and effectiveness of CAP-based learning



2.3. Data Analysis

In terms of effectiveness, several criteria must be fulfilled, with at least three out of five criteria being met. These criteria include: 1) moderate value in the experimental class; 2) significant difference between the pre-test and post-test results in the experimental class; 3) medium N-gain for the experimental class; 4) medium effect size for the experimental class; and 5) significant differences between the experimental and control classes (Prahani et al., 2020). Criteria 1, 3, and 4 necessitate the use of descriptive statistics based on the criteria presented in Table 2 (Hake, 1999; Morgan et al., 2012), while criteria 2 and 5 require inferential statistics. Therefore, it is essential to test prerequisites such as normality and homogeneity for the data groups, followed by the utilization of the t-test to determine their significance. Lastly, students' responses were assessed based on their positiveness with the following criteria: R < 25% (Not Positive), 25% ≤ R < 50% (Less Positive), 50% ≤ R< 75% (Positive), and ≥ 75% (Very Positive) (Limatahu et al., 2018).

Table 2
Measurement of critical thinking, N-gain, and effect size criteria

Critical Thinking Criteria		*Hake's N-Gain Criteria*		*Cohen's d-Effect Size Criteria*	
0 – 1.66	Low	< 0.3	Low	≥1.00	Very Large
1.67 – 3.32	Medium	0.3 – 0.6	Medium	0.8	Large
3.33 – 5.00	High	≥ 0.7	High	0.5	Medium

3. Results

Table 6 presents the scores of students' critical thinking skills in both the experimental and control groups, including the pre-test scores, post-test scores, N-gain values, and effect sizes.

Table 6
The results of the pre-test, post-test, N-gain, and effect size on critical thinking skills

Group		*n*	*Critical Thinking Skill*			*N-gain*		*Effect Size*	
			Mean	*SD*	*Criteria*	*N-gain*	*Criteria*	*Cohen's d*	*Criteria*
Experiment	Pre-test	28	0.20	0.17	Low	0.73	High	2.40	Very Large
	Post-test	28	3.70	0.38	High				
Control	Pre-test	26	0.15	0.10	Low	0.49	Medium		
	Post-test	26	2.48	0.61	Medium				

The results indicate that initially, both classes exhibited low levels of critical thinking skills. However, after receiving the CAP-based learning treatment, the experimental class showed a significant improvement, reaching a high level of critical thinking skills, while the control class demonstrated a moderate improvement. This improvement is evident from the N-gain values, with the experimental class achieving a high level and the control class reaching a moderate level. Additionally, the effect size reveals a substantial difference in the impact of the treatment between the two variables, with a very large effect size observed. Therefore, CAP-based learning fulfills several criteria for enhancing students' critical thinking skills and demonstrates its effectiveness as a teaching approach.

Statistically, Table 7 shows the results of paired *t* -tests and independent *t*-tests on critical thinking skills scores. Paired and independent *t*-tests are used because the data has met the requirements of normal and homogeneous distribution. It can be seen that there is a significant difference in skills between pre-test and post-test results for both classes. In addition, there was also a significant difference in skills between the experimental class and the control class. This corroborates the finding that CAP-based learning effectively improves students' critical thinking skills.

Table 7
Result of paired and independent t-test of critical thinking skill

Group	Paired t-test			Independent t-test			
	t	*df*	*Sig.*	*F*	*t*	*df*	*Sig.*
Experiment	−48.10	27	.00*	4.71	8.66	52	.00*
Control	−20.39	25	.00*				

Note. *p < .05.

In terms of learning motivation, the sample size differs from the assessment of critical thinking skills due to difficulties in controlling students to willingly and conscientiously fill out questionnaires. Furthermore, data collection in the control class faced obstacles as some mischievous students went directly to the cafeteria after the physics class ended before the break. Despite these challenges, the experimental class's average post-test score of learning motivation was higher than that in the control class, as presented in Table 8.

Table 8
The results of the pre-test, post-test, N-gain, and effect size on learning motivation

Group		*n*	Learning Motivation		N-gain		Effect Size	
			Mean	*SD*	*N-gain*	*Criteria*	*Cohen's d*	*Criteria*
Experiment	Pre-test	28	3.19	0.60	0.63	Medium	1.37	Very Large
	Post-test	28	4.35	0.45				
Control	Pre-test	26	3.61	0.46	0.03	Low		
	Post-test	26	3.74	0.44				

Additionally, the N-gain value in the experimental class indicated a medium level of improvement, showing a significant difference compared to the control class. The effect size, measuring the difference in field operational impact, revealed a very large difference. Consequently, CAP-based learning fulfills several criteria for enhancing student motivation and demonstrates its effectiveness.

Table 9 provides the results of the paired t-test and the Mann-Whitney U test to determine the statistical differences. The paired t-test was employed as the data variance satisfied the criteria of normality and homogeneity, while the Mann-Whitney U test was utilized when the data variance was normally distributed but not homogeneous. The findings indicated a significant difference in learning motivation between the pre-test and post-test results in the experimental class, while the difference was insignificant in the control class. This finding is further supported by the significant difference in learning motivation observed between the experimental and control groups.

Table 9
Result of paired t-test and Mann-Whitney U test on learning motivation

Class	Paired T-test			Mann-Whitney Test		
	t	*df*	*Sig.*	*Mann-Whitney U*	*Z*	*Sig.*
Experiment	−7.72	23	.00*	3.00	−5.59	.00*
Control	−1.52	19	.14			

Note. *p < .05.

The student response to CAP-based learning pertains to the feedback students provide after the learning process. The majority of students responded positively to this learning approach, as evidenced by the percentages exceeding 50% or meeting the positive criteria, as witnessed in Table 10. In statement number 6, "I feel a new experience in learning physics using the Adventuring Physics application," received the highest percentage of positive responses. Overall, the percentage of positive responses was notable, indicating favorable student feedback.

Table 10
Students' feedback

n	*Statement Number (%)*							*Average (%)*	*Criteria*
	1	*2*	*3*	*4*	*5*	*6*	*7*		
28	61.8	62.9	61.1	62.5	63.9	68.2	63.9	61.1	Positive

4. Discussion

CAP-based learning has the characteristics of cooperation, involving students working together in small groups to achieve predetermined goals together with the teacher. This social interaction can enhance the depth of understanding and develop interpersonal skills. In the process of achieving the goal, the Adventuring Physics application intervenes in an adventure-genre game and AR. Well-designed educational games are highly participatory and uniquely adept at embedding learning content within meaningful challenges and authentic contexts. Their strategies allow learners to find meaningful connections between gameplay activities and educational learning objectives (Yu et al., 2022).

Furthermore, according to Joyce et al. (2015), the characteristics of learning model development, one of them, must meet the criteria of logical theoretical rationality. The theoretical rationale of CAP-based learning is:

(1) Social constructivism learning theory by Lev Vygotsky, in which students construct knowledge through social interaction with others in a collaborative work. This implies that students find it easier to find and understand difficult concepts if they discuss them with their peers (Schunk, 2011).

(2) Situated learning theory by Jean Lave and Etienne Wenger, where learning is best achieved when situated in authentic contexts. Adventure games, AR, and authentic problem-orientation scenarios provide realistic and meaningful contexts for learning, allowing students to apply knowledge and skills in relevant situations (Anderson et al., 1996).

(3) Multimodal learning theory by Gunther Kress and Theo van Leeuwen, where the learning process using Adventuring Physics involves various sensory modalities, such as visual, auditory, and tactile experiences. This multimodal approach accommodates different learning styles, making the content more accessible to a diverse group of students (Kress et al., 2001).

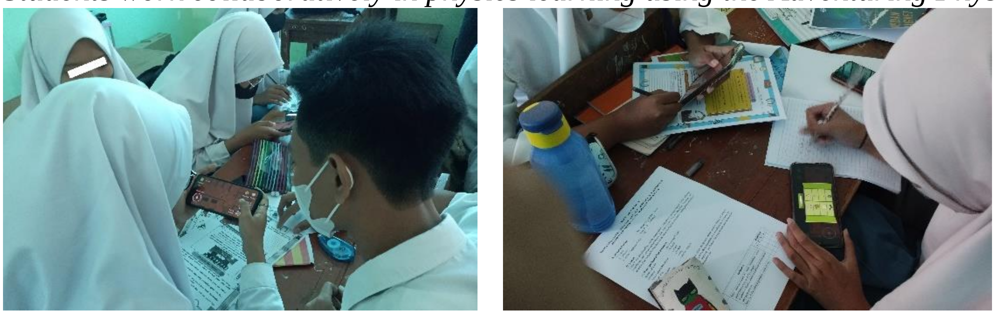
There are several novelties in CAP-based learning, which contribute to its innovative nature as a teaching method. Firstly, the learning process incorporates integrated AR game applications, providing a unique and interactive learning experience. This integration of AR technology enhances student engagement and promotes active participation in the learning process (Wibowo, 2023). Secondly, the CAP-based learning process is designed to align with the latest curriculum. By ensuring relevance to current educational standards, these materials facilitate the acquisition of up-to-date knowledge and skills, preparing students for real-world challenges (Cohen et al., 2010). Moreover, the learning model is intentionally crafted to improve critical thinking skills and learning motivation. By design, they encourage students to analyze, evaluate, and think critically about the subject matter (Reynders et al., 2020). This approach fosters intellectual curiosity, problem-solving abilities, and a deeper understanding of the content.

Collectively, these novelties in CAP-based learning model offer a comprehensive and innovative teaching method. By utilizing AR, staying up-to-date with the curriculum, emphasizing critical thinking and motivation, and leveraging digital technology. This approach provides a dynamic and engaging learning environment for students. These features enhance the effectiveness and relevance of the learning process, ultimately leading to improved educational outcomes (Camilleri & Camilleri, 2017; Tucker et al., 2016). These findings are consistent with Bakri et al. (2020) research that valid AR learning media can be considered feasible physics teaching material. Tirta et al. (2018) also confirmed that valid cooperative teaching material is able to improve students' learning achievement and self-efficacy effectively.

Integrating cooperative learning, adventure games, and AR provides an engaging and interactive learning environment. Students actively participate in collaborative activities, work together in teams, and solve problems within the game context (Hartt et al., 2020; López Belmonte et al., 2020). This active engagement promotes critical thinking as students analyze information, evaluate options, and make informed decisions collectively (Mao et al., 2022). Moreover, adventure game scenarios often present students with complex problems or challenges requiring critical thinking skills. Meanwhile, AR assists students in visualizing abstract concepts (i.e., magnetic field direction, magnetic force, current direction), and promoting their understanding related to the material (Hasibuan & Chairad, 2023). Students are encouraged to think critically, consider multiple perspectives, and devise effective strategies to overcome obstacles or accomplish game-related objectives (Sung & Hwang, 2013; Syawaludin et al., 2019). The practical application of critical thinking skills in solving in-game problems can transfer to real-life scenarios. In this context, students are required to connect the concepts they have learned in the game with magnetic field concepts, such as a magnetic pulley, a maglev train, and a solenoid.

Cooperative learning models also emphasize collaboration and communication among students (see Figure 3). In the context of adventure games and AR, students collaborate, share ideas, negotiate, and communicate their thoughts and perspectives to solve problems and achieve game objectives. These collaborative experiences enhance their communication skills (i.e., presentation) and encourage them to think critically about different viewpoints, fostering effective teamwork and interpersonal abilities (Loes & Pascarella, 2017; Warsah et al., 2021). What is more, the integration of adventure games and AR into the cooperative learning model enhances student motivation and engagement (Lin & Hou, 2022). These immersive and interactive technologies create a stimulating and enjoyable learning experience (Hao & Lee, 2021). Students are motivated to actively participate, persist in problem-solving, and apply critical thinking skills to succeed in the game (Huizenga et al., 2009; Partovi & Razavi, 2019). This heightened motivation and engagement contribute to improved learning outcomes.

Figure 3
Students work collaboratively in physics learning using the Adventuring Physics app



CAP-based learning is goal-oriented learning, having clear goals, objectives, and challenges for students to achieve (Arends, 2011; Hao & Lee, 2021; Warsah et al., 2021). These goals provide a sense of purpose and direction to students' learning, setting a target for them to strive towards (Cloude et al., 2019). Additionally, the CAP-based learning model creates an immersive and enjoyable learning experience (Suprapto et al., 2021). These interactive and engaging technologies capture students' interest and stimulate their intrinsic motivation to learn (Duncan, 2020; Marougkas et al., 2023). The excitement, challenge, and sense of accomplishment associated with the game elements motivate students to actively participate, explore, and invest effort in their learning (Davidson & Candy, 2016). By leveraging technology-enhanced cooperative learning approaches, educators can tap into students' intrinsic motivation, create meaningful learning experiences, and promote critical thinking skills, ultimately fostering a positive and motivating learning environment (Eyupoglu & Nietfeld, 2019).

This finding is consistent with some previous research. Hung et al. (2014), and Lutfi et al. (2023) confirmed that game-based learning could improve learning motivation, self-efficacy, and learning outcomes in some science subjects. Research by Duncan (2020), and Mao et al. (2022) revealed that immersive and collaborative game-based learning have a greater development of students' critical thinking skills and creativity. In terms of AR-based learning, this research is in line with Faridi et al. (2021), Khan et al. (2019), and Low et al. (2022) that the implementation of AR applications positively impacts students' learning motivation and critical thinking skills in science and engineering subjects. Furthermore, the findings are also consistent with Huang et al. (2017) and Warsah et al.'s (2021) research that cooperative learning can significantly enhance students' critical thinking skills as well as learning motivation. Based on the theoretical framework, CAP-based learning is supported by cooperative learning, with its focus on collaborative activities and peer interactions, which aligns well with social constructivist principles.

Students respond positively and well to CAP-based learning because they feel that this learning environment is new to them, resulting in an increase in their motivation and curiosity. In addition, they also argue that CAP-based learning should be developed on other physics materials or other subjects. This positive response corroborates the effectiveness findings because it is based on students' perspectives as active learners who are primarily involved in the learning process. Sastradika et al. (2021), and Uma'iyah et al. (2023) developed digital learning materials that received a positive response from students, indicating improved critical thinking skills in science subjects. Therefore, CAP-based learning has met the criteria of being valid, practical, and effective in enhancing students' critical thinking skills and learning motivation, while also receiving a positive response from them.

5. Implications, Limitations, and Future Directions

For educational practice, this research implies an innovative learning model that can improve students' critical thinking skills and learning motivation by design, spesifically in the physics subject. In terms of curriculum, the intervention of advanced technologies, such as digital games and AR in learning has a strong potential in increasing students' participation and engagement in the process. Although some studies suggest that teachers' acceptance in digital technology is not very satisfactory (Dele-Ajayi et al., 2019; Hoareau et al., 2021), training in the use of digital technology in education is essential for teachers today, enhancing their ability to create dynamic and engaging learning experiences.

However, one limitation of this study is socioeconomic factors that can also influence learning, as students without mobile phones may not have access to the Adventuring Physics application and may have to borrow from their peers. Another limitation is that the topic of study is only limited to magnetic fields with the subject of high school students. As a remediation, future research may develop CAP-based learning on other study topics, not only physics, as well as on different subjects, such as junior high school or university students. Additionally, extending the duration of the study would provide further insights into the sustainability and persistence of the observed improvements.

6. Conclusion

A CAP-based learning model has been developed that meets valid, practical, and effective criteria to improve students' critical thinking skills and learning motivation. The learning products and instruments demonstrate strong validity and reliability, presenting a comprehensive and innovative approach to teaching that creates a dynamic and captivating learning atmosphere for students. Learning has a level of practicality that indicates that all syntax meets practical and reliable criteria, meaning that the implementation of learning alligns with the lesson plan. Learning is also effective and significant for improving critical thinking skills and learning motivation in experimental classes. Students also respond positively to this learning model.

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