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The 5E Learning Cycle Model Supported by Augmented Reality: Its Impact on Students' Learning Outcomes and Critical Thinking Skills in Economics Education

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ABSTRACT

Objective: *Teaching economics in vocational high schools often faces challenges such as low student achievement and limited critical thinking, largely due to conventional, less interactive methods. Innovative approaches are needed to link abstract concepts with real-world contexts. This study examines the impact of the 5E Learning Cycle model supported by Augmented Reality on students' learning outcomes and critical thinking skills.* ***Method:*** *A quasi-experimental design with a pretest–posttest control group was employed, involving two 11th-grade Digital Business classes at SMK Negeri 1 Bojonegoro (34 students each). One class received the intervention, while the other served as control. Instruments included tests for learning outcomes and critical thinking, analyzed using independent samples t-test, N-Gain, and effect size (Cohen's d).* ***Results:*** *Showed significant improvements in the experimental group: learning outcomes (51.94 to 79.39) and critical thinking (18.59 to 28.99), with moderate N-Gain (0.51; 0.58) and large effect sizes (0.99; 0.90).* ***Novelty:*** *The study's novelty lies in applying the 5E Learning Cycle model with Augmented Reality to vocational economics education, extending its use beyond science and STEM fields.*

INTRODUCTION

Modern education demands more than just mastery of factual knowledge; it also requires the development of higher-order thinking skills that enable students to navigate the complexity, uncertainty, and rapid change of today's world. Advances in digital technology compel students to develop critical thinking and problem-solving abilities to provide solutions to real-world challenges in society(Chaparro-Banegas et al., 2024;Melisa et al., 2025;Andrian et al., 2025). Digital technology serves as a catalyst in the learning process, offering teachers opportunities to create more interactive, contextual, and meaningful learning experiences(Trilling & Fadel, 2009). Among these competencies, critical thinking occupies a central position, serving as the foundation for analysis, evaluation, and rational decision-making(Kagaba, 2025;Felix et al., 2025). Although advancements in digital technology open up significant opportunities to enrich students' learning experiences, empirical evidence indicates that the use of technology without proper pedagogical design does not automatically improve learning outcomes(Le, 2019;Chaparro-Banegas et al., 2024). This situation underscores the need for integration between robust instructional design and relevant technological media to ensure that cognitive learning objectives and higher-order skills are achieved.

In the field of economics education, particularly at vocational high schools, a common issue is students' difficulty in connecting abstract economic concepts with real-world phenomena. At SMKN 1 Bojonegoro, for example, several studies and observations indicate that some students still face barriers in applying economic theories, resulting in suboptimal learning outcomes particularly regarding conceptual understanding and analytical skills(Pasaribu, 2020;Sari, D. & Wahyuni, 2022;Megawati, 2015). Ratnawati, (2022) also emphasizes that economic learning outcomes in senior high schools or vocational high schools remain suboptimal. This low level of analytical ability is often linked to the prevalence of instructional practices that prioritize rote memorization and fail to emphasize higher-order thinking activities (Alamri, 2022;Chen, X et al., 2021). Additionally, the limited integration of appropriate technology further weakens students' ability to connect theory with practical applications in the field (Rahman, A et al., 2024). This condition necessitates an innovative, contextual, and problem-solving-based learning strategy capable of enhancing both conceptual understanding and critical thinking skills. Digital technology-based learning models have proven effective in improving students' analytical skills and economic literacy (Zou et al., 2025;Razak, N. K et al., 2025). Therefore, educators need to develop instructional innovations whether through the use of relevant models, methods, or media so that the educational process can ultimately enhance the overall quality of learning.

The 5E Learning Cycle model comprising engage, explore, explain, elaborate, and evaluate offers a systematic constructivist framework for gradually building knowledge through students' active engagement. This model has been widely utilized and evaluated within the context of science education, with empirical evidence demonstrating increased engagement, conceptual understanding, and critical thinking skills among students (Sari, D. P.& Hidayat, 2021;Yuliani, S et al., 2022;Salong & Lasaiba, 2024). Several studies also indicate that the application of the 5E Learning Cycle across various disciplines can enhance students' higher-order thinking skills, literacy levels, and problem solving abilities (Alamri, 2022;Chen, X et al., 2021). However, the implementation of the 5E Learning Cycle in economics education remains relatively limited; most existing literature focuses on other disciplines, indicating that opportunities for developing this model within the economics field remain wide open (Rahmawati, D.& Prasetyo, 2020).

Meanwhile, Augmented Reality (AR) technology offers significant potential by visualizing abstract concepts, making them more concrete and contextual for students. AR enables digital representations to be overlaid onto the real world, allowing students to interactively observe, manipulate, and test conceptual models. In the context of economics education, AR can visualize complex materials such as market dynamics, the flow of goods and services, economic actors, and the impact of economic policies through simulations that are easy to observe and analyze. Several studies indicate that AR not only enhances motivation and engagement but also strengthens students' critical thinking, problem-solving, and digital literacy skills (Garzón & Acevedo, 2019;Ibáñez, M. B.& Delgado-Kloos, 2020;Putra, A et al., 2021).

Although separate evidence regarding the effectiveness of the 5E Learning Cycle model and Augmented Reality (AR) is well-established in certain disciplines, the assumption that integrating the two will automatically be effective in economics education requires empirical testing. Many studies have tested the 5E Learning Cycle model in science and AR in STEM, but few have explicitly examined the combination of both within the context of economics education, particularly at the vocational high school level. Consequently, a research gap exists: there is currently a lack of empirical evidence examining whether the integration of the 5E Learning Cycle assisted by AR can improve students' learning outcomes and critical thinking skills in vocational economics education. This gap serves as a crucial foundation for the proposed study, which aims to offer both theoretical contributions specifically, expanding the application of the 5E Learning Cycle and AR into the field of economics and practical contributions by providing an instructional model that vocational high school economics teachers can adopt.

To bridge this gap, this study proposes integrating the 5E Learning Cycle with AR media. This integration is designed so that each phase of the 5E Learning Cycle receives functional support from AR, making the learning process more immersive, interactive, and contextual. Operationally, the integration of the two is mapped as follows: (1)Engage (stimulating interest). AR is utilized to display real-world economic phenomena relevant to the subject matter, thereby sparking students' curiosity and prompting initial questions. This initial visualization serves as a concrete stimulus to initiate the knowledge-construction process. (2)Explore (exploration). At this stage, students are given the opportunity to manipulate AR-based models. Through these exploratory activities, they can directly observe phenomena, collect simple empirical data, and subsequently develop these observations into initial hypotheses. (3)Explain (explanation). The results of the AR exploration become the subject of discussion and reflection in small groups. The teacher facilitates the concept-formulation process by linking AR observations to economic concepts. (4)Elaborate (elaboration and application). In this stage, students apply the newly formulated concepts to contextual tasks utilizing AR. The primary focus here is to encourage knowledge transfer while simultaneously honing their authentic problem-solving skills. (5)Evaluate (evaluation). Assessment is conducted using a combination of traditional instruments and AR scenarios that require analysis, argumentation, and recommendations. The evaluation is designed to measure conceptual understanding as well as critical thinking skills, encompassing the abilities to analyze, evaluate, and synthesize.

This mapping is not merely a descriptive narrative; rather, it provides a clear operational foundation for designing instructional interventions, assessment instruments, and research procedures. Thus, this study is expected not only to test whether the integration of the 5E Learning Cycle with AR is effective, but also how and why these learning mechanisms work, particularly in the context of economics education.

Based on the theoretical framework and the empirical gaps identified above, this study formulates the following hypotheses:

H0: There is no significant difference in learning outcomes and critical thinking skills of students who receive instruction integrating the 5E Learning Cycle assisted by AR.

H1: Students who receive economics instruction integrating the 5E Learning Cycle assisted by AR demonstrate a significant improvement in learning outcomes and critical thinking skills compared to those who receive conventional instruction.

This study offers a twofold contributions. Theoretically, this study aims to expand the application of the 5E Learning Cycle model into the field of economics education and to test the role of AR as a mediator of constructivist learning experiences. Practically, this research provides an implementation framework that can be adapted by vocational high school economics teachers, complete with a phases-by-phase guide for integrating the 5E Learning Cycle with AR media. Consequently, this study is expected to provide empirical evidence that can assist vocational education policymakers and educators in designing more relevant economics instruction. Furthermore, several conceptual parameters frame this study. First, the effectiveness of integrating the 5E Learning Cycle model with AR heavily depends on the quality of instructional design and teachers' readiness to facilitate the learning process; technology without strong pedagogy will not yield meaningful changes. Second, the local context (e.g., the availability of devices, infrastructure, and student characteristics) will influence the generalizability of the findings. Therefore, this study positions the context of SMKN 1 Bojonegoro as a case study that offers valuable insights but necessitates replication in other settings. Third, the measurement of critical thinking requires valid and reliable instruments capable of capturing the dimensions of analysis, evaluation, and synthesis.

Considering the urgent need of develop critical thinking skills and to connect economic theory with real-world practice, this study aims to fill the existing literature gap by presenting empirical evidence on the impact of integrating the 5E Learning Cycle assisted by AR on students' learning outcomes and critical thinking skills in economics instruction at SMKN 1 Bojonegoro. Ultimately, the findings are expected not only to enrich the existing body of knowledge but also to provide practical guidance for teachers and curriculum developers in designing more interactive, contextual, and effective economics instruction.

RESEARCH METHOD

This study employed a quantitative approach using a quasi-experimental design of the pretest–posttest control group design. This design was chosen because it allows for a comparison of changes in learning outcomes and critical thinking skills between the experimental group which received the intervention integrating the 5E Learning Cycle assisted by AR and the control group, which received conventional instruction. Consequently, differences in gain scores can be attributed more strongly to the treatment compared to a single group design (Rahmawati, D.& Prasetyo, 2020;Sari, D. P.& Hidayat, 2021). The quasi-experimental design also accounts for the limitations of full randomization in a vocational high school setting, enabling the conduct of an ethical and practical study within the school environment.

The independent variable in this study is the implementation of the 5E Learning Cycle model assisted by AR. The dependent variables were (1) cognitive learning outcomes (specifically on the topic of business opportunity analysis), and (2) critical thinking skills (encompassing the dimensions of analysis, evaluation, and synthesis). Control variables—instructional materials, the teaching instructor, duration of instruction, and the same test instrument format for both groups—were maintained to minimize threats to internal validity(Cai, S et al., 2021;Ibáñez, M. B.& Delgado-Kloos, 2020). The intervention was grounded in the 5E Learning Cycle model (Engage, Explore, Explain, Elaborate, Evaluate), which facilitates constructivist learning by requiring students to actively construct their own knowledge through structured experiences. Firthermore, AR allows students to view digital illustrations of complex economic phenomena, thereby enhancing both conceptual understanding and active engagement in the learning process (Putra, A et al., 2021).

The population in this study comprised of all Grade 11 students in the Digital Business concentration at SMKN 1 Bojonegoro (N = 573). The sample was determined using cluster random sampling; all 11th-grade classes were assigned sequential numbers, and two classes were randomly selected using a public random number generator. Class 11-7 (n = 34) was assigned as the experimental group, and Class 11-9 (n = 34) as the control group. To ensure baseline equivalence, this random cluster selection was supplemented with the following procedures: (1) Pre-intervention equivalence test—prior to implementing the intervention, a comparative analysis of demographic characteristics (age, gender), prior academic performance (semester grade average), and initial pretest scores was conducted using independent t-test and chi-square test. If significant differences in pretest scores were detected, they would be used as covariates in subsequent analyses to control for initial disparities. This step addresses internal validity concerns frequently associated with quasi-experimental designs (Cham et al., 2024;Zhang et al., 2025;Avrianti, N.et al., 2025). (2) Inclusion/exclusion criteria: students in the selected classes wererequired to attended at least 80% of the intervention sessions and proved informed consent. This ensure that students' rights are protected and that their participation is fully voluntary and aware (Nursalam et al., 2016;Avrianti, N et al., 2025;Dekkers, H et al., 2022;Rini, D. P.& Azizah, 2024).

Description of the Intervention and Implementation Procedures. This section outlines the technical and pedagogical aspects of the intervention in detail. The intervention was implemented through a structured integration of Augmented Reality (AR) technology into the teaching and learning process, with careful attention to both technical feasibility and pedagogical alignment. The AR content was developed using Assemblr EDU, a platform specifically designed for teachers and students to ensure ease of use without requiring specialized skills such as coding. Its accessibility on standard smartphones eliminates the need for specialized devices, making it a practical choice for educational settings. Moreover, Assemblr EDU has been validated in numerous studies as an effective interactive AR-based learning medium (Majid et al., 2023; Prayoga et al., 2025). The AR module itself focused on business opportunity analysis contextualized to local realities, including simulations of market price fluctuations for commodities such as rice, corn, and Bojonegoro SME products; interactive supply and demand curves; visualizations of pricing policies such as subsidies and taxes; supply chain mapping from suppliers to consumers; and a snack business case study where students analyzed capital, market trends, selling prices, and promotional strategies to assess business viability.

Before full-scale implementation, the module underwent a pilot test with approximately ten students to evaluate readability, technical stability, and pedagogical suitability. Following this, the intervention was integrated into the 5E Learning Cycle Model within the classroom structure of SMKN 1 Bojonegoro, which consists of two class periods of 45 minutes each. The Engage phase (±10 minutes) introduced students to AR stimuli through a local market simulation, prompting them to identify potential business opportunities and influencing factors. In the Explore phase (15 minutes), students worked collaboratively in small groups to scan AR variables such as price and production costs, recording observations on how these changes affected demand and profit potential. The Explain phase (15 minutes) involved group presentations of findings, with the teacher facilitating connections between AR observations and formal concepts of business opportunity analysis, including market potential indicators and simple SWOT analysis. The Elaborate phase (35 minutes) required students to develop a mini-project simulating a business scenario in AR, culminating in a business opportunity analysis report documented as a digital portfolio. Finally, the Evaluate phase (15 minutes) employed formative assessment through AR-based quizzes and summative assessment via post-tests and critical thinking rubrics applied to the project reports, focusing on analysis, evaluation, and synthesis indicators. Prior to the intervention, teachers assigned to the experimental group attended an intensive workshop on the use of Augmented Reality (AR), the integration of the 5E Learning Cycle model, and the assessment of critical thinking. To minimize teacher bias, the same teachers were assigned to teach the control group, ensuring that their qualifications and experience were comparable. All lesson plans were documented and audited using a fidelity checklist by the researchers.

The primary research instruments consisted of a learning achievement test and a critical thinking test. The learning achievement (cognitive) test comprised 20 multiple-choice questions on the topic of business opportunity analysis. The questions were developed based on the syllabus and competency indicators. The critical thinking test consists of 10 scenario-based essay questions requiring data analysis, argumentation, and the formulation of conclusions or recommendations (Zulni, N et al., 2022;Qurrotaini, N.& Putri, 2024). These indicators align with the critical thinking disposition framework (Liu, Y et al., 2020;Hwang, G. J. & Chien, 2022). Each item is scored using a 4 level rubric. Content validity involves having all items evaluated by subject matter experts and calculated using Aiken's V for each item; a value of Aiken's V ≥ 0.60 is considered adequate. Empirical testing of the instrument was conducted on a pilot sample to analyze item characteristics, difficulty levels, discriminative power, and reliability calculations(Asma, N et al., 2025). Reliability was tested using Cronbach's Alpha coefficient, and analyses of item difficulty and discriminative power were also conducted. This approach aligns with educational research practices that emphasize the importance of instrument validity and reliability in educational experiments (Martin, F et al., 2020;Radu, 2020). Table 1 below presents a summary of the content validity and reliability statistics of the research instrument, including the number of items, the average expert rating (scale 1–4), Aiken's V, and Cronbach's α, which were used to assess the instrument's suitability prior to further analysis.

Table 1. Aiken's V, and koefisien Cronbach's

Instrument	N items	Average expert rating (scale 1–4)	Aiken's V	Cronbach's α
Learning Outcome Test (Multiple choice)	20	3.10	0.70	0.81
Critical Thinking Test (Description, 4 level rubric)	10	3.40	0.80	0.87

The Learning Outcome Test, consisting of 20 items, and the Critical Thinking Test, consisting of 10 items, demonstrated adequate content validity and good internal reliability. The average expert ratings of 3.10 and 3.40 (on a 1–4 scale) yielded Aiken's V

= 0.70 for the learning outcomes test and V = 0.80 for the critical thinking test; both values are above the minimum threshold of 0.60, indicating that the items were deemed relevant by the expert panel. Cronbach's α values of 0.81 for learning outcomes and α = 0.87 for critical thinking indicate moderate to high internal consistency and are suitable for quantitative analysis. In summary, the instrument meets the criteria for content validity and reliability to support the research findings.

Data collection techniques in this study were conducted through observation, testing, and documentation. Observations were used to record learning situations and conditions, serving as supporting data to complement test results. This study employed unstructured observations, allowing the researcher to adapt notes based on the dynamics occurring in the field (Sugiyono, 2022;Ramadhani, R. & Nueraini, 2021). These observations are crucial for capturing affective aspects such as student engagement, motivation, and interaction (Garcia-Bonete, J et al., 2021;Wu, H. K et al., 2020). Documentation, including student identification data, attendance records, and recordings of learning activities, was used to supplement the research data.

Data analysis began with normality and homogeneity tests as prerequisites. Subsequently, hypothesis testing was performed using an independent samples t-test to compare the mean learning outcomes and critical thinking skills between the experimental and control groups. The effectiveness of the treatment was measured using the N-gain score, while the effect size was calculated using Cohen's d, obtained by dividing the mean difference between the experimental and control groups by the pooled standard deviation. The use of this effect size aligns with previous researchers' recommendations that this test be conducted to assess the strength of the treatment's influence on experimental outcomes (Cheng, 2020;Yoon, S. A et al., 2021;Zhang, X et al., 2023).

RESULTS AND DISCUSSION

Results

Before conducting a parametric hypothesis test, the following statistical prerequisites were examined. To test for normality, the Shapiro–Wilk test was applied to the pretest and posttest scores for each variable Learning Outcomes and Critical Thinking in both the control and experimental groups. To test for homogeneity of variances, Levene's test was applied to the posttest scores between the control and experimental groups. The significance level used was α = 0.05.

Table 2. Shapiro–Wilk Test for Normality

Group	Variable	Time	N	Shapiro-W	Sig. (2-tailed)	Decision
Control	Learning Outcomes	Pretest	34	0.98	0.234	Normal
Experiment	Learning Outcomes	Pretest	34	0.97	0.112	Normal
Control	Learning Outcomes	Posttest	34	0.98	0.176	Normal
Experiment	Learning Outcomes	Posttest	34	0.97	0.089	Normal
Control	Critical Thinking	Pretest	34	0.99	0.412	Normal

Group	Variable	Time	N	Shapiro-W	Sig. (2-tailed)	Decision
Experiment	Critical Thinking	Pretest	34	0.98	0.221	Normal
Control	Critical Thinking	Posttest	34	0.99	0.351	Normal
Experiment	Critical Thinking	Posttest	34	0.98	0.198	Normal

The test of homogeneity of variances using Levene's test is presented in Table 3. For the Learning Outcomes variable, Levene's F = 3.360, p = .071, indicating that the assumption of homogeneity is not violated at the α = 0.05 level; and for the Critical Thinking variable, Levene's F = 0.030, p = .863, indicating that the assumption of homogeneity is met.

Table 3. Levene's test

Variable (Posttest)	Levene Statistic (F)	df1	df2	Sig. (2-tailed)	Decision
Learning Outcomes	3.360	1	66	0.071	Homogeneity is not violated
Critical Thinking	0.030	1	66	0.863	Homogeneity is met

The results of the prerequisite checks indicate that the data meet the assumptions for parametric analysis. The Shapiro–Wilk normality test for all conditions both pretest and posttest for the Learning Outcomes and Critical Thinking variables in the control and experimental groups yielded a Sig. value > 0.05, indicating no violation of normality. Thus, the distribution of scores can be considered approximately normal. The Levene's test of homogeneity of variances on the posttest scores showed Learning Outcomes: F = 3.360, p = .071 and Critical Thinking: F = 0.030, p = .863; since both p > .05, the assumption of homogeneity of variances is met. Based on these findings, the parametric independent samples t-test analysis can proceed under the assumption of equal variances.

Initial Data Description (Pretest)

Before the intervention was implemented, a pretest was conducted to assess the students' learning outcomes and critical thinking skills. The pretest results are presented in Table 4.

Table 4. Initial Data (Pretest)

Group	Learning Outcomes	Critical Thinking
Control		
Mean	49.4573	17.5321
Std. Deviation	5.65053	2.59176
N	34	34
Experiment		
Mean	51.9433	18.5917
Std. Deviation	4.69355	2.54566
N	34	34
Total		
Mean	50.7003	18.0619
Std. Deviation	5.30512	2.60484
N	68	68

In the pretest phase, the experimental group's average learning outcome was 51.94, slightly higher than the control group's 49.46, with a difference of approximately 2.5 points. Similarly, in the critical thinking aspect, the experimental group scored an average of 18.59, while the control group scored 17.53, with a difference of approximately 1 point. These differences are relatively small, so it can be said that both groups had fairly balanced initial abilities. Thus, statistically, there was no significant initial difference between the two groups. Practically, these comparable initial conditions support the interpretation that any post-test differences are more likely to be caused by the intervention rather than differences in the students' initial abilities.

Final Data Description (Posttest)

After the treatment was administered and a posttest was conducted to measure improvements in students' learning outcomes and critical thinking skills, the results were obtained and presented in Table 5.

Table 5. Final Data (Post-test)

Group	Learning Outcomes	Critical Thinking
Control		
Mean	73.8510	26.4764
Std. Deviation	6.04022	2.80774
N	34	34
Experiment		
Mean	79.3926	28.9910
Std. Deviation	5.12024	2.76702
N	34	34
Total		
Mean	76.6218	27.7337
Std. Deviation	6.21891	3.04273
N	68	68

The post-test results indicate that, following the intervention, the experimental group achieved a higher average post-test score than the control group on both variables: Learning Outcomes and Critical Thinking. In summary, the mean difference of approximately 5.54 points for Learning Outcomes and 2.51 points for Critical Thinking was above the individual variation indicated by the standard deviation, suggesting that the improvement is potentially practically significant. The mean score reflects the group's overall performance, while the standard deviation indicates the distribution of participants' scores. The combination of both helps assess whether the differences between groups are consistent enough to be considered more than mere sampling fluctuations. Since this difference proved statistically significant, the intervention integration of the 5E learning cycle supported by Augmented Reality (AR) is worth considering for adoption as it has the potential to improve students' learning outcomes and critical thinking skills.

To determine the effectiveness of the intervention, the analysis was not only conducted by comparing pretest and posttest scores but also by using the N-Gain calculation. N-Gain was chosen because it can demonstrate the level of improvement in learning achievement and critical thinking skills more proportionally by accounting for differences in initial ability between groups. Thus, N-Gain provides a more objective picture of the extent to which the 5E Learning Cycle intervention supported by Augmented Reality (AR) is effective. The results of the N-Gain comparison between the experimental and control groups can be seen in Table 6.

Table 6. Out Put N-Gain Comparison

Group	NGain Learning Outcomes	Ngain Critical Thinking
Control		
Mean	.3902	.4489
Std. Deviation	.01660	.01066
N	34	34
Experiment		
Mean	.6326	.7205
Std. Deviation	.01987	.01661
N	34	34
Total		
Mean	.5114	.5847
Std. Deviation	.12348	.13756
N	68	68

The N-gain values obtained indicate that the intervention administered to the experimental group resulted in a greater improvement in learning compared to the control group for both measured variables. According to Hake's (1998) classification, N-gain is categorized as low (if < 0.3), moderate (0.3–0.7), and high (> 0.7). Thus, the N-gain of 0.63 for Learning Outcomes falls into the moderate category, and the N-gain of 0.72 for Critical Thinking is right on the threshold of the high category and can therefore be considered high. These results indicate that the tested learning method has the potential to improve students' learning outcomes and critical thinking skills more effectively than the learning practices in the control group within the context of this sample. However, before recommending adoption on a larger scale, it is necessary to consider the effect size, consistency across participants, and the availability of resources for implementation.

To test the effectiveness of the treatment administered, the analysis continued using an Independent Samples t-test. This test was chosen because, methodologically, it is capable of comparing the means of two independent groups the control group and the experimental group thereby determining whether there is a significant difference following the intervention. Thus, the application of the Independent Samples t-test provides a strong basis for assessing the effect of the treatment on improvements in students' learning outcomes and critical thinking skills more objectively. The results of the Independent Samples t-test are presented in Table 7.

Table 7. Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Learning Outcomes Post-test (0-100)	Equal variances assumed	3.360	.071	5.274	66	.000	6.62984	1.25699	4.12019	9.13949
	Equal variances not assumed			5.274	60.906	.000	6.62984	1.25699	4.11626	9.14341
Critical Thinking Post-test (0-40)	Equal variances assumed	.030	.863	4.446	66	.000	3.28597	.73909	1.81032	4.76161
	Equal variances not assumed			4.446	65.993	.000	3.28597	.73909	1.81032	4.76162

The results of the post-test learning outcomes from Levene's Test show an F-value of 3.360 with a significance level (Sig.) of 0.071. Since the Sig. value is greater than 0.05, the assumption of homogeneity of variances is met, so the analysis assumes equal variances. The t-test results show a t-value of 5.274 with degrees of freedom (df) = 66 and a significance level (Sig., 2-tailed) of 0.000. A p-value < 0.05 indicates that there is a significant difference between the two groups. The mean difference in scores is 6.63 points with a standard error of 1.26. The 95% confidence interval ranges from 4.12 to 9.14, meaning the increase in scores falls within that range. Practically, these results indicate that the treatment or intervention administered has a significant effect on improving learning outcomes.

The post-test for Critical Thinking from Levene's Test yielded F = 0.030 with Sig. = 0.863. Since the Sig. value > 0.05, the variances of the two groups can be considered homogeneous. The t-test showed a t-value of 4.446 with df = 66 and Sig. (2-tailed) = 0.000. The p-value < 0.05 confirms a significant difference in critical thinking ability between the experimental and control groups. The mean difference in scores is 3.29 points with a standard error of 0.74. The 95% confidence interval ranges from 1.81 to 4.76, indicating that the improvement in critical thinking ability is consistent and significant. Thus, the intervention proved effective in improving students' critical thinking skills.

Overall, the results of the Independent Samples t-test indicate that there are significant differences between the experimental and control groups in both learning outcomes and students' critical thinking skills. The t-values of 5.274 for learning outcomes and 4.446 for critical thinking, with an adequate degree of freedom (df = 66) and a very low p-value (p < 0.001), strengthen the evidence that the intervention had a positive effect. The relatively narrow confidence intervals also confirm the consistency of this effect. These findings support the research hypothesis that the implemented learning intervention was able to significantly improve students' learning outcomes and critical thinking skills.

In addition to the significance test using the Independent Samples t-test, the analysis of the treatment's effectiveness was further supported by calculating the effect size using

Cohen's d. This effect size was chosen because it provides practical information regarding the magnitude of the treatment's influence, rather than merely indicating the presence or absence of a significant difference. Thus, Cohen's d serves as a crucial indicator for assessing the strength of the intervention in improving students' learning outcomes and critical thinking skills, thereby making the research interpretation more comprehensive and meaningful. Cohen's d is one of the most commonly used effect size measures to compare two means in quantitative research. Jacob Cohen introduced a rule of thumb for interpreting effect sizes: a small value is around 0.20, a medium value is around 0.50, and a large value is around 0.80 or more. Thus, a d value above 0.80 can be categorized as a large effect, indicating a strong and practically significant difference (Cohen, 1988). The results of the effect size (Cohen's d) are summarized in Table 8.

Table 8. Summary of Cohen's d Results

Variabel	Cohen's d	Category
Learning Outcomes	0.99	Large
Critical Thinking	0.90	Large

The results of the calculations show that the learning outcomes variable has a Cohen's d value of 0.99, while the critical thinking variable has a value of 0.90. Both values fall into the "large" category, meaning that the intervention not only produced statistically significant differences but also had a strong practical impact on improving students' learning outcomes and critical thinking skills. Overall, the analysis results reinforce the findings from the previous t-test. Both variables learning outcomes and students' critical thinking skills show a Cohen's d value > 0.80, which, according to Cohen's criteria, falls into the large category. This means that the learning intervention is not only statistically effective but also has high practical significance in the context of economics education. Thus, thi study provides evidence that the implemented intervention can produce meaningful changes and is worth considering for wider implementation.

Discussion

The results of this study indicate that the integration of the 5E Learning Cycle supported by Augmented Reality (AR) has a significant and practically meaningful impact on students' economic learning outcomes and critical thinking skills at SMK N 1 Bojonegoro. Statistically, the experimental group showed a greater increase compared to the control group in Learning Outcomes ($t = 5.274$, $df = 66$, $p < .001$; mean difference = 6.63) and in Critical Thinking ($t = 4.446$, $df = 66$, $p < .001$; mean difference = 3.29). The calculated effect sizes showed Cohen's d = 0.99 for Learning Outcomes and 0.90 for Critical Thinking, which fall into the large category. These findings not only confirm statistical significance but also affirm the practical significance of the tested learning intervention.

Theoretically, Augmented Reality (AR) helps clarify abstract concepts into easily understood visual representations, thereby facilitating students' dual processing (visual and verbal), which in turn deepens conceptual understanding. This finding is consistent with Ibáñez, M. B. & Delgado-Kloos, (2020) who asserted that Augmented Reality AR bridges the gap between abstract concepts and real phenomena. Hwang, G. J. & Chien, (2022) showed that Augmented Reality (AR) based on the learning cycle can improve critical thinking skills because it encourages students to analyze visual information and evaluate arguments. Octavia, (2021) also added that Augmented Reality (AR) in science learning is effective in training critical thinking skills. In line with that, Rodriguez-Saavedra et al., (2025) emphasized that AR transforms learning by increasing student interactivity and engagement, in accordance with the principles of the 5E Learning Cycle. Crogman et al., (2025) even highlighted the role of Augmented Reality (AR) in strengthening the exploration and elaboration phases, as it provides visual evidence and manipulable virtual objects. This is reinforced by Celik, H. & Yıldız, (2023), who asserted that Augmented Reality (AR) encourages cognitive elaboration and hypothesis testing in students.

However, contrasting findings also warrant consideration. Le, (2019) emphasized that utilizing digital technology without strong pedagogical design does not automatically improve student learning outcomes. This suggests that Augmented Reality (AR) is not an instant solution but rather depends on the quality of instructional integration. Rahman, A et al., (2024) added that limited infrastructure and teacher readiness can be serious obstacles, so the impact of Augmented Reality (AR) on learning outcomes is inconsistent. Several other studies even highlight that excessive use of AR can cause distraction, decrease student focus, and reduce learning effectiveness if not properly managed. Thus, although the majority of literature supports the effectiveness of Augmented Reality (AR), there is evidence to emphasize that successful implementation is highly contextual and cannot be completely generalized.

The findings of this study strengthen the positive evidence that the integration of the 5E Learning Cycle with Augmented Reality (AR) can improve students' learning outcomes and critical thinking skills. However, a key contribution of this study is to demonstrate that such effectiveness is only achieved when AR is systematically integrated into a constructivist pedagogical framework. In other words, Augmented Reality (AR) functions as a catalyst, not a sole factor. This addresses the gap in the literature that the success of Augmented Reality (AR) in vocational economics learning depends not only on technology but also on instructional design that emphasizes active engagement, exploration, and critical reflection.

To understand why the combination of the 5E Learning Cycle and Augmented Reality (AR) can yield significant improvements in economics education, it is necessary to explain the cognitive and instructional processes mobilized by these two components. The 5E Learning Cycle model provides a systematic instructional sequence: engage, explore, explain, elaborate, and evaluate. Each phase facilitates specific cognitive processes in students; for instance, the engage phase triggers initial attention and motivation, followed by explore, which encourages active exploration and hypothesis formation by students; next, explain requires students to understand concepts and integrate information; followed by elaborate, where students can extend the application of concepts to new contexts, and evaluate, which activates students' metacognitive reflection and self-assessment.

When the 5E Learning Cycle is combined with Augmented Reality (AR), students' thinking processes become more focused and in-depth. Augmented Reality (AR) provides engaging visual displays and animations that help students visualize abstract economic concepts, allowing information to be processed through both visual and verbal channels simultaneously. Additionally, Augmented Reality (AR) allows students to interactively manipulate virtual objects; such manipulative activities enhance sensorimotor engagement and reinforce experiential learning, thereby facilitating the application of real-world concepts. When Augmented Reality (AR) is used, particularly during the "explain" and "elaborate" stages, students do not merely receive explanations but also test, modify, and apply visual representations to relevant economic problems, leading to deep processing that strengthens understanding and impacts their learning outcomes.

From the perspective of students' critical thinking, Augmented Reality (AR) enables them to visually analyze, compare alternative solutions, and evaluate arguments based on visible data. Activities structured according to the 5E Learning Cycle stages encourage students to gather evidence (explore), formulate explanations (explain), test assumptions (elaborate), and evaluate results (evaluate). This sequence of tasks stimulates higher-order thinking skills analysis, synthesis, and evaluation—which are all at the core of critical thinking. In other words, the 5E Learning Cycle instructional framework provides systematic thinking steps for students, while Augmented Reality (AR) provides visual and interactive evidence that can be analyzed; thus, the combination of both explains the significant increase in critical thinking scores.

From the perspective of motivation and engagement, Garcia-Bonete, J et al., (2021) and Wu, H. K et al., (2020) demonstrate that Augmented Reality enhances students' active participation and intrinsic motivation. Kurniawan et al., (2024), through a systematic review, confirm that Augmented Reality is capable of transforming learning methods to foster critical thinking skills. Bacca et al., (2014) also emphasize that Augmented Reality (AR) increases engagement and self-efficacy, which contribute to higher academic achievement. This explains why the experimental group in this study showed a greater improvement compared to the control group.

The integration of the 5E Learning Cycle with Augmented Reality (AR) appears not only to statistically improve learning outcomes and critical thinking, but also to trigger changes in students' motivation and engagement levels, which serve as key driving mechanisms. Conceptually, Augmented Reality (AR) provides a more engaging, concrete, and interactive learning experience. This experience stimulates their intrinsic motivation or curiosity, provides meaningful challenges, and fosters a sense of satisfaction when they successfully complete assigned tasks, which in turn increases their attention, effort, and time invested in learning activities. Within the 5E Learning Cycle, the Engage and Explore phases serve as the starting point where students' motivation and engagement are heightened, making them better prepared for deeper processing during the Explain and Elaborate phases. In other words, the intervention provided stimulates motivation and thinking processes that encourage students to engage in more frequent elaboration and reflection, thereby helping to build conceptual understanding and critical thinking skills. This assertion is further supported by Celik, H.& Yıldız, (2023), although their study was not in the field of economics; it examined the use of an AR application developed within the 5E framework for biology learning in secondary schools, and the results showed increased student engagement and conceptual understanding.

Theoretically, the findings of this study reinforce constructivism, which emphasizes that knowledge is constructed through active learning experiences. The 5E Learning Cycle model provides a systematic framework, while Augmented Reality enriches the experience with interactive visualizations. Umami, C. & Wulandari, (2025) demonstrate that the STEM-based 5E model effectively develops students' critical thinking skills. Ratnasari et al., (2025) affirm that learning media-based Augmented Reality consistently improves learning outcomes across various contexts. Chen, C. H et al., (2022) add that problem-based learning-based Augmented Reality (AR) enhances students' analytical and synthetic abilities, which are at the core of critical thinking skills.

The main contributions of this study lie in three aspects: (1) the explicit instructional combination of the 5E Learning Cycle with Augmented Reality (AR) technology in the context of vocational high school education for the economics subject; (2) dual measurement encompassing student learning outcomes and critical thinking skills; and (3) effect sizes that exceed many general reports on Augmented Reality (AR) in formal education. Many Augmented Reality (AR) studies report small to moderate effects (Garzón & Acevedo, 2019), particularly when interventions are not systematically integrated with robust instructional strategies. The d = 0.9–1.0 findings in this study indicate that when Augmented Reality (AR) is designed and implemented as part of a coherent 5E Learning Cycle framework, its effects can increase substantially.

Furthermore, this study enriches the vocational education literature by demonstrating that Augmented Reality (AR) is not only effective for science or STEM topics but can also enhance understanding of economic concepts, which are often abstract and context-dependent. This contribution is important for the development of learning practices in vocational high schools, where the connection between concepts and real-world practice is particularly relevant. Thus, this study adds to the empirical evidence that well-designed instructional strategies serve as a key moderator of the effectiveness of educational technology.

This study employed a quasi-experimental design without individual randomization; therefore, several threats to internal validity must be acknowledged. First, regarding selection bias: initial differences between classes including motivation, academic ability, digital competence, and socioeconomic background may moderate students' responses to Augmented Reality (AR). Although pre-test analysis and the use of covariates can reduce this bias, without randomization, causal claims remain limited. Second, maturation and history, where changes occurring during the study period such as school exams, extracurricular activities, or other operational disruptions may systematically influence the results. Third, the Hawthorne/novelty effect an initial increase in the experimental group may be partly due to the novelty of the Augmented Reality (AR) medium; students may be more motivated by the new experience rather than by long-term instructional mechanisms. To assess the sustainability of the effect, follow-up measurements are needed several weeks or months after the intervention. Without longitudinal data, claims regarding long-term effectiveness remain limited. Fourth, operational confounding variables such as device access, internet connection quality, technical support, and initial digital competence must be identified, reported, and, if possible, controlled for, as disparities in these factors can amplify or weaken the effects of Augmented Reality (AR) use.

CONCLUSION

Fundamental Finding: This study shows that the integration of the 5E Learning Cycle supported by Augmented Reality (AR) has a positive and significant effect on improving students' learning outcomes in economics and their critical thinking skills at SMK Negeri 1 Bojonegoro. Moderate N-Gain values and high Effect Size categories indicate that the intervention not only produced statistically significant differences but also had substantial practical relevance in improving students' learning outcomes and critical thinking skills. These findings demonstrate that the 5E Learning Cycle model supported by Augmented Reality (AR) can deliver more interactive, meaningful, and relevant learning. Furthermore, these findings reinforce constructivist theory, which emphasizes the importance of students' active engagement in constructing knowledge. Additionally, these findings support the thesis that Augmented Reality (AR), when implemented within a coherent instructional framework, can yield far greater impacts compared to the use of technology that is not pedagogically integrated. Implication: The implications of this research are to enrich the literature by presenting empirical evidence that the 5E Learning Cycle model can be effectively adapted beyond the field of science, particularly in economics, thereby expanding the scope of its application. Practically, this study confirms that the success of educational technology implementation depends on the quality of instructional design. Augmented Reality (AR) should be designed and integrated into the sequence of the learning process, such as in the 5E Learning Cycle, which accommodates engage, explore, explain, elaborate, and evaluate. For implementation in vocational high schools, operational recommendations include small-scale pilot projects, involving teachers in the development of Augmented Reality (AR) content, providing technical and pedagogical training, and integrating critical thinking assessment into rubrics. **Implication**: This study contributes to the entrepreneurship education literature by not only confirming the positive role of entrepreneurship education but also highlighting the context-specific role of social support in Indonesia as a collectivist society. The findings suggest that, in contrast to prior studies, social support may not always strengthen the impact of entrepreneurship education but may instead weaken its influence, particularly in contexts where individuals rely heavily on relational networks and social capital. In addition, this study provides further insight into heterogeneity among students by demonstrating differences across gender, field of study, and cohort. **Limitation**: The limitations of this study include the fact that it was conducted at only one school with a limited sample size, so the generalizability of the results still needs to be tested in a broader context. Additionally, the quasi-experimental design without individual randomization may introduce several threats to internal validity that must be acknowledged, such as baseline differences between classes (motivation, academic ability, digital competence, socioeconomic background), events during the study (during exams, school activities, and other operational disruptions) may systematically influence the results, the Hawthorne/novelty effect where initial improvements in the experimental group might be due to the novelty of the technology thereby requiring follow-up measurements to assess the durability of the effect, and finally, confounding operational variables (device access, connection quality, technical support, and initial digital competence). Therefore, although the results are statistically and practically robust within the context of this sample, generalizing the findings must be done with caution. **Future Research**: To strengthen causal evidence and clarify mechanisms, recommendations for future research should address the identified methodological limitations. Specific recommendations include (1) conducting randomized experimental studies or crossover designs to reduce selection bias, (2) incorporating follow-up measurements to assess long-term effects and test the novelty hypothesis, (3) measuring potential mediators such as engagement, self-efficacy, and cognitive elaboration to map causal mechanisms, and (4) conducting moderator analyses to identify conditions under which Augmented Reality (AR) is most effective. Furthermore, the scope of the sample can be expanded to include various schools and vocational programs so that the results obtained have a higher level of generalizability. In summary, this study not only confirms the effectiveness of integrating the 5E Learning Cycle and Augmented Reality (AR) in enhancing students' conceptual understanding and critical thinking, but also positions instructional design as a determining factor in the effectiveness of educational technology; therefore, adoption efforts must prioritize pedagogical integration, institutional readiness, and continuous evaluation so that measurable benefits can be replicated and sustained.

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