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ABL CER Learning Improves Basic Physics Conceptual Understanding

Pembelajaran ABL CER Meningkatkan Pemahaman Konsep Fisika Dasar

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Abstract
General Background: Higher education requires students to master conceptual knowledge alongside scientific reasoning through structured argumentation involving claims, evidence, and reasoning. **Specific Background:** However, students' conceptual understanding in basic physics often remains weak due to unstructured learning practices that fail to reveal reasoning processes and support evidence-based explanations. **Knowledge Gap:** Although argumentation-based learning is recognized in science education, its structured implementation using Claim-Evidence-Reasoning (ABL-CER) in higher education physics contexts remains insufficiently examined. **Aims:** This study aims to determine the effect of ABL-CER on students' conceptual understanding in Basic Physics. **Results:** Using a quasi-experimental posttest-only control group design with 71 students, the experimental group achieved a higher mean score (72.43) than the control group (64.50), with a significant difference (Sig. 0.001 < 0.05). **Novelty:** This study demonstrates that structured argumentation through CER explicitly supports conceptual reasoning by requiring students to formulate claims, select relevant evidence, and connect them through scientific reasoning. **Implications:** The findings suggest that ABL-CER provides a systematic and assessable framework for strengthening conceptual understanding, particularly in physics topics prone to misconceptions, and supports its application in higher education and teacher preparation contexts.

Highlights

- Experimental class achieved higher posttest scores than comparison group
- Structured reasoning process supports deeper conceptual processing
- Argumentation activities facilitate evaluation and revision of ideas

Keywords
Argumentation-Based Learning; Claim Evidence Reasoning; Conceptual Understanding; Basic Physics; Higher Education

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INTRODUCTION

Higher education today is expected to produce graduates who not only master concepts but also demonstrate scientific reasoning namely, formulating claims, weighing evidence, and providing logical justification during discussions and problem solving. This expectation has become stronger in the era of modern learning, when students face an abundance of information and must be able to select valid evidence to build conceptual understanding. Recent research shows that learning environments that structure argumentation for example, through scaffolding can improve scientific knowledge understanding as well as the quality of learners' arguments (Lin & Hung, 2025)

However, classroom practice often still leads students to provide answers without revealing their thinking processes. Arguments tend to be weak, evidence may be irrelevant, and reasoning frequently fails to connect to core concepts. This condition aligns with findings indicating that conceptual understanding in basic science remains vulnerable to misconceptions or alternative conceptions. For example, a study involving pre-service science teachers found that most respondents demonstrated inadequate scientific understanding of the concepts of work–power–energy, and several common alternative conceptions appeared at meaningful proportions (Irmak et al., 2023). Similar findings also appear in other physics topics: diagnostic measurements using tier tests have identified persistent knowledge gaps and misconceptions that hinder conceptual understanding (Auliya et al., 2025; Bessas et al., 2024)

One approach that can address theses problems is Claim-Evidence-Reasoning based Argumentation-Based Learning (ABL-CER). This approach is a more modern and directed form of discussion-based learning. In ABL–CER, students are not only asked to discuss, but are guided to: (1) formulate a clear claim, (2) select or present relevant evidence (data, concepts, observations, or problem-solving results), and (3) construct reasoning that links evidence to the claim using scientific principles or concepts. Such a framework has been shown to make argumentation learning more concrete and not merely a relabeling of discussion methods (Altun & Ozsevgec, 2025)

The selection of ABL–CER is motivated by its ability to make students' conceptual reasoning visible. Instructors can evaluate not only whether an answer is correct, but also the quality of evidence and the logic connecting it to the claim. Structured argumentation also encourages students to compare ideas, test conceptual consistency, and revise understanding mechanisms that are important for reducing misconceptions. Studies on university students show that well-designed argumentation activities (including representational supports and tools) can help students better understand topics by differentiating arguments and strengthening cognitive processes (Alt, 2022; Berland & McNeill, 2010). In addition, learning that integrates inquiry and scientific practices (including argumentation) has been reported to contribute to improved scientific literacy outcomes that are relevant to conceptual understanding (Cavagnetto, 2010; Eymur & Çetin, 2024).

Beyond the demand for scientific reasoning skills, basic science learning in higher education also often faces persistent misconceptions about fundamental concepts such as work and energy. Research developing a three-tier diagnostic test for pre-service science teachers found that scientific understanding of work and energy is often insufficient and dominated by specific alternative conceptions, which may hinder subsequent learning (Irmak et al., 2023)

In this context, scientific argumentation is important because it requires students not merely to answer, but to coordinate claims, evidence, and reasoning so that their thinking becomes visible and can be evaluated. When learners are asked to interpret and evaluate evidence to support a claim, they are encouraged to build justifications that are more conceptual rather than opinion-based (Guilfoyle & Erduran, 2021; Jonassen & Kim, 2010)

Theoretically, scientific argumentation is also related to conceptual change. A systematic review reported that argumentation-based learning has the potential to promote conceptual change through cognitive and intentional dimensions, and the effect tends to be stronger when argumentation is supported by appropriate scaffolding (Li et al., 2022; Weiss et al., 2022).

Nevertheless, argumentation learning does not automatically become effective if students do not receive a clear structure for building arguments. A scoping review of online argumentation scaffolding showed that structured supports such as prompts or templates are generally associated with improved argumentation skills, although fading and the transfer of responsibility are often not optimized (Noroozi et al., 2018; Ucar-Longford et al., 2024). Moreover, AI-supported argumentation learning environments have been reported to strengthen argumentation learning through the synergy of cognitive, affective, and skill supports (Lin & Hung, 2025; Raza, 2024).

Thus, this study aims to determine the impact of implementing ABL-CER on students' conceptual understanding, particularly in the topic of Basic Physics. The results of this study are expected to provide evidence that ABL-CER is effective in enhancing students' conceptual understanding compared to conventional learning..

The novelty of this study lies in the implementation of ABL-CER in the Fundamentals of Science course at the higher education level and in examining its impact on students' conceptual understanding across various topics in Basic Physics. This is in line with recommendations from previous studies on argumentation development, which emphasize the need for a gradual and structured argumentation-based learning design (Altun & Ozsevgec, 2025; Iordanou & Rapanta, 2021).

METHODS

This study is a quantitative study using a quasi-experimental method with a posttest-only control group design. This study compares students' conceptual understanding scores between the experimental and control classes, with measurements taken once at the end of the treatment. The experimental group learned through ABL-CER, while the control class learned through conventional learning. Table 1 presents the posttest-only control group design.

[Table 1 about here]

The population in this study consisted of 212 students enrolled in the Fundamental of Science course. The sample included two classes: one experimental class with 34 students and one control class with 37 students. The classes were selected through cluster purposive sampling. The independent variable was ABL–CER, and the dependent variable was conceptual understanding.

Conceptual understanding data were collected using a multiple-choice conceptual understanding test developed based on conceptual understanding indicators for Fundamental of Science topics, including (1) quantities and units, (2) uniform linear motion, (3) uniformly accelerated linear motion, and (4) work and energy.

The treatment procedure in the experimental class followed an ABL–CER scenario focusing on structured argumentation activities. In general, each meeting included: (1) problem/case orientation, (2) small-group discussion to formulate a claim, (3) selection of evidence (observational data, information from learning resources, or problem-solving results), (4) construction of reasoning connecting evidence to scientific principles, (5) argument presentation and a challenge–response Q&A session, and (6) argument revision based on feedback. Explicit and staged argumentation learning designs like this have been reported to be effective in developing pre-service teachers'/learners' argumentation competencies (Altun & Ozsevgec, 2025).

To maintain argument quality, students in the experimental class used a CER worksheet in a concise format: **Claim** (the answer statement), **Evidence (**relevant evidence such as data, facts, calculation results, graphs, or cited conceptsand). **Reasoning** (an explanation of why the evidence supports the claim using scientific principles). Scaffolding through prompts or templates such as these is generally associated with improved argumentation skills, especially when integrated into learning activities and accompanied by feedback (Lin & Hung, 2025; Ucar-Longford et al., 2024).

In data analysis, besides the independent-samples t-test, it is recommended that the study report an effect size (e.g., Cohen's d) to describe the magnitude of the effect of ABL–CER on conceptual understanding so that interpretation is not based solely on statistical significance.

Data were analyzed descriptively (mean scores) and inferentially. Prior to hypothesis testing, a prerequisite normality test (Kolmogorov–Smirnov) was conducted. Differences in posttest scores between the experimental and control groups were examined using an independent-samples t-test, and the analysis was performed using SPSS.

FINDINGS AND DISCUSSION

This study involved two classes that received different instructional treatments: the experimental class was taught using ABL–CER, while the control class was taught using conventional instruction. After the instructional interventions in both classes were completed, a posttest was administered to both groups. This was conducted to compare the mean conceptual understanding scores between the experimental and control classes and to determine whether there was a significant difference between students taught using ABL–CER and those taught using conventional instruction.

Figure 1 shows a comparison of the mean conceptual understanding scores obtained by students in the experimental and control classes. The experimental class taught using ABL–CER achieved a higher mean conceptual understanding score than the control class taught using conventional instruction. Therefore, it can be concluded that ABL–CER is better at fostering students' conceptual understanding than conventional instruction.

[Figure 1 here]

The data obtained in this study were also analyzed inferentially using an independent-samples t-test for hypothesis testing. Before conducting the t-test, a normality test was performed. **Table 2** presents the results of the normality test, and **Table 3** presents the results of the independent-samples t-test.

[Table 2 about here]

Based on the Kolmogorov–Smirnov normality test in Table 2, the experimental class taught using ABL–CER obtained a significance value of 0.076, which is greater than 0.05; therefore, the experimental group data were normally distributed. Similarly, the control class taught using conventional instruction obtained a significance value of 0.200, which is greater than 0.05; therefore, the control group data were also normally distributed.

[Table 3 about here]

Based on the independent-samples t-test in Table 3, the Sig. (2-tailed) value was 0.001, which is less than 0.05. Based on the criteria, H0 was rejected and H1 was accepted. This indicates that there is a significant difference in students' physics conceptual understanding between those taught using ABL–CER and those taught using conventional instruction. These findings indicate that ABL–CER was effective in improving students' conceptual understanding. More importantly, the findings do not merely show score differences, but also suggest that structured argumentation can function as an instructional mechanism that supports deeper conceptual processing. In this regard, the contribution of the study lies not only in demonstrating instructional effectiveness, but also in strengthening the theoretical view that conceptual understanding develops more effectively when students are required to justify knowledge claims with evidence and scientific reasoning.

The results of this study illustrate that ABL-CER encourages students to construct their knowledge through the practice of stating claims, selecting relevant evidence, and then connecting evidence and concepts through reasoning. This pattern requires students not to stop at a final answer but to test why the answer is correct, thereby strengthening conceptual structure and reducing misconceptions. Meanwhile, conventional learning provides a way for students to organize their ideas, evaluate their explanations, and revise their understanding when evidence and reasoning are weak. These results align with previous research suggesting that scientific argumentation has strong potential to drive conceptual change through intense cognitive learning (Li et al., 2022; Zhou, 2010). Thus, the advantage of ABL–CER is that it not only encourages discussion but also structures the discussion into a directed reasoning process so that concept learning is more effective and evidence-based.

From a learning-process perspective, CER functions as scaffolding that guides elaboration. Students externalize ideas, check the consistency among claim–evidence–reasoning, and revise arguments when they receive counterarguments or questions from peers. Such activities enrich conceptual sensemaking because students must align evidence with relevant scientific principles (Fitzgerald & Palincsar, 2019). Studies emphasizing scaffolding and explicit instruction in argumentation also show that without support, many learners remain at an early level of argumentation competence; structured learning helps them engage more meaningfully (Lin & Hung, 2025; Ucar-Longford et al., 2024; Zhang & Browne, n.d.). In classroom implementation, this scaffolding can be observed when students present their answers, show supporting data, concepts, observational results, and calculation outcomes. In addition, they are asked to explain why the evidence is relevant. During the presentation and question-and-answer sessions, students may receive opposing arguments, which encourages them to revise incomplete claims and weak reasoning. This repeated process of explanation, evaluation, and revision can contribute to strengthening students' conceptual understanding, as found in the experimental class that learned through ABL-CER.

Furthermore, ABL CER can improve the quality of students' conceptual understanding because it not only cites information but also trains them to evaluate evidence. When students are asked to assess evidence and reasons that strengthen or weaken a position, they practice distinguishing relevant data, reasoning strength, and truth, leading to deeper understanding. This is a unique contribution of this study. While previous studies generally only show that argumentation is useful in science learning, this study specifically shows that organizing arguments through the CER structure in the context of basic physics in higher education can make students' conceptual understanding more systematic and assessable. Therefore, the contribution of this study is not only confirmatory but also explanatory. Evidence from argumentation tasks focusing on evaluating evidence also indicates learning opportunities and challenges, reinforcing the need for well-designed argumentative tasks to support conceptual reasoning development (Guilfoyle & Erduran, 2021; Pohan et al., 2025).

The results are also consistent with findings that learning environments promoting argumentation can positively affect knowledge outcomes and academic performance. For example, a study integrating argumentation into interactive simulation activities found significant increases in academic achievement compared with a control group, indicating that argumentative engagement can strengthen content learning outcomes (Canoz et al., 2022).

More broadly, one of the positive effects on content knowledge and scientific skills is argumentation, particularly when activity strategies provide a structure for developing and communicating explanations or arguments (Chen & Chen, 2025). This is relevant because ABL-CER essentially provides structured activities (claim, evidence, reasoning) similar to argumentation templates to keep discussions conceptual and evidence-based, rather than opinion-based.

Therefore, the application of ABL-CER can be considered to strengthen students' conceptual understanding, especially for concepts that are prone to misconceptions. This is because ABL-CER integrates: (1) explanation construction; (2) evidence evaluation; (3) explicit conceptual justification, which are the main pathways to conceptual change.

This study has several limitations. First, the posttest-only method does not directly measure the equivalence of the two groups' initial abilities. Therefore, further research is recommended to use a pretest–posttest design. Second, the sample was drawn from only two classes at a single institution, so generalization should be made cautiously. Third, while multiple-choice instruments are strong for measuring conceptual outcomes, they do not fully capture the quality of reasoning, even though reasoning quality is a key aspect in ABL–CER (Addido et al., 2022).

My recommendations for future researchers are: (1) to measure conceptual understanding while also assessing the quality of CER, such as the accuracy of claims, the appropriateness of evidence, and the clarity of reasoning; (2) to include a delayed posttest to determine whether students' conceptual understanding remains stable over time; and (3) to investigate other forms of scaffolding, such as automated feedback (Ucar-Longford et al., 2024).

The implication of this study is that ABL-CER is suitable for application to physics topics that are difficult to understand, require cause-and-effect explanations, or often lead to misconceptions, such as quantities and units, motion, as well as work and energy. Lecturers can use CER worksheets, structured questions, small group discussions, and presentation feedback sessions so that students receive more evidence-based explanations. This approach is also relevant in teacher education because pre-service teachers need not only conceptual mastery, but also the ability to explain scientifi ideas logically and pedagogically.

CONCLUSIONS

The results of this study indicate that students taught using ABL-CER achieved higher conceptual understanding scores than students taught through conventional instruction. In the experimental class, the mean score was 72.43, which was higher than the mean score of the control class, namely 64.50. Meanwhile, the results of the independent samples t-test showed a significance value of 0.001, which was lower than 0.05, indicating a significant difference. These findings show that the conceptual understanding of students in the experimental class who learned through ABL-CER was better than that of students in the control class who learned through conventional instruction. This is because ABL-CER provides a more structured learning process that requires students to formulate claims, select appropriate evidence, and construct reasoning that connects the evidence with scientific concepts. As a result, students are encouraged to test and revise their conceptual understanding more clearly. ABL-CER can be considered an alternative learning approach to strengthen students' conceptual understanding, especially in physics topics that are prone to misconceptions. For future research, it is recommended to determine the effect size and examine the implementation of ABL-CER across broader topics and learning contexts.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Table 1. Research Design: Posttest-Only Control Group Design

Group	Treatment	Measurement
E	X	O_1
C	-	O_2

Keterangan:
X = ABL–CER learning treatmen;
\- = conventional instruction;
O_1 = conceptual understanding posttest in the experimental class
O_2 = conceptual understanding posttest in the control class

Table 2. Results of the Normality Test Analysis of Students' Learning Outcomes in the Experimental Class and the Control Class

Tests of Normality

	Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Postest	Kelas Kontrol	.131	34	.146	.951	34	.129
	Kelas Eksperimen	.167	37	.011	.947	37	.076

a. Lilliefors Significance Correction

Table 3. Results of the Independent-Samples *t*-Test Analysis in the Experimental Class and the Control Class

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
Posttest	Equal variances assumed	22.295	.000	-3.358	69	.001	-7.93154	2.36170	-12.64301	-3.22007
	Equal variances not assumed			-3.261	44.037	.002	-7.93154	2.43234	-12.83349	-3.02959

LIST FIGURE

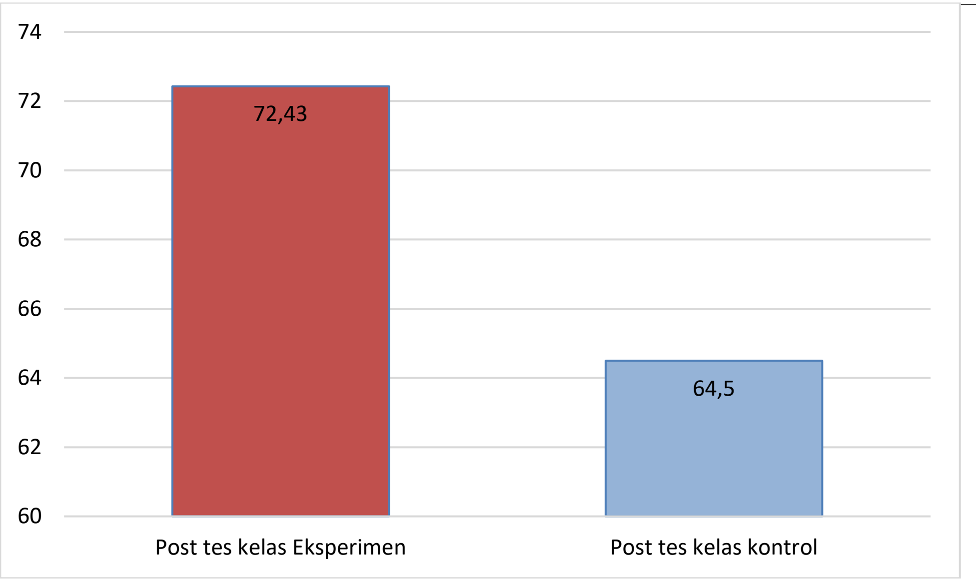

Figure 1. Comparison of the average scores of students' conceptual understanding in the experimental class and the control class.