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The Effect of a Mini Hydropower Instructional Medium on Students' Argumentation Skills

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Abstract

Low argumentation skills in physics classrooms motivate practice-based instruction. This quasi-experimental study tested whether a mini hydropower instructional medium improves students' argumentation skills. Using a Non-Equivalent Control Group Design, two Grade 10 science classes at SMA TI NWDI Wanasaba participated (n = 21 per class). Class X IPA 1 used the mini hydropower medium, while Class X IPA 2 received regular instruction. Instruments comprised a teaching module, observation sheets, and an argumentation pre-test and post-test aligned with the Toulmin Argument Pattern. Normality and homogeneity assumptions were met. Pre-test means were 34.05 (experimental) and 31.00 (control). Post-test means were 78.05 and 76.57, respectively. A one-tailed independent-samples t test showed a statistically significant difference at $\alpha = .05$, with $t = 4.23$ exceeding the critical value of 1.72. The findings indicate that integrating a mini hydropower instructional medium can enhance students' argumentation skills in high-school physics. For interpretive caution, future studies should analyze gain scores or apply ANCOVA to adjust for baseline differences, report effect sizes and confidence intervals, and document instrument validity and reliability. The study suggests that authentic, hands-on energy contexts can provide a productive platform for students to formulate claims, marshal evidence, and articulate warrants in physics reasoning.

Keywords: Mini hydropower; Instructional medium; Argumentation skills; Quasi-experiment; Physics education

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INTRODUCTION

Rapid advances in science and technology require countries to raise the quality of education so that graduates can compete internationally. Classroom instruction is expected to keep pace with those advances, not simply by adding digital artifacts but by reshaping learning so students engage with ideas, tools, and evidence in disciplined ways (Anzani et al., 2023). In Indonesia, persistent concerns about student outcomes remain visible in physics. The problem is not only cognitive performance on physics content but also students' dispositions toward the subject, which often include anxiety, low confidence, and weak engagement (Supardi et al., 2015). Many students view physics as heavy and serious, dominated by abstract concepts and complex problem solving, which they find tedious rather than meaningful (Aswara et al., 2022). If that is the learning climate, it is unsurprising that some students become reluctant to participate and their achievement suffers. Reported causes include limited variety in pedagogy, low motivational support, and explanations that do not connect ideas with tangible experiences (Nurmadanti, 2021; Setiawan et al., 2022).

Instruction links theory and practice. Theory offers conceptual scaffolds and language for thinking; practice tests those ideas in concrete contexts and yields feedback that can reorganize understanding (Arifin et al., 2024). In this sense, learning media are not mere accessories. Well-chosen media function as representational bridges that help students make sense of phenomena and coordinate multiple forms of evidence (Baharin et al., 2019). Teachers therefore need room to be creative and to choose or design media that match learning goals, sustain interest, and surface productive struggle rather than boredom (Ewar et al., 2023). This is not only about motivation. It is about giving students structured opportunities to evaluate claims, weigh reasons, and decide what counts as an adequate explanation.

Argumentation sits at the center of that ambition. In everyday life and in science, people encounter contested claims and must judge which conclusions are warranted by the available evidence. Classroom routines that cultivate argumentation help students move from opinion to reasoned judgment, articulate warrants for their claims, and consider counterevidence with care (Setiawan & Fadillah, 2023). In science learning specifically, argumentation sharpens how students identify the strengths and weaknesses of their own reasoning and supports the search for the best explanation of natural phenomena rather than the quickest answer (Istiana et al., 2019). The literature shows that engaging students in scientific argumentation can involve them in complex practices of constructing and justifying knowledge claims, not only recalling facts (Belland et al., 2011). It also suggests that growth in argumentation interacts with students' conceptual resources; when core ideas become intelligible and useful, students argue more productively about them (Heng et al., 2015). At the same time, prior knowledge and experience shape how readily students participate in argumentation, which cautions teachers to design supports that meet students where they are (Von et al., 2008).

Across science subjects, researchers have documented argumentation in biology, chemistry, earth science, and physics classrooms, with promising but uneven results (Riwayani et al., 2019). The common thread is that students benefit when tasks invite them to coordinate data, claims, and warrants around observable or investigable events. Energy and electricity topics are good candidates because they allow direct measurement and modeling. Yet, few studies have investigated a mini hydropower instructional medium as a vehicle for argumentation in secondary physics, and fewer still have tested its effect with a quasi-experimental design at the senior high school level. This gap matters. If a low-cost, school-appropriate device can anchor investigations of renewable energy while eliciting structured argumentation, teachers gain a practical tool that links curriculum aims with authentic inquiry.

A local needs analysis motivated the present study. In an interview with a physics teacher at SMA TI NWDI Wanasaba (14 January 2025), students were described as anxious about physics, hesitant to voice ideas or ask questions, and weak in argumentation. Classroom interaction was largely one-way under conventional methods. That description does not condemn lectures per se, but it does highlight a mismatch between instructional routines and the stated goals of the curriculum. The problem is not only that students are quiet; it is that the classroom offers too few occasions to frame a claim, provide evidence, and justify the link between them. In such conditions, a hands-on medium that produces measurable effects may help redistribute classroom talk toward evidence-based reasoning.

This study examines a mini hydropower instructional medium for teaching renewable energy. The choice is principled. A working water-driven generator, scaled for classroom use, creates a context where students can manipulate variables, observe electrical output, and debate explanations for observed patterns. The device is simple enough to be safe and repairable, yet rich enough to support questions about energy transformation, system efficiency, and measurement uncertainty. It sets the stage for argumentation aligned with the Toulmin Argument Pattern, where students formulate claims, cite data, and articulate warrants that connect evidence to theory. The goal is not only to raise test scores but to create disciplined talk where students challenge and refine one another's reasoning.

Given the prior literature and the local problem framing, the study tests a clear question: Does using a mini hydropower instructional medium influence students' argumentation skills compared with conventional instruction? We do not assume that any hands-on activity will automatically produce better reasoning. The claim under investigation is narrower and testable in a classroom: when instruction is organized around the mini hydropower medium with explicit attention to evidence and warrants, students' argumentation skills will improve more than under standard lessons. The study adopts a quasi-experimental Non-Equivalent Control Group Design to compare outcomes between two intact classes. This design acknowledges school constraints while allowing a cautious estimate of the treatment effect.

The expected contributions are practical and conceptual. Practically, the study offers a feasible, low-cost setup that physics teachers can adapt without specialized laboratory infrastructure. Conceptually, it probes whether a concrete renewable-energy context can serve as a scaffold for argumentation, consistent with the view that material engagement can stabilize and extend students' conceptual resources (Belland et al., 2011; Heng et al., 2015). By situating argumentation in measurable phenomena rather than purely verbal debate, the study aims to support students in moving from assertion to justification and in treating counterexamples as opportunities to refine ideas rather than threats to be avoided.

This study addresses persistent difficulties in physics learning by situating instruction around a concrete, measurable device and evaluating students' argumentation outcomes. The research question as follow:

- Is there a statistically significant difference in post-test argumentation scores between Grade 10 students taught with the mini hydropower instructional medium and those taught with conventional instruction at SMA TI NWDI Wanasaba?

METHODS

This study employed a quasi-experimental approach because it compared at least two intact groups under school constraints that precluded random assignment. One class received the instructional treatment and one class continued with conventional instruction. In this context, a quasi-experiment is an appropriate method for estimating the effect of an educational intervention when full experimental control is not feasible; it allows the researcher to examine whether exposure to a specific treatment is associated with differences in learning outcomes while acknowledging that some background factors cannot be fully controlled. The analytic focus was to test whether exposure to a mini hydropower instructional medium was associated with higher argumentation scores than conventional instruction under ordinary classroom conditions.

Consistent with its purpose and data structure, the study adopted a quantitative approach in which evidence of learning was represented by numeric scores and analyzed with inferential statistics suited to mean comparisons. The design was a Non-Equivalent Control Group Design. Two existing Grade 10 science classes at SMA TI NWDI Wanasaba served as the comparison units: Class X IPA 1 was designated the experimental group and Class X IPA 2 the control group. Assignment to condition followed administrative scheduling and programmatic considerations of the school rather than randomization, as is typical in school-based research with intact classes. Both groups completed a pre-test to establish baseline comparability and a post-test after instruction to gauge outcomes. The experimental group engaged with the mini hydropower instructional medium as part of the unit on renewable energy, while the control group followed the conventional lesson sequence already in use at the school. The generic structure of the design is summarized in Table 1.

Table 1. Research design

Group	Pretest	Treatment	Postest
Experimental	O_1	X_1	O_2
Control	O_1	X_2	O_2

Notes. O_1 = pre-test administered before instruction; O_2 = post-test administered after instruction; X_1 = instructional treatment in the experimental class; X_2 = conventional instruction in the control class.

The instructional treatment centered on a classroom-scaled mini hydropower setup that allowed students to observe and measure energy transformations and electrical output under varying conditions. The purpose of the device was not merely motivational, but epistemic: to anchor claim–evidence–reasoning exchanges in directly observable phenomena and to provide common data for discussion and critique. In the control condition, teachers followed the school's standard lesson format for the topic without using the mini hydropower medium. Both classes covered the same content objectives within the same time window to reduce curricular confounds and ensure that any detected differences in scores could plausibly be attributed to the presence or absence of the medium and the associated practices of evidence-based discussion.

The target outcome was students' argumentation skills, operationalized with reference to the Toulmin Argumentation Pattern (TAP) (Toulmin, 2003). The TAP framework distinguishes six elements: claim (the conclusion or answer advanced), data (the facts or observations offered in support of the claim), warrant (the reasoning that links the data to the claim), backing (the theoretical or authoritative support for the warrant), qualifier (an indication of the claim's scope or strength), and rebuttal (consideration of counterevidence or exceptions). Following Robertshaw and Campbell (2013), the scoring rubric assigned credit to each component based on the presence, accuracy, and coherence of student responses. In practical classroom terms, students were expected to state a clear claim, cite relevant measurements or observations from the mini hydropower investigations, justify why those data supported the claim using appropriate physical principles, reference supporting ideas when needed, acknowledge the strength and limits of their conclusions, and address possible counterexamples or alternative explanations.

Four instruments supported data collection. The primary instrument was a written test of argumentation administered as a pre-test and a post-test. It consisted of six essay prompts aligned to the TAP components and to the curricular content on renewable energy. The same form, difficulty, and scoring criteria were used in both classes to support fair comparisons. A set of observation sheets guided the documentation of classroom activities for teachers and students, focusing on the enactment of the lesson sequence and the occurrence of argumentation-relevant practices (for example, whether the teacher pressed for warrants or whether groups explicitly compared data across trials). A Student Worksheet (Lembar Kerja Peserta Didik, LKPD) provided structured tasks and data tables to standardize opportunities for measurement and reasoning; the LKPD was derived from an existing Grade 10 physics worksheet on the relevant topic and had undergone expert review for content appropriateness. Finally, a documentation protocol was used to archive instructional artifacts and capture salient classroom events. The test items, observation sheets, and LKPD were reviewed by a physics education expert to ensure content relevance and clarity. While formal indices (such as Aiken's V or interrater reliability coefficients) are not reported here, expert validation was used to support the content validity of the instruments.

The population comprised all Grade 10 students at SMA TI NWDI Wanasaba enrolled in the science track, organized into two instructional groups (X IPA 1 and X IPA 2). The sample consisted of these two intact classes. This choice reflects the study's goal of maintaining ecological validity by working within existing school structures. Because students were already grouped administratively, random assignment to conditions was not feasible; instead, one intact class served as the experimental group and the other as the control group, consistent with a non-equivalent groups design. Both groups received instruction during the same term, used the same school facilities, and were assessed with the same instruments under similar conditions to reduce extraneous variation.

Data collection proceeded in three stages common to classroom quasi-experiments. First, both groups took the argumentation pre-test to characterize baseline performance on the target skills. Second, the experimental class completed the unit using the mini hydropower instructional medium while the control class completed the corresponding unit with conventional methods. Throughout instruction, observation sheets documented the implementation to ensure that the core difference between conditions was the presence of the medium and the associated emphasis on evidence-based discussion. Third, both groups completed the argumentation post-test. All responses were scored according to the TAP rubric, with component-level judgments synthesized to produce an overall argumentation score for each student.

Statistical analysis followed standard steps for comparing two independent groups with pre/post measurement. Prior to hypothesis testing, distributional assumptions were examined. Normality of the score distributions was checked using the Lilliefors test applied to pre-test and post-test scores in each class.

Homogeneity of variance across groups was examined using Fisher's F test, computed as the ratio of the larger sample variance to the smaller one, $F = S_1^2/S_2^2$, with degrees of freedom tied to the two group sizes. These diagnostics served to justify the use of a pooled-variance t test in the subsequent analysis. Where assumptions were met, group means were compared with an independent-samples t test under the equal-variances assumption. The decision rule, aligned with the directional hypothesis that the experimental group would outperform the control group, used a one-tailed test at α = .05. In accordance with the study's research question—restricted to a single post-test comparison—the focal inferential statistic contrasted post-test argumentation scores between the two classes. The null hypothesis stated that the experimental and control groups have equal population means on the post-test; the alternative stated that the experimental group mean exceeds the control group mean. Decisions were made by comparing the calculated t statistic with the critical value; if $t_{\text{calc}} > t_{\text{critical}}$, the null hypothesis was rejected in favor of the directional alternative at the specified alpha level. Descriptive statistics (means and standard deviations) for pre-test and post-test scores were also computed to document baseline comparability and the direction of change.

To maintain fidelity to classroom realities and avoid introducing confounds, instructional time, curricular objectives, and assessment windows were matched across groups. Both classes were taught by the same subject-matter teacher following the school's pacing plan for the unit on renewable energy. In the experimental class, the mini hydropower device structured the sequence of tasks: students observed the apparatus, formulated predictions about how changes in flow rate or load might affect voltage and current, conducted measurements using the provided data tables in the LKPD, and engaged in guided discussions that required them to state claims about observed relationships, cite their recorded data, and explain why the data supported those claims in light of energy and circuit principles. In the control class, parallel content was delivered through conventional methods without the device. This ensured that any differences captured by the post-test could be attributed to the instructional medium and its associated opportunities for argumentation rather than to topic coverage or time on task.

Scoring procedures were standardized to strengthen internal validity. The TAP-aligned rubric specified performance indicators for each component, with anchors illustrating acceptable evidence for claims, data, warrants, backing, qualifiers, and rebuttals. Student responses were read holistically but scored at the component level, and the component scores were aggregated to an overall argumentation score. Although interrater reliability coefficients are not reported here, scoring followed the same rubric across groups, and the same scorer applied the criteria to all scripts to maintain consistency. Observation notes were reviewed after the unit to verify that the mini hydropower medium had indeed been used as planned and that students had opportunities to collect and compare measurements, articulate warrants, and consider counterexamples.

Finally, the analysis plan was deliberately aligned with the single research question to avoid inflating the Type I error rate through multiple unplanned comparisons. The focal comparison was the difference in post-test means between the experimental and control groups under the equal-variances, one-tailed independent-samples t test at α = .05, contingent on normality and variance homogeneity checks. This sequence—assumption checks, descriptive statistics, and a single confirmatory test—was chosen to provide a clear and interpretable answer to the study's question about the effect of a mini hydropower instructional medium on students' argumentation skills, while keeping the analysis anchored in the data collected under ordinary school conditions (Toulmin, 2003; Robertshaw & Campbell, 2013).

RESULTS AND DISCUSSION

This study examined whether using a mini hydropower instructional medium was associated with higher argumentation skills than conventional instruction in two intact Grade 10 science classes. The intervention was embedded in a renewable energy unit in which the experimental class operated a classroom-scaled water turbine and collected simple electrical measurements to support claim–evidence–reasoning discussions, while the control class covered the same content using the school's regular lesson format. The intention was not only to motivate students but to provide shared, inspectable evidence for structured argumentation.

Hands-on measurements in the experimental class were taken by directing school tap water onto the turbine at three settings (low, medium, high) and recording the electrical output with a digital multimeter. As recorded, the generator produced direct current (DC) voltages of 1.3 V (low flow), 2.5 V (medium), and 8.7 V (high). The corresponding current readings were reported as 0.0 A, 1.4 A, and 5.9 A. To provide a qualitative check, a 1-W DC HPL LED was used as an indicator: the lamp glowed very dimly at low flow, dim at medium flow, and very bright at high flow. These observations are pedagogically useful because they create visible differences that students can reference in arguments about energy conversion and system behavior. At the same time, the relatively large ampere values, if taken at face value, would imply power levels that may exceed what a small classroom turbine typically delivers; this could reflect meter range, unit notation, or circuit conditions. For purposes of classroom argumentation, the trend across conditions—rather than the absolute magnitude—served as the main evidentiary anchor for students' claims.

Learning outcomes were assessed with a pre-test and post-test of argumentation skills aligned to the Toulmin Argumentation Pattern. Table 2 shows pre-test descriptive statistics. Both classes started below the school's minimum mastery criterion, with comparable ranges and means.

Table 2. Pre-test scores in the experimental and control classes

Class	n	Maximum	Minimum	Mean
Experimental	21	48	16	34,05
Control	21	46	16	31,00

Based on Table 2, the experimental class recorded a maximum pre-test score of 48 and a minimum of 16, with a mean of 34.05. The control class showed a maximum of 46 and a minimum of 16, with a mean of 31.00. These results indicate that both classes began with relatively low argumentation scores, below the school's minimum mastery criterion.

To determine final outcomes, both classes completed a post-test after instruction. The experimental class received the mini hydropower instructional medium, while the control class followed conventional lessons. The post-test consisted of six essay items on renewable energy aligned with the argumentation construct. The resulting post-test scores are summarized in Table 3.

Table 3. Post-test in the experimental and control classes

Class	n	Maximum	Minimum	Mean
Experimental	21	92	68	78,05
Control	21	89	66	76,57

Based on Table 3, the experimental class that received the mini hydropower instructional medium achieved a maximum post-test score of 92 and a minimum of 68, with a mean of 78.05, whereas the control class taught with conventional instruction reached a maximum of 89 and a minimum of 66 with a mean of 76.57. From these data, it can be concluded that learning with the mini hydropower instructional medium is more effective for improving students' argumentation skills than learning with conventional instruction, although both classes can be considered to have met mastery because their mean scores are above the minimum mastery criterion.

Next, a normality test was conducted. The results of the normality tests for students' argumentation scores in both groups are shown in Table 4.

Table 4. Normality test of argumentation skills

α	Variable	$L_{calculated}$	L_{table}	Decision
0,05	Pre-test_argumentation skills, experimental class	0,10	0,18	Normally distributed
	Post-test_argumentation skills, experimental class	0,10		
	Pre-test_argumentation skills, control class	0,09		
	Post-test_argumentation skills, control class	0,08		

Based on the calculations for the experimental class, the mean pre-test score was 34.05 and the mean post-test score was 78.05; the standard deviations were 9.70 and 7.34, respectively. The Lilliefors statistics for the pre-test and post-test were both 0.10. For n = 21 at α = 0.05, the critical L value was 0.18 for both tests. Since L_calculated < L_table at α = 0.05, the pre-test and post-test scores in the experimental class were normally distributed.

Based on the calculations for the control class, the mean pre-test score was 31.00 and the mean post-test score was 76.57; the standard deviations were 9.45 and 6.93, respectively. The Lilliefors statistic for the pre-test was 0.09 and for the post-test was 0.08. For n = 21 at α = 0.05, the critical L value was 0.18 for both tests. Since L_calculated < L_table at α = 0.05, the pre-test and post-test scores in the control class were normally distributed.

Next, a homogeneity test was conducted. The results of the homogeneity test for students' argumentation skills in both groups are presented in Table 5.

Table 5. Homogeneity test of students' argumentation skills

α	Variabel	N	$F_{calculated}$	F_{table}	Decision
0,05	Pre-test_argumentation skills, experimental class	21	1,05	2.12	Homogeneous
	Post-test_argumentation skills, experimental class	21			
	Pre-test_argumentation skills, control class	21	1,12		
	Post-test_argumentation skills, control class	21			

The calculated F value for the pre-test comparison between the experimental and control classes was 1.05, which is below the critical value of 2.12 at the 0.05 level. For the post-test comparison, the calculated F value was 1.12, also below the same critical value. With 21 students in each class, these results indicate that the variances of the two groups can be treated as homogeneous.

Because the post-test score distributions for the experimental and control classes were also found to be normally distributed, the study proceeded with an independent-samples t test to evaluate the hypothesis. The test examined whether there was a difference in argumentation skills between the class taught with the mini hydropower instructional medium and the class taught with conventional methods.

The post-test score distributions for the experimental and control classes were found to be normally distributed. Accordingly, an independent-samples t test was used to evaluate the study hypothesis, comparing argumentation skills between students taught with the mini hydropower instructional medium and those taught with conventional methods. The results of this hypothesis test are presented in Table 6.

Table 6. Hypothesis test of students' argumentation skills

Class	Mean	$t_{calculated}$	$t_{(critical, one tailed)}$	Decision
Experimental	78,05	4,23	1,72	Ha accepted
Control	76,57			Ho rejected

Using a two-sample t test assuming equal variances, the calculated t value was 4.23 and the one-tailed critical t value was 1.72. Since the calculated t exceeded the critical value, the analysis indicates a difference in the improvement of students' argumentation skills between the experimental and control classes, as reflected in the post-test means of 78.05 for the experimental class and 76.57 for the control class. Therefore, it can be concluded that the mini hydropower instructional medium positively influenced students' argumentation skills at SMA TI NWDI Wanasaba, leading to acceptance of Ha and rejection of Ho.

Improvements in students' argumentation skills were identified from the pre-test and post-test results for each class. A comparison of the average scores obtained from the pre-test and post-test in the class that used the mini hydropower instructional medium and in the class that did not use the medium (control class) is presented in Figure 1.

Figure 1 shows the mean pre-test and post-test argumentation skills in the experimental and control classes. The class that used the mini hydropower instructional medium began with a mean pre-test score of 34.05 (categorized as medium), while the control class began with a mean of 31.00 (also medium). Both classes showed gains on the post-test. The experimental class reached a mean of 78.05 (high), whereas the control class reached 76.57 (high). The increase was greater for the class taught with the mini hydropower instructional medium than for the class taught without it.

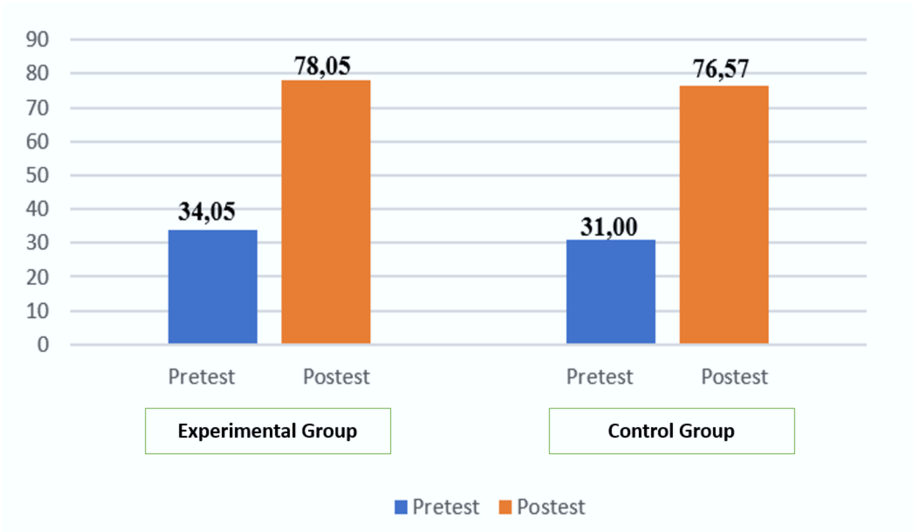

Figure 1. Students' argumentation skills

The distribution and category patterns of students' argumentation skills indicate that both classes engaged across all Toulmin components, yet the experimental class showed a larger share of very-high performances. This pattern is consistent with classroom notes: students who worked with the mini hydropower instructional medium were more likely to ask clarifying questions, propose tentative claims, support those claims with measurements, and revise their ideas when peers introduced counterexamples. The control class participated and made progress, but typical interactions leaned toward listening and note taking. That contrast matters because argumentation skills rarely develop in passive settings. When learners interact with an observable system that produces measurable effects, they have concrete reasons to articulate claims and scrutinize warrants. This helps explain the post-test advantage observed for the experimental class.

Situating these findings within prior work clarifies the mechanism. Argumentation is a core strand of scientific literacy because citizens and students must weigh interpretations of data and form reasoned judgments about socio-scientific issues (Ismial, 2016). Many investigations show that students possess preliminary cognitive structures for argumentation, yet these are fragile and hard to deploy without guidance in real tasks (Heng et al., 2015). The present intervention offered two kinds of support at once: a tangible hydropower context that yielded shareable data, and prompts that pressed for warrants, qualifiers, and rebuttals. This combination reduced the effort of sourcing evidence while raising the standard that evidence should justify claims. In that sense, the medium worked as a representational bridge between phenomena and ideas, the role learning media are expected to play when instruction aims to deepen reasoning.

Growth in both classes also fits the view that explicit scaffolds matter. Instructional designs that structure how students generate, evaluate, and communicate evidence improve the completeness and coherence of their arguments (Rundgren et al., 2016; Songsil et al., 2019). Although the control class did not use the hydropower device, both classes worked through a common sequence in the renewable energy unit with repeated opportunities to practice claims and reasons. That shared structure likely contributed to the general improvement above the school's mastery threshold. The experimental class, however, benefited from an added layer of support: real-time measurements that could be inspected, questioned, and repeated. This aligns with reports that guidance is most effective when learners test ideas against data they generate themselves (Heng et al., 2015).

A helpful lens for understanding the experimental condition is Argument-Driven Inquiry. Research on ADI shows consistent gains in argumentative writing and reasoning because students must collect data, defend analytic choices, and respond to peer critique (Lismawati et al., 2021; Purwandari et al., 2023). The hydropower lessons in this study were not formally branded ADI, yet they shared key features: students predicted how flow rate or load might influence output, recorded measurements, and used those records to support or revise claims. That structure likely improved links between data and warrants, a junction where many novices struggle. The alignment with ADI studies helps explain why the experimental mean edged above the control mean.

Inquiry-based learning provides a broader frame. In inquiry lessons, students plan investigations, interpret patterns, and justify conclusions, which places argumentation at the center of activity rather than at the margins (Munawaroh et al., 2020). In practice, scaffolding is the hinge. Data tables, guiding questions, and checkpoints for comparing trials make it more likely that students tie claims to empirical patterns and understand why particular measurements matter. Designs that include collaborative tasks and metacognitive prompts strengthen these effects, helping learners monitor the strength of their arguments and consider alternatives before committing to a conclusion (Litman & Greenleaf, 2017; Wale & Bishaw, 2020). The observation that experimental-class students asked more questions and articulated hypotheses suggests that the mini hydropower device, combined with these supports, fostered productive self-monitoring and peer critique.

Authentic context also plays a role. Argumentation improves when tasks connect to relevant technologies or local concerns, because students invest more effort and are more willing to construct multi-component arguments (Permana et al., 2020; Purwandari et al., 2023). Hydropower is familiar in many Indonesian settings, and even a classroom-scaled turbine makes energy transformation visible in ways that a static diagram cannot. Authenticity here does not mean industrial scale. It means students can see and influence the system. The social dimension matters as well. Studies show that argument quality improves when students exchange perspectives, question assumptions, and co-construct explanations in small groups (Christensen-Branum et al., 2018; Weyand et al., 2018). Field notes from the experimental class document precisely that kind of interaction, which likely contributed to the higher proportion of very-high performances.

These mechanisms help interpret the mean difference. The reported inferential test supports a difference favoring the experimental class, but the gap is modest. That pattern is common when an active treatment is compared with a reasonably structured control that covers the same content. Rather than dismissing the gap, it is more informative to ask which components moved most and why. Observations suggest the device especially supported data and warrant links, since students could point to a voltage reading or visible lamp brightness and then argue for why that observation followed from energy or circuit principles. Backing and qualifier were present but less robust, a familiar result when students are beginning to include theoretical support and scope in their explanations. This distribution matches earlier reports that components beyond claim and data require intentional practice before they become routine parts of students' arguments (Heng et al., 2015; Rundgren et al., 2016).

The experiential character of the lessons provides another explanation. Hands-on projects can bridge the gap between abstract knowledge and application by giving students a platform to test and revise ideas in real time. When learners design, build, or analyze an artifact, they are pushed to marshal evidence, anticipate counterexamples, and justify design or interpretive choices under constraints. This mechanism aligns with experiential learning theory, which emphasizes cycles of concrete experience, reflective observation, abstract conceptualization, and active experimentation. Such cycles help stabilize and extend conceptual understanding and can raise the quality of evidence-based reasoning and argumentation skills (Kolb, 1984). The hydropower device met these conditions at a scale suitable for school. Students could vary a parameter, observe consequences, and debate plausibility without leaving the classroom. The design made it harder to offer opinion-only explanations and easier to anchor reasoning in shared observations.

Observation sheets reinforce this interpretation. Across four meetings, both groups moved from acceptable to good and very good implementation ratings, but the experimental class moved further and faster. This is consistent with work showing that the quality of classroom talk improves when tasks elicit evidence and when teachers regularly ask students to justify and critique ideas rather than merely state answers (Litman & Greenleaf, 2017). In the experimental class, students not only completed measurements but also discussed discrepancies across trials, asked why a reading seemed off, and proposed steps to improve accuracy. Such routines cultivate metacognition about evidence quality and argument strength, a precondition for sustained growth in argumentation.

It is useful to situate the current results among adjacent studies that link varied media to argumentative outcomes. Reports of positive effects from wall charts, Padlet, cartoon media, and audiovisual-supported inquiry suggest that multiple tools can improve argumentative performance when they are embedded in tasks that require justification and comparison (Baan, 2016; Lubis et al., 2024; Danis & Pratiwi, 2024; Hartidini et al., 2018). The common denominator is not the device itself but the way it structures attention and talk around evidence. The mini hydropower medium matches this profile. It shifted what counted as a satisfactory answer by making it routine to point to observations and connect those observations to principles, rather than recite formulas detached from context.

At the same time, a careful reading is warranted. The design used intact classes, so unmeasured factors such as peer dynamics or prior attitudes may have contributed to outcomes. The apparatus produced strong qualitative differences that aided discussion, yet some quantitative readings could reflect meter range or circuit configuration rather than the load that a school-level turbine can deliver. Future cycles should calibrate the measurement setup, document uncertainty, and report effect sizes with confidence intervals. Where feasible, gain-score analysis or covariate-adjusted models can provide a tighter estimate of the magnitude. These steps would not replace the current finding, but would strengthen claims about what the medium contributes and for whom.

Practical implications follow. Teachers aiming to develop argumentation can adopt simple, durable versions of the hydropower device and pair them with structures that keep evidence central: clear data tables, prompts that ask for warrants and qualifiers, and routines for comparing across trials. Collaborative groups should be designed to surface diverse viewpoints and to normalize rebuttal, given the benefits of social interaction for argument quality (Christensen-Branum et al., 2018; Weyand et al., 2018). Sequencing matters. Early lessons can emphasize data quality and claim clarity, while later lessons focus on backing and qualifiers, which often lag without explicit attention. These moves are compatible with inquiry-based and argument-driven approaches that have been shown to enhance argumentative reasoning in school science (Munawaroh et al., 2020; Lismawati et al., 2021; Purwandari et al., 2023).

Finally, the local context gives this approach a practical edge. Mini hydropower models are low-cost, robust, and locally meaningful. They support repeated measurement and visible outcomes while remaining safe and manageable in typical classrooms. That combination matches the developmental path described in the literature: moving from tentative, sometimes incomplete structures of argumentation toward more mature, multi-component arguments through guided practice in authentic settings (Ismial, 2016; Heng et al., 2015; Rundgren et al., 2016; Songsil et al., 2019). Taken together, the findings are plausible in light of prior research and classroom observation. The experimental class's advantage likely arose from the way the mini hydropower medium organized talk around evidence, made warrants discussable, and created opportunities for students to experience and debate real consequences of their ideas. With incremental refinement of the measurement setup, continued scaffolding for backing and qualifiers, and analytic follow-ups that quantify magnitude, this approach offers a practical route to strengthen argumentation skills in high-school physics.

CONCLUSION

The study indicates that a Mini Hydropower Instructional Medium improves high-school students' argumentation skills in physics at SMA TI NWDI Wanasaba (2024/2025), with both classes starting from low pre-test means—34.05 in the experimental class and 31.00 in the control—and rising on the post-test to 78.05 and 76.57, respectively; the larger gain in the experimental class aligns with the interpretation that working with a concrete, measurable system helps students formulate clear claims, cite data they collected, and articulate warrants that connect observations to principles more effectively than conventional lessons. While the intact-class design limits causal certainty, converging evidence from classroom observations and statistical testing supports the practical value of integrating a simple, school-appropriate mini hydropower setup into lessons on renewable energy, where visible outcomes and repeatable measurements can anchor disciplined reasoning. In this context, the medium functions not as a motivational add-on but as an epistemic tool that normalizes evidence-based discussion, invites critique and revision, and, ultimately, strengthens students' argumentation skills in ways that conventional instruction alone did not achieve.

RECOMMENDATION

To develop students' argumentation skills optimally, schools should apply evidence-centered learning media consistently and over multiple cycles rather than as a one-off activity, with explicit routines that ask students to state claims, cite data, provide warrants, and consider rebuttals. Teachers are encouraged to use the Mini Hydropower Instructional Medium not only for renewable energy but also as an anchor for other physics concepts (e.g., energy transformation, electricity, measurement uncertainty), adapting tasks so that measurements and comparisons remain central to discussion.

Future researchers should extend this work by targeting specific components of argumentation skills (e.g., backing, qualifiers), testing complementary media that align with the physics concept under study, and reporting effect sizes, confidence intervals, and implementation fidelity to clarify which designs yield the strongest gains and under what classroom conditions.

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