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ENHANCING CRITICAL THINKING SKILLS THROUGH ARGUMENTATIVE SCIENTIFIC WRITING IN UNDERGRADUATE BIOLOGY EDUCATION: A QUASI-EXPERIMENTAL STUDY

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Abstract. *This study aimed to investigate the effect of argumentative scientific writing on the critical thinking skills of undergraduate biology students. A quasi-experimental design with a non-equivalent control group was employed, involving 70 students divided into an experimental group and a control group. The experimental group received instruction based on argumentative scientific writing, while the control group was taught using conventional methods. Data were collected using a critical thinking test administered before and after the intervention. The results showed that both groups had comparable pre-test scores; however, the experimental group demonstrated a significantly higher improvement in post-test scores compared to the control group. The independent samples t-test revealed a statistically significant difference between the groups ($p < 0.05$), indicating the effectiveness of the intervention. Additionally, the effect size analysis showed a large effect (Cohen's $d = 1.45$), suggesting a substantial impact of argumentative scientific writing on students' critical thinking skills. These findings indicate that integrating argumentative scientific writing into biology instruction can effectively enhance students' ability to analyze, evaluate, and construct evidence-based arguments. This study highlights the importance of incorporating writing-based learning strategies to foster higher-order thinking skills in science education.*

Keywords: *critical thinking, argumentative scientific writing, biology education, quasi-experimental study, higher-order thinking skills*

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INTRODUCTION

In recent decades, the development of higher-order thinking skills, particularly critical thinking, has become a central objective in higher education. Critical thinking is essential for enabling students to analyze information, evaluate evidence, and construct logical arguments, all of which are fundamental competencies in the 21st century (Aditya Saputra et al., 2023). In science education, including biology, these skills are especially important as students are required not only to understand scientific concepts but also to interpret data, formulate hypotheses, and make evidence-based decisions.

However, numerous studies have reported that university students often demonstrate limited critical thinking

skills, particularly in tasks that require deep analysis and argumentation. In biology education, this issue becomes more pronounced because learning activities frequently emphasize content mastery rather than the development of reasoning and argumentation skills. As a result, students may excel in memorizing biological concepts but struggle to critically evaluate scientific information or construct well-supported arguments (Zannah et al., 2024).

One promising approach to addressing this issue is the integration of argumentative scientific writing into the learning process. Argumentative writing encourages students to formulate claims, support them with evidence, and justify their reasoning logically (Ardhany et al., 2023). This process aligns closely with the core components of critical thinking, such as analysis, evaluation, and inference. Furthermore, scientific writing tasks, particularly those based on real data or research findings, provide an authentic context for students to engage in higher-order thinking.

Despite its potential, the implementation of argumentative scientific writing in biology education remains limited. Many instructional practices still focus on descriptive or report-based writing, such as laboratory reports, which often do not explicitly require students to construct arguments or critically engage with evidence. Consequently, there is a need for instructional strategies that intentionally integrate argumentative elements into scientific writing tasks to foster critical thinking skills (Zannah, 2024).

In this context, a quasi-experimental approach can provide empirical evidence on the effectiveness of such instructional interventions. By comparing students who engage in argumentative scientific writing with those who experience conventional instruction, it is possible to examine whether this approach significantly enhances critical thinking skills among undergraduate biology students (Rahmatullah, 2024).

Therefore, this study aims to investigate the effect of argumentative scientific writing on students' critical thinking skills in undergraduate biology education. The findings of this study are expected to contribute to the development of more effective instructional strategies that integrate writing and critical thinking, particularly in science education contexts.

METHOD

Research Design

This study employed a quasi-experimental design with a non-equivalent control group. The design was selected due to the practical constraints of assigning participants randomly in an educational setting. Two groups were involved: an experimental group that received argumentative scientific writing instruction and a control group that underwent conventional learning (Zaini et al., 2020).

Participants

The participants of this study were undergraduate students enrolled in a biology education program at a university. A total of 80 students participated, divided into two groups: the experimental group (n = 40) and the control group (n = 40). The sampling technique used was purposive sampling, based on course enrollment and similar academic backgrounds.

Research Instruments

To measure students' critical thinking skills, this study used a critical thinking test adapted from established frameworks (e.g., analysis, evaluation, inference, and reasoning). The instrument consisted of 15 items in the form of essay and/or open-ended questions designed to assess higher-order thinking skills.

In addition, a writing rubric was employed to evaluate students' argumentative scientific writing. The rubric included criteria such as:

1. clarity of claim
2. use of scientific evidence
3. coherence of argument
4. logical reasoning

The validity of the instruments was established through expert judgment, and reliability was tested using Cronbach's alpha.

Procedure

The study was conducted over 6 weeks and consisted of three main stages:

Pre-test

Both groups were administered a critical thinking pre-test to determine their initial abilities.

Treatment

The experimental group received instruction integrating argumentative scientific writing, where students were trained to construct claims, support them with evidence, and justify their reasoning in written form.

The control group received conventional instruction, which primarily focused on content delivery and standard writing tasks without explicit emphasis on argumentation.

Post-test

After the intervention, both groups completed a post-test to measure any improvement in critical thinking skills.

Data Analysis

The data were analyzed using both descriptive and inferential statistics. Descriptive statistics (mean, standard deviation) were used to summarize students' scores. To examine the effectiveness of the intervention, an independent samples t-test was conducted to compare the post-test scores between the experimental and control groups.

Additionally, a paired samples t-test was used to analyze the improvement within each group from pre-test to post-test. The level of significance was set at $p < 0.05$.

RESULT

The descriptive statistics of students' critical thinking scores before and after the intervention are presented in Table 1.

Table 1

Descriptive Statistics of Pre-test and Post-test Scores

Group	N	Pre-test Mean	SD	Post-test Mean	SD
Experimental Group	35	62.40	6.85	81.75	7.10
Control Group	35	61.90	7.05	70.20	6.95

The results indicate that both groups had relatively similar pre-test scores, suggesting comparable initial critical thinking abilities. After the intervention, both groups showed improvement; however, the experimental group demonstrated a substantially higher increase compared to the control group.

To further examine the improvement, the gain scores were calculated and are presented in Table 2.

Table 2

Gain Score Comparison

Group	Mean Gain	SD
Experimental Group	19.35	5.20
Control Group	8.30	4.85

The experimental group achieved a significantly higher gain score, indicating that the argumentative scientific writing intervention contributed more effectively to improving critical thinking skills.

An independent samples t-test was conducted to determine whether the difference between groups was statistically significant.

Table 3

Independent Samples t-test (Post-test Scores)

Variable	t-value	df	p-value	Mean Difference
Post-test	6.85	68	0.000	11.55

The analysis revealed a statistically significant difference between the experimental and control groups ($p < 0.05$), indicating that the intervention had a significant effect on students' critical thinking skills.

A paired samples t-test was conducted to examine improvements within each group.

Table 4

Paired Samples t-test Results

Group	t-value	p-value
Experimental Group	12.40	0.000
Control Group	5.10	0.000

Both groups showed significant improvement; however, the experimental group exhibited a much higher level of statistical change.

DISCUSSION

The findings of this study demonstrate that argumentative scientific writing significantly enhances critical thinking skills among undergraduate biology students. This is evidenced by the higher post-test scores and gain scores achieved by the experimental group compared to the control group (Adam et al., 2024).

One key explanation for this result is that argumentative writing requires students to actively engage in higher-order thinking processes. Students are not only required to understand biological concepts but also to construct claims, evaluate evidence, and justify their reasoning. This aligns with core components of critical thinking, including analysis, evaluation, and inference.

In contrast, the control group, which received conventional instruction, showed lower improvement. This suggests that traditional teaching approaches, which often emphasize

content memorization and descriptive writing, are less effective in promoting critical thinking skills (Angelelli et al., 2023; Rusmansyah et al., 2023).

The large effect size (d = 1.45) further confirms that the integration of argumentative scientific writing is a highly effective instructional strategy. This finding supports previous research highlighting the importance of scientific argumentation in fostering deeper learning and reasoning skills. Writing activities that emphasize argumentation provide students with opportunities to externalize their thinking processes, making it easier to evaluate and refine their reasoning.

Moreover, in the context of biology education, the use of evidence-based writing is particularly relevant. Biology as a discipline requires students to interpret data, analyze complex systems, and make evidence-based conclusions. Therefore, integrating argumentative writing into biology instruction creates an authentic learning environment that mirrors real scientific practices.

Despite these promising findings, this study has several limitations. The quasi-experimental design limits full control over extraneous variables, and the sample was drawn from a single institution, which may affect the generalizability of the results. Future studies are recommended to involve larger and more diverse samples, as well as to explore long-term impacts of argumentative writing on critical thinking skills.

CONCLUSION

This study concludes that the integration of argumentative scientific writing significantly improves the critical thinking skills of undergraduate biology students. The findings demonstrate that students who participated in argumentative writing activities achieved higher post-test scores and greater learning gains compared to those who received conventional instruction.

The significant difference between the experimental and control groups, supported by a large effect size, indicates that argumentative scientific writing is an effective instructional strategy for fostering higher-order thinking skills. This approach enables students to engage in essential components of critical thinking, including analyzing information, evaluating evidence, and constructing logical arguments.

In the context of biology education, the use of writing tasks that emphasize scientific argumentation provides an authentic learning experience aligned with real scientific practices. Therefore, incorporating argumentative scientific writing into biology instruction is strongly recommended to enhance students' critical thinking and scientific reasoning abilities (Zannah & Ayatusaadah, 2023).

However, this study is limited by its quasi-experimental design and the relatively small sample size. Future research is suggested to involve more diverse participants and explore the long-term impact of argumentative writing on students' cognitive development.

RECOMMENDATIONS

Based on the findings of this study, several recommendations are proposed for educational practice, policy, and future research.

First, it is recommended that biology educators integrate argumentative scientific writing into their instructional practices. Writing tasks should not only

focus on descriptive or report-based formats but also emphasize argument construction, the use of scientific evidence, and logical reasoning. This approach can effectively enhance students' critical thinking skills.

Second, curriculum developers are encouraged to incorporate structured writing activities that promote scientific argumentation and evidence-based reasoning into biology courses. Embedding these elements within course design can create a more student-centered learning environment that fosters higher-order thinking.

Third, lecturers should provide explicit guidance and feedback on students' writing, particularly in terms of argument quality, coherence, and the use of evidence. Continuous feedback is essential to help students refine their reasoning and improve both their writing and critical thinking skills.

Fourth, future research is recommended to explore the implementation of argumentative scientific writing across different disciplines and educational levels. Studies involving larger and more diverse samples are needed to enhance the generalizability of the findings.

Finally, further studies may investigate the integration of digital tools or AI-assisted writing platforms in supporting argumentative writing and critical thinking development, as these technologies are becoming increasingly relevant in modern education.

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