RESEARCH ARTICLE

The effect of argument-driven inquiry to pre-service biology teachers' argumentation skills and metacognitive awareness in Mendelian genetics

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Abstract: In recent years, pre-service teacher education programs have recognized the importance of equipping future educators with the necessary skills such as argumentation skills and metacognitive awareness. However, the extent to these skills in ore-service biology teachers remains relatively unexplored. This study aimed to explore the effect of argument-driven inquiry on pre-service biology teachers' argumentation skills and metacognitive awareness. This study also investigated the correlation between argumentation skills and metacognitive awareness in pre-service biology teachers. This research was conducted as quasi experiment using nonrandomized control group pretest–post-test design with two classes. One class as experiment group (N=44) which participated in series of activities in laboratory work using argument-driven inquiry, and control group (N=44) which participated in the regular laboratory activities. The laboratory work focused on the topic of mendelian genetic. This research was conducted on the second year of pre-service biology teachers in the Department of Biology Education. Data were generated by administrating pre-test and post-test on argumentation skill using open-ended question and metacognitive awareness using Metacognitive Awareness Inventory (MAI). Result showed a significant difference between experimental group and control group in argumentation skills (p value= .016) as well as in metacognitive awareness (p value = .005). However, the correlation between argumentation skills and metacognitive awareness were relatively low (r= -.119). This research findings can be used as suggestions for policy makers and educational institute to integrate argumentation skills and metacognitive awareness in designed for professional development program in teacher training program.

Keywords: argumentations; argument-driven inquiry; Mendelian genetics; metacognition; TAP

Introduction

The proficiency of pre-service biology teachers in both argumentation skills and metacognitive awareness holds significant importance in the realm of science education. Argumentation is very important to foster scientific reasoning, problem-solving in science education (Wess et al., 2023). as well as the generation and justification of knowledge (Erduran et al., 2006). The argumentation skills are strongly related to critical thinking skills. Study revealed that the frequency of using critical thinking skills varies based on the use of argumentation method (Demircioglu et al., 2023). Moreover, it is necessary to understand about the emerging scientific issues, for instance in genetics related issues such as genetically modified organism (Demiral & Çepni, 2018) to involve in scientific debate.

Argumentation skills are substantial skills in science students. Previous study conducted by Seixas Mello et al (2023) mentioned that undergraduate students enrolled in immunology merely described the data rather than relating the obtained data to the original question that lead to the experiment. This result suggested that students need to be engaged in procedure to generate knowledge and incorporate scientific reasoning. In biology context, for instance, most high-school students used lack of data to justify their claims. The semi-structured interviews to high-school students in the topic of biotechnology examined about their understanding of biotechnological processes such as genetic testing, cloning, and genetically modified food (Dawson & Venville, 2009). In addition, result of embedded case-study in argumentation focusing on genetic for high school students showed that classroom-based argumentation could improve students' complexity and quality of their arguments (Venville & Dawson, 2010).

Furthermore, not only is important to science students, but it is also pivotal to develop pre-service science teacher capabilities to read the data, create scientific explanations to back up the arguments (Romero Ariza et al., 2021). Given the importance of developing students thinking skills such as argument skills, it is important to scaffolding knowledge and skills to design learning environment that can engage students in various laboratory activities (Gouvea et al., 2022). Various learning approach has been implemented to improve argumentative writing. Blended learning approach involving thesis, analysis, and synthesis key can increase argumentative writing This research also investigate whether gamification approve can also improve students writing skills (Lam & Chiu, 2018). Teaching-Learning Sequence (TLS) could also be used to promote students' argumentation. Research conducted in the history of the discovery of oxygen. In this research students used evidence from experimentation and scientific communication to argue of their decisions. The result of the study explained that historical case can be utilized to promote student's argumentation skills (Archila, 2015).

Developing students' argumentation also can be conducted through integrating technology in the classroom, for instance, case study on augmented reality- based argumentation activities were proven to improve students' engagement in the classroom as we ll as enhance the quality of students' argument (Demircioğlu & Uçar, 2012). Pre-service teachers' argument quality was significantly increased by discussions activities supported by Youtube assisted classroom in socio-scientific issues such as sugar loading in pregnancy, raw or loose milk, and processed or pasteurized milk, and nuclear power plan (Türköz & Öztürk, 2019). Moreover, professional development programs also played an important role in promoting science teacher argumentation (Wess et al., 2023). Previous study mentioned that students were able to engage in the scientific thinking including argumentation through writing laboratory report. In this research, the learning activities were design with restructuring the role of instruction as an audience who interested in students thinking. The activities, hence, more focused on developing students' curiosity toward that lead to the multiple interpretation (Gouvea et al., 2022). Another approach to enhance pre-service teacher argumentation skill is using argument-based inquiry.

Argument-driven inquiry (ADI) enables teacher to integrate inquiry-based laboratory experience with other subjects such as reading and writing (Sampson & Gleim, 2009). ADI is designed to design the classroom activity that can develop, understand, or evaluate scientific explanation for a certain problem. It is also designed to engage students in meaningful inquiry activities. It is also designed to encourage students to generate an argument and purpose, support, evaluate, or revise idea through discussion and writing. It also enables to create classroom community that values evidence and critical thinking. ADI also enables student to regulate their own learning (Sampson & Gleim, 2009). ADI is a pedagogical framework that empowers learners to construct and defend scientific arguments through collaborative, evidence-based reasoning. ADI involves eight steps, 1) identification of a task, 2) laboratory-based experience, 3) production of tentative argument, 4) argumentation session, 5) investigation report, 6) double-blind peer review, 7) revision of the report, and 8) explicit and reflective discussion.

Argumentation in science, both oral and written including claim and support, is different than argument that used in everyday context or other disciplines (Sampson et al., 2013) . The difference between scientific argumentation with other context and disciplines. The differences can be explained using framework of scientific arguments. Claims are conjecture, conclusion, explanation, or response to research question. Claim means a statement that provides an answer to a research question. Claims are supported by evidence which are observation that show trends over time or relationship between variables. The term evidence is to describe the reasons used by scientists based on the data gathered through investigations (Sampson & Schleigh, 2015). Evidence use data or finding from studies rather that opinion or belief, because evidence and data can be retested and reexamined empirically. The evidence reflects analysis of the findings from studies (Sampson et al., 2013). This evidence is justified by reasoning which explains the evidence and why it supports the claim (Sampson et al., 2011). In scientific argumentation, the term reasoning is used to describe the support offers for a conclusion or refute a claim, while adhering to the values of the scientific community (Luft et al., 2008). Given the complex aspect of scientific argumentation, it is therefore a fundamental aspect of critical thinking

(Romero Ariza et al., 2021).

Furthermore, students need to understand the empirical and theoretical criteria that scientist use to evaluate and critique the scientific arguments. Empirical criteria are used to assess how data was obtained and evaluated, as well as how effectively the claims were supported by the evidence. Theoretical criteria, on the other hand, address the claim's consistency with acknowledged scientific knowledge as well as the adequacy of the theoretical framework employed to guide the results' interpretation. The quality of the categories can be different from discipline to discipline and across field within discipline. The differentiation based on the various types of investigated phenomena which use different modes of inquiry (Sampson et al., 2013).

In this study, students' argument skill was evaluated using the Toulmin's Argument Pattern (TAP) (Toulmin, 2003). Toulmin model is a process for evaluating or creating arguments named after a philosopher Stephne E. Toulmin. The Toulmin model is a structured way to analyze or construct logical and thorough argument. In the Toulmin model there are six parts, claim, grounds, warrant, backing, qualifier, and rebuttal. Claim is a crucial component in the Toulmin model. Claim is supported by data. Grounds are the evidence of the claim. The evidence includes facts, data, or reasoning making the case for the claim. It may also include the opinions from the experts. Warrants is what links the claim to the grounds. Backing is additional support of warrant. It may include specific examples. Qualifier adds strength to the claims. Rebuttal is acknowledgement for the opposing views. Jiménez-Aleixandre and TAP analysis can be applied to teaching and learning strategies, even for those unfamiliar with science concepts (Seixas Mello et al., 2023).

Not only argumentation skills, but metacognition also play an important role in teacher education (Al-Gaseem et al., 2020). Metacognition is defined as cognition about cognition (Flavell, 1979). Metacognition refers as aware of owning the knowledge and ability of understand, control, and manipulate cognitive process (Meichenbaum, 1985). Metacognitive skills include orientation, goal setting, planning, monitoring, evaluation, and recapitulation (Veenman, 2011). Vrugt and Oort (2008) also mentioned that metacognition skills include selecting the best approach and managing the resources of learning process, understanding and performance learning process, and evaluate the results and performance of learning. However, previous studies reveal that Indonesian pre-service biology teachers' metacognitive awareness should be developed (Amin & Adiansyah, 2020; Fauzi & Sa'diyah, 2019). Therefore, it is essential that students should be given opportunities to develop an understanding of their knowledge and leaning processes (Colthorpe et al., 2018). Developing metacognitive awareness of students is very critical (Hartman, 2002).

Metacognition framework was commonly used in biology education research (Schraw & Moshman, 1995). The framework divided metacognition into two levels: metacognitive knowledge and metacognitive regulation. Metacognitive knowledge refers to the abilities of demonstrating the self-knowledge. Students tend to understand what strategies and condition that work best form them while learning. It also refers to understanding of the thinking process and knowledge of various learning strategies (Stanton et al., 2021). Metacognitive knowledge includes declarative knowledge, procedural knowledge, and conditional knowledge. Declarative knowledge involves knowing about the requirements of the task, and the learning strategies that exist. Procedural knowledge involves understanding how to use learning strategies effectively. Conditional knowledge involves understanding when and why to use specific learning strategies. Furthermore, metacognitive regulation is students' knowledge about the implementation of strategies and the ability to monitor the effectiveness of their strategies. Metacognitive regulation involves taking appropriate actions to enhance learning. Metacognitive regulation consists of planning, monitoring, and evaluating (Stanton et al., 2021).

Metacognition can be integrated into the designed course and become part of the everyday language for teachers and students (Tanner, 2012). Metacognition can also help students to think like biologist. There were two potential approaches to increasing attention to metacognition in undergraduate students (Tanner, 2012). First, by teaching metacognitive strategies explicitly. A set question asking about the process of planning, monitoring, and evaluating students learning process including class session, homework, exams, and overall course. Second approach is building classroom culture by modifying the existing strategies. It means that metacognition can be integrated in any courses. Not only in learning process, metacognition of learning could also be implemented during the assessment. Meta-learning assessment was developed by (Colthorpe et al., 2018). This meta-learning assessment was designed to increase self-regulatory process and recognize the effectiveness of learning strategies. This research used self-regulatory process of forethought and self-reflection as parts of assessment. The results shows that students become more independent and gain self-reflective skills. It shows by how they approach to learning, reflecting the study strategies, adapting, and improving performance, and developing of lifelong learning skills. Given the importance of metacognition, pre-service biology teachers should be able to plan, monitor, and evaluate their learning, they should be metacognitively aware. The metacognitive awareness is very crucial in term of regulating and controlling individual learning. Hacker et al., (2009) mentioned that metacognitive awareness consists of three parts, metacognitive knowledge, metacognitive skill, and metacognitive experience.

The development of metacognition awareness of pre-service teacher has been developed using various strategies, such as problem-based learning and project-based learning. In secondary school level, problem-based learning with scientific argumentation have been implemented to increase students understanding of basic genetics (Choden & Kijkuakul, 2020). Problem-based learning such as in environmental science course was effective intervention to promote metacognitive awareness including procedural knowledge, planning, and debugging (Kuvac & Koc, 2019). Furtemore, Project based learning was modified by integrating with metacognition framework (Payoungkiattikun et al., 2022). This designed instruction incorporates five metacognitive (Ambrose et al., 2010) skills such as assessing task, evaluating strength and weakness, applying strategies and monitoring performance, as well as reflecting and adjusting approaches into project-based leaning stages. A mixed method approach conducted by Palle Antonio (2020) showed that learning using metacognitive and Argument-Driven Learning Environment (MADLE) can affect students' reflective thinking skills. Although this research showed insignificant difference in students reflective thinking after four-week exposure to MADLE which can stimulate and support students' reflective thinking skills. In addition, Argument- Driven Inquiry also happened to be used in improving pre-service teacher metacognitive awareness and writing skills (Erenler & Cetin, 2019).

ADI is proven to improve students' argumentation skills and metacognitive awareness. However, research on improving pre-service biology teachers' argumentation skills and metacognitive awareness particularly in mendelian genetics is limited. Based on the research problem, two research question guided the design and implementation of this research are whether the argument-driven inquiry affect pre-service biology teachers' argumentation skills and metacognition and how the relationship between pre-service biology teachers' argumentation skills and metacognition. These two research questions lie its potential to contribute to the field of science education, particularly in biology teacher training by developing pre-service biology teachers' thinking skills as well as metacognition and ultimately benefiting the future students.

Method

Research Design

The study was quasi experimental study using nonrandomized control group, pretest–posttest design (Ary et al., 2010). The research used two groups, experimental group which implementing designed laboratory activities using ADI whereas control group conducted general laboratory activities design. Table 1 illustrates nonrandomized control group, pretest–posttest design.

Table 1. The quasi experiment using nonrandomized control group, pretest–posttest design.

Group	Pretest	Independent Variable	Posttest
Experimental	Y1	X	Y2
Control	Y1	-	Y2

Y1 represent the dependent variable before the manipulation of the independent variable X. Y2 represents the dependent variable after the manipulation of the independent variable X.

Research Participants

This study involved two group of pre-service biology teachers in Department of Biology Education, Universitas Negeri Yogyakarta, Indonesia. The total of participant was 88 pre-service biology teacher (78 females and 10 males) which was grouped into experimental group ($N = 44$) and control group ($N = 44$). All participants were enrolled in laboratory work of Genetics during the first semester of the academic year 2023/2024.

Research Instruments

This research used two instruments, including argumentation skills test and metacognitive awareness questionnaire. To measure argumentation skills, this research used four open-ended questions in the topic of mendelian genetics. The argumentation skills questionnaire was constructed before the exposure of the treatment. This instrument was tested before and after the treatment to measure students' argumentation skills. Prior to the data collection, the argumentation skills instruments were reviewed by the expert. In addition, the validity of the items was estimated using Pearson's correlation, The results shows that all the items were valid (Question 1 = .635; Question 2 = .689, Question 3 = .621, and Question 4 = .640). The value for Cronbach's Alpha for this test was α = .750. The value indicated that the instrument was reliable and ready to be used.

The Metacognitive Awareness Inventory (MAI) by Schraw and Moshman (1995) was adapted in this research to measure pre-service metacognitive awareness which each statement was adjusted to the context and translated in Indonesian language. In this inventory, metacognitive awareness refers to two levels, the knowledge about cognition and regulation of cognition. The knowledge about cognition involves declarative (8 items), procedural (4 items), and conditional knowledge (5 items) which are essential for the development of conceptual knowledge. In regulation of cognition, it refers to the implementation of strategies and the ability to monitor the effectiveness of their strategies which involves planning (7 items), Information Management Strategies (10 items), Comprehension Monitoring (7 items), Debugging Strategies (5 items), and evaluation (6 items). In this study, total 51 multiple choice question were valid and reliable to be used. Each item scored one point for each true and zero point for false questions were valid to be used for measuring metacognitive awareness. The reliability of the instrument was established by acceptable Cronbach's alpha values α = .772.

Research Procedures

Research was conducted in genetics laboratory work in the topic of mendelian genetic. In this laboratory work, pre-service teachers are involved in series of laboratory work using model organism for six weeks. The experimental group involved in the designed laboratory work using ADI (Sampson & Gleim, 2009) which depicted in the Table 2, whereas control group involved in the regular laboratory work scenarios. Before the activities begun, Argumentation skills test and metacognitive awareness questionaries were administered in both groups. To demonstrate the mendelian genetics, this laboratory work used *Vigna unguiculata*. The laboratory works has series of activities including planting the *Vigna unguiculata*, crossing *Vigna unguiculata,* observing the distinct characteristics on the offspring and determining the dominance trait in that model organism. These activities were conducted for eight weeks.

Table 2. Argument-Driven Inquiry Phases

Phase	Activities	
	Teacher's activities	Students' activities
The identification of the task	• The lecturer conveys the topic of the problem. • Lecturer guides students to develop investigative objectives based on the chosen topic.	• Students choose the topic of the problem to be discussed. • Students develop investigative objectives based on the chosen problem topic.
Laboratory-based experience	• The lecturer gives direction to students to prepare an investigation plan in the form of the tools and materials needed. • The lecturer guides students to develop steps in investigative activities.	• Students arrange tools and materials needed for investigative activities. • Students develop steps in the investigation.
Production of tentative argument	• The lecturer directs students to prepare tentative arguments which are conveyed through presentations of investigation results and discussions in class.	• Students prepare tentative arguments based on the results of investigations in class discussion forums.
Argumentation session	• The lecturer guides students to convey arguments directly. • The lecturer guides students to provide comments on the arguments presented by other groups during the discussion.	• Students convey arguments directly. • Students provide comments and suggestions on the arguments presented by other groups.
Investigation report	• Lecturer guides • students to compile the results of the investigation in the form of a written report.	• Students compile the results of the investigation in the form of a written report.
Double-blind peer review	• Lecturer directs students to assess peer reports based on criteria.	• Students provide an assessment of the report based on criteria.
Revision report	• The lecturer gives students the opportunity to revise the investigation report according to the assessments and suggestions of their peers as reviewers. • Lecturers provide opportunities to • students to collect the results of revised reports again for assessment.	• Students revise reports according to assessments and suggestions from peers as reviewers. • Students return the results of the revised report to the lecturer for assessment.
Explicit and reflective discussion	• Lecturer guides students to carry out reflections on the learning activities that have been carried out.	• Students fill out a reflection sheet on the learning activities that have been carried out.

In the first phase of argument-driven inquiry, lecturer explained the major topic in mendelian genetic. The topic was. This explanation aimed to introduce and capture students' attention. In this session, lecturer reminded students about their past learning experiences. During the second phase of ADI, students conducted laboratory-based experience for eight weeks. In the first week, students plant the *Vigna unguiculata*. The location was in the green house in the Department of Biology Education, Universitas Negeri Yogyakarta. Prior to planting, the students prepared the soil to be used for planting. Once the soil was ready, they proceeded to plant two seeds in each hole, leaving enough space between them. After planting the seeds, the students placed a pole between the two and watered them. They then monitored the plant growth to ensure that the plants were growing well. On the 14th day after planting, they applied fertilizer.

After 25 days of planting or when the flowers appear, the students need to remove the stamens from the flowers on the plants that are going to become female. To achieve this, they need to carry out castration. Additionally, when the plants are 30 days old, students must pollinate the female plants. They can do this by taking flowers from plants that were not castrated and pollinating them on the female plant population. Once pollination is carried out, the female flower should be covered with a paper bag and marked. After 75-80 days, the Vigna unguiculata fruit is harvested when the pods look dry. The seeds are then extracted as offspring (F1). After that, the students will need to observe the number and color of seeds produced per pod from each cross.

In production of tentative argument stage, students were encouraged to construct arguments. The argument consisted of creating explanation, evidence, and reasoning. During the interactive argumentation session, students were given the opportunity to create arguments by purposing, supporting, critiquing, and revising the arguments including conclusion, explanation, and conjectures. These activities were conducted for the group formats. In this session, students were encouraged to discuss whether they are agreeing or disagreeing with the data interpretation. In the end of the session, students learnt that conclusions could be made and depend on sharing and critiquing methods, data, and interpretation (Sampson & Gleim, 2009). Following the interactive argumentation session, the investigation report stage was designed to develop students' abilities in writing. Writing is an important skill in science. In this stage, students in a group creating report which consist of introduction, literature review, method, result and discussion. In this report, students also answered the questions in the mendelian topic.

In the double-blind peer review, students were given to the questioner asking about the quality of the report. The peer-review consisted of goals, investigation process, argument, and writing. The double peer-review stage was followed by revision of the report. During this stage, the author revised the report and then re-submitted the report. The revision process encouraged students to engage in a scientific writing that involved production, evaluation, as well as revision of the laboratory work report. The last stage of the learning was explicit and reflective discussion. in this session, students reflected the whole activities during producing the arguments and writing the scientific report. In the end of the laboratory activities, argumentation skills test and metacognitive awareness were also administered in both groups.

Data Analysis

To analyze the argumentation level, Toulmin's Argument Pattern (TAP) was used to identify the pattern of argumentation in mendelian genetics before and after intervention. To evaluate student's argumentation, Toulmin Arguments Pattern was used. The arguments consist of three major parts, such as the claim (C), the data (D), and the warrants (W). Claim is supported by data (D). Warrants (W) provide the link between the data (D) and the claim (C). Backing strengthens the warrants (W), whereas rebuttals (R) indicate condition under which the claim (C) would not be true (Toulmin, 2003. Students' argumentation skills were then investigated using rubric (Venville & Dawson, 2010) to identify the level of argument skill. The benefit of using TAP is that this framework can be utilized to assess the quality of argumentation based on identifying the number of component and the complexity of arguments used (Simon, 2008). Tabel 3 shows the rubric of pre-service biology teachers' argumentation skills.

Tabel 3. Rubric of Students Argumentation Skills

Level	Description
Level 1	Claim with no backing (statement, conclusion proposition only)
Level 2	Claim, data (evidence supporting the claim) and/or warrant (relationship between claim and data)
Level 3	Claim, data/warrant, backing (assumptions to support warrant) or qualifier (conditions under which claims are true)
Level 4	Claim, data/warrant, backing and qualifier

In this study, a Mann-Whitney U test used to compare pre-service teachers' argumentation skills and metacognitive awareness between the experimental group and the control group. Mann-Whitney U test was used to compare the differences between two independent samples when the sample distributions are not normally distributed. In addition, argumentation skills and metacognitive awareness for both groups were analyzed Wilcoxon's signed rank to draw comparisons within group. Prior to the inferential statistical analysis was conducted, Shapiro-Wilk goodness-of-fit test used to check the normal distribution because the sample was less than 100 and Brown-Forsythe test was then used to test the homogeneity of variance.

Results and Discussion

Research Question 1: Does argument-driven inquiry affect pre-service biology teachers' argumentation skills and metacognition?

The first research question is to answer whether argument-driven inquiry affect pre-service biology teachers' argumentation skills and metacognition. Prior to the test, the Shapiro-Wilk goodness-of-fit test on the pre-test scores was conducted. The results showed that the distribution departed significantly for normality (W = 0.813, p value <0.00 for experimental group, whereas W = 0.714, p value <0.001 for the control group). Additionally, we used which Brown-Forsythe to test the assumption of equal variances. The results revealed that both groups have equal variance (F= 1.834, p value .179). Based on the outcome, a non-parametric test was used to analyzed data obtained on the pre-test score for experimental group and control group. As the Table 4 shows, there was not a significant difference between the pre-test scores of experimental group and control group (p = .079). It revealed that both groups have the same level of argumentation skills.

Table 4. Mann-Whitney U test result on Pretest scores from Argumentation Skills of experimental and control group

Group	N	Mean	SD	W	p
Experimental	44	8.5000	1.191	1154.000	.079
Control	44	8.273	0.949		

In this research, we also examined the level of argument skills before and after the laboratory activities in mendelian genetics. Figure 1 depicts the level of argumentation skills before the intervention from experimental and control group.

Figure 1. Levels of argumentation before the intervention.

Figure 1 shows that before the intervention, the level of argumentation of pre-service teacher in both classes were majority in the level 2 for all questions. In the first, second, and fourth question, the control group had a higher frequency of level 2 arguments than the experimental group. Meanwhile, at the third question, the experimental group had a higher frequency of level 2 argument than the control group. However, in the first and second question, experimental group could produce more argument in level 2 than control group. The results indicated that majority of pre-service teacher could make claim and supported with data as evidence to support the claim including warrant which strengthen the relationship between claim and data.

Argumentation skill on pre-service teachers was also measured after the treatment. Shapiro-Wilk goodness-of-fit test on the post-test scores was conducted. The results showed that the data was not normally distributed (W = 0.816, p value <0.00 for experimental group, whereas W = 0.934, p value = 0.015 for the control group). Additionally, we used which Brown-Forsythe to test the assumption of equal variances. The results revealed that both groups have difference variance (F= 4.194, p value = 0.044). Based on the outcome, a non-parametric test was used to analyzed data obtained on the post-test score for experimental group and control group. Table 5 shows that there was a significant difference between the pre-test scores of experimental group and control group (p = 0.016). It revealed that both groups have the difference level of argumentation skills. This research also examined the differences within group for the experimental group. Before caried out the test, Shapiro-Wilk goodness-of-fit test on the post-test scores was conducted. The results showed that the data was not normally distributed (W = 0,939, p value = 0.022). Therefore, Wilcoxon's signed rank was used to determine if pre-test and post-test score were different. Table 6 shows the result of Wilcoxon's signed-rank results on post-test argumentation skill scores of the experimental and control group. The result indicated that pre-service teacher's argumentation skills was significantly higher after following laboratory work using ADI (z = -5.488. p = 0.001).

Table 5. Mann-Whitney U test result on post-test score of argumentation skills from experimental and control group

Group	N	Mean	SD	W	p
Experimental	44	11.0000	1.100	1248.000	0.016
Control	44	10.432	1.437		

Table 6. Wilcoxon's signed-rank result on pretest and post-test score of argumentation skills from experimental group

Test	N	Mean	SD	W	z	p
Pre-test	44	8.500	1.191	7.000	-5.488	< 0.001
Post-test	44	11.000	1.100			

The Figure 2 depicts pre-service teachers' level of argumentation was also measured again after following the Mendelian genetics laboratory work using argument-driven inquiry for eight weeks. The results showed that overall, there was an increase in the level of argumentation from level 2 to level 3 for all questions. In detail, the level of argumentation from experimental group produced more level 3 arguments than the control class on all questions. However, at the argumentation level 4, the control class can produce one more argument than the experimental class.

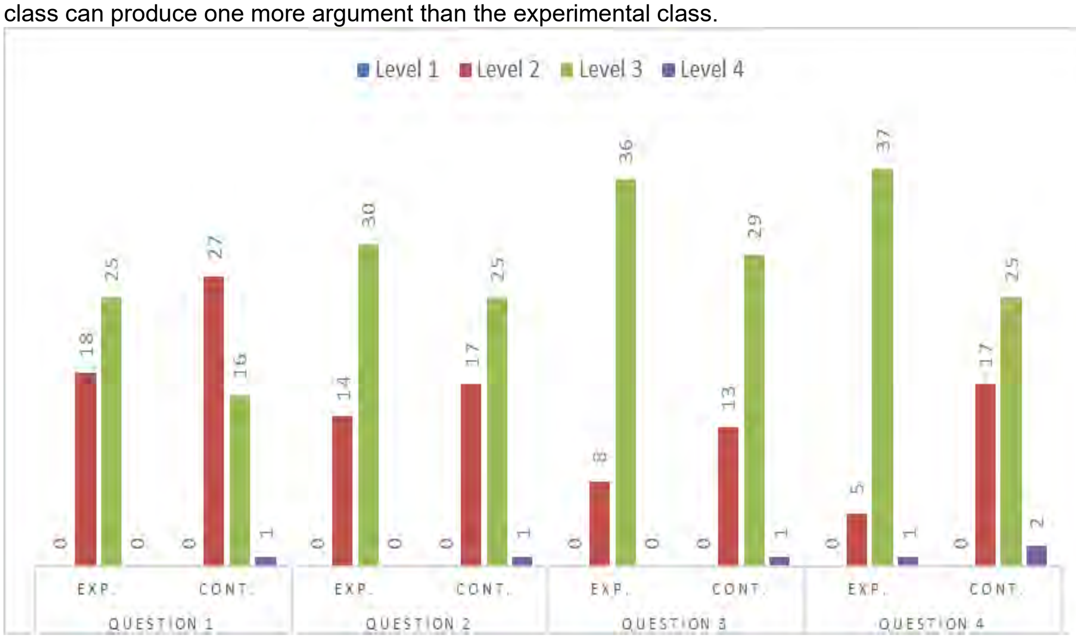

Figure 2. Level of argumentation after the intervention

Pre-service biology teachers' metacognition was measured using modified Metacognitive Awareness Inventory (MAI). The metacognitive knowledge involves declarative knowledge (8 items), procedural knowledge (4 items), and conditioning knowledge (5 items). Metacognitive process includes planning (7 items), information management strategies (10 items), comprehension monitoring (7 items), debugging strategies (5 items), and evaluation (6 items). Prior to the argument driven inquiry laboratory work begin, pretest was administered in both group, experimental group, and control group. Shapiro-Wilk was caried out to determine normality of the distribution. The result showed that the data was not normally distributed for experimental group (W = 0.922, p value = 0.005) and control group (W = 0.897, p value < 0.001). Brown- Forsythe test result showed that groups have the same variance (F= 2.810, p value= 0.097). Based on the assumption result test, a non-parametric analysis should be conducted. Table 7 shows the Mann-Whitney U test result. The result indicated that there was a not significant difference between experimental group and control group (W= 838.500, p value = 0.280). The result shows that both group, experimental group, and control group have the same level of metacognitive skills before the treatment. Preservice teachers' metacognitive awareness was also measured after the intervention. Assumption test was caried out to determine the statistical analysis being used. e result shows that data was not normally distributed for experimental group (W=.906, p value=.002) and control group (W=.831, p value < .001), whereas the variance is equal for both group (F= 3.094, p value = .082). Based on the result of assumption test, non-parametric was also conducted to analyze the post test score. Refer to the Table 8, the result Mann-Whitney U test indicated that there was a significant difference between experimental group and control group after the treatment (W=630.500, p value = .005). However, Tabel 9 present that the control group shows higher mean of the metacognitive awareness ($\bar{X}$ = 46.023) compared to experimental group ($\bar{X}$ =42.614).

Table 7. Mann-Whitney U test result on Pretest scores from Pretest of Preservice Teachers Metacognitive Awareness

Group	N	Mean	SD	W	p
Experimental	44	42.591	6.489	838.500	0.280
Control	44	44.477	5.106		

Table 8. Mann-Whitney U test result on Posttest scores from Pretest of Preservice Teachers Metacognitive Awareness

Group	N	Mean	SD	W	p
Experimental	44	42.614	6.402	630.500	0.005
Control	44	46.023	5.124		

Analysis was also carried out on every aspect of metacognitive knowledge and metacognitive regulation. In declarative knowledge, the results of the analysis show that there was a significant difference between the experimental class and the control class (p value = .010). The result shows that control group ($\bar{X}$ = 7.092) has higher mean than experimental group ($\bar{X}$ = 6.295). In procedural knowledge, the results of the analysis show that there was not a significant difference between the control class and the experimental class (p value = .228) as well as in conditional knowledge (p value = .413).

In the metacognition regulation aspect, the five sub-aspects were also analyzed to determine the differences between the experimental group and the control group including planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation. As seen in the Table 9, there were no significant differences between the experimental group and the control group. It means that pre-service teachers have the same metacognitive regulation in planning (p value = .228), debugging strategies (p value = .882), and evaluation (p value = .061). In addition, the analysis of sub-aspects of information management strategies and comprehension mentoring showed the significant difference with p value = .002 and p value = .030 respectively.

Table 9. Mann-Whitney U test result on the Aspect of Metacognitive Awareness on Post-test Score

Variable		Group	Mean	SD	W	p
Metacognitive knowledge	Declarative knowledge	Experimental	6.295	1.651	670.500	.010
		Control	7.091	1.197		
	Procedural knowledge	Experimental	3.591	0.726	860.000	.228
		Control	3.750	0.576		
	Conditional knowledge	Experimental	4.455	1.044	892.000	.413
		Control	4.682	0.639		
Metacognitive	Planning	Experimental	5.864	1.357	763.000	.063

Variable		Group	Mean	SD	W	p
regulation		Control	6.386	0.920		
	Information Management Strategies	Experimental	8.136	1.424	612.500	.002
		Control	8.977	1.355		
	Comprehension Monitoring	Experimental	5.795	1.173	723.500	.030
		Control	6.250	1.184		
	Debugging Strategies	Experimental	3.659	0.608	982.500	.882
		Control	3.659	0.568		
	Evaluation	Experimental	4.818	1.147	756.000	.061
		Control	5.227	1.031		

Research Question 2: How is the correlation between pre-service biology teachers' argumentation skills and metacognitive awareness?

In this research, a Pearson correlation coefficient was computed to assess the correlation between teachers' argumentation skills and metacognitive awareness. There was a negative correlation between two variables, r (86) = -.117, p = .276. It indicated that the correlation is low. Table 10 shows the result of correlation between argumentation skills and metacognitive awareness.

Table 10. Correlation between argumentation skills and metacognitive awareness

		Argumentation	Metacognition
Argumentation	Pearson Correlation	1	-.119
	Sig. (2-tailed)		.268
	N	88	88
Metacognition	Pearson Correlation	-.119	1
	Sig. (2-tailed)	.268	
	N	88	88

The research findings show that after the intervention, pre-service biology teachers in experimental group which involved in Argument-Driven Inquiry (ADI) has higher average on argumentation skill. ADI gave the opportunities to improve students' argumentation skills by participating in an authentic laboratory activity which followed by tentative argumentation session and composing written arguments (Sampson et al., 2011). ADI has crucial phase in fostering argumentation skills. The production of tentative argument encourages students to construct arguments which consists of claim, evidence, and reasoning. This stage followed by argumentation session when small group of pre-service teachers share the arguments with other groups. In this session, they will also give comments and revise their arguments. These activities benefits students such as increasing pre-service biology teachers understanding of important science content (Venville & Dawson, 2010). By engaging in argumentation session will also improve communication skills and reasoning skills (Jiménez-Aleixandre & Erduran, 2007). Following the argumentation session, investigation repost is written. During writing the laboratory report, pre-service biology teacher also using their abilities in critically evaluate evidence (Colthorpe et al., 2017). Moreover, ADI can be implemented to develop students' habits of mind and critical thinking skills by emphasizing the important of argumentation (Sampson & Gleim, 2009).

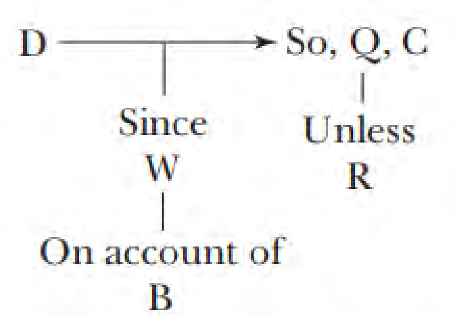

Figure 3. The Pattern of Arguments

In this study, Toulmin's Argument Pattern (Figure 3) was used to analyze the argument process rather than evaluating its content. These methods can enhance the constructing argument skills which supported by evidence. The more the elements of TAP emerge, the better the quality of the argumentation (Simon, 2008). This research asked students whether they agree or disagree with the statement that in the procedure of crossing long bean plants, female flowers are castrated by cutting the stamen to avoid self-pollination. These are the example of arguments structure on the students' answers.

Student A	:	"I agree with the statement, because if the stamens are not cut, long bean plants can pollinate themselves."
Student B	:	"Agree, this stage is the emasculation stage where in this stage the male genital organs (stamen) are removed from the flower which will become the female parent. Removal of stamens aims to avoid self-pollination. Self-pollination occurs when pollen from a flower fall on the pistil of the same flower or on flowers of the same plant. If the male genital organs in the form of stamens found in female flowers are not removed, it is very likely that self-pollination will occur by the pistils and stamens from the same flower. The action of emasculation in the castration process helps to control crossbreeding and obtain offspring with certain desired characteristics from both parents."
Student C	:	"I do not agree with this statement. Castration is one of the steps in crossing long bean plants, namely the process of cutting/removing the female flower crown (the flower chosen as the female parent). Meanwhile, cutting the stamens is an activity in long bean crossing, namely emasculation. So, the correct statement should be: "..., female flowers are emasculated by cutting off the stamen to avoid self-pollination." However, castration and emasculation are sequential steps intended to prevent self-pollination of female flowers. These two steps are carried out when the female parental flower is still in bud condition."

For instance, the answer of student A and B show a claim (A) I *agree with the statement….*, B) *Agree*), whereas the student C shows a counter claim (*I do not agree with the statement*). TAP was empirically proven to assess the argumentation skills in students, this framework has limitations in evaluating the quality of evidence. Using this framework, sometimes claims are still needed to be deducted, identifying data, warrants and backing can be ambiguous (Simon, 2008).

Research findings on pre-service biology teachers' argumentation skills indicate that there is an increase of argumentation level after the intervention. There are several factors influencing argumentation skills, such as classroom discussion, writing activities, roles of students, and socioscientific issues (Venville & Dawson, 2010). Argumentation skills in form of discussion should be taught through certain instruction, task structuring, and modelling (Mason, 1996). According to the research finding, it indicates that students should practice their academic writing skills particularly in developing scientific arguments. Direkci et al., (2022) mentioned that academic writing practices based on argumentation, for instance, can enhance student's argumentation skills. Learning settings which appropriate to demonstrating the role of interpretation and reasoning in scientific inquiry are found in extended activities that emphasizing the depth rather than the materials, promoting curiosity, examining beliefs, providing accessible data, and using data from observation and experiment (Luft et al., 2008). Science content also plays an important role during the development of argument skills particularly using scientific topic that require students to engage in dialogue, discussion, and debate. The issues used real-world problem and sometimes controversial and socially relevant (Sadler et al., 2007; Zeidler & Nichols, 2009). In addition, motivation, and self-efficacy as well as critical thinking skills such as focusing, open-mindedness, understanding opposing ideas, and finding missing parts are associated the argumentation skills (Demiral & Çepni, 2018).

Argumentation contributes to students thinking. It also relates to objectivity, motivation in research and more importantly critical thinking (Direkci et al., 2022). Argumentative practices can promote students reasoning skills and develop students understanding of scientific concepts. The increase of argumentation skill can be achieved through working as a group. This finding is in line with Ling Heng et al., (2015) that students who work in group outperformed students who work individually. Students who work in group were able to construct more complex arguments because they have opportunities to share idea, review and revise each other's mistakes, find the explanation, and explain ideas.

Although metacognition was proven increasing students' argumentation skills by incorporating with other scientific learning approaches such as problem-based learning (Marthaliakirana et al., 2022), in this research findings experimental group has lower average on argumentation skill. The result of metacognitive awareness showed that control group has higher average of metacognitive awareness. However, experimental group show an increase of metacognitive awareness after the treatment. Prior to the study, experimental group barely involved in ADI learning activities. ADI is relatively new model conducted in the genetics topics for pre-service teacher. Metacognitive knowledge and skills are very pivotal to pre-service teacher. This knowledge and skills are used to plan including choosing the right learning strategies, monitor, regulate, assess, and revise a designed lesson to increase the learning effectiveness (Artzt & Armour-Thomas, 2001; Hartman, 2001). Teacher should utilize their own metacognitive skills and knowledge because teacher who cannot effectively use these skills and knowledge will lack the abilities to develop their students' learning and metacognition (Kuvac & Koc, 2019).

Argument skill and metacognitive awareness are pivotal to understand complex topic such as Mendelian Genetics. Mendelian genetics introduces students to fundamental principles governing inheritance and variation. Mendelian genetics is one of the biology topics that are perceived as difficult. It has abstract concept, various terminologies, mathematical component, and complex interaction. Understanding and effectively teaching this intricate subject requires more than mere content knowledge, therefore it necessitates a deep understanding of pedagogical strategies, coupled with the capacity for critical thinking and self-reflection. One such approach gaining prominence is ADI, a model of teaching that places argumentation at the core of scientific exploration. However, the research finding shows that the correlation between argumentation skills and metacognitive awareness was relatively low. It might be caused that students might lack of motivation or capabilities to execute appropriate learning strategies, even they possess metacognitive knowledge (Veenman, 2011). Thus, metacognitive knowledge often inadequately predicts the learning results. In consequence, teacher should facilitate the activities that can support metacognitive skills and critical thinking which includes problem solving skills, decision making, and independent thinker (Buku et al., 2016).

Furthermore, Norman, (2020) mentioned that metacognition may reduce cognitive achievement. His argument claimed that metacognition sometimes hider task performance, for instance by verbalization of metacognitive experiences and cognitive process or its outcome such as in problem solving. Metacognitive strategies involve individual consciousness to control cognition by using various learning skills. However, implementing metacognitive strategies internationally could be time consuming and require cognitive resources. Metacognitive strategies must be learned explicitly or implicitly through everyday experience. In addition, metacognition judgment involving negative self-evaluation that might reduce mental well-being. The relationship between argumentation skills and motivation was not enough to explain. The process of developing arguments was complex process and was not only affected by metacognition.

Conclusion

Two conclusions were reached in this study. First argument-driven inquiry (ADI) affects pre-service biology teachers' argumentation skills and metacognition. Second, although the ADI affect significantly on pre-service biology teachers' argumentation skills and metacognition, the correlation between pre-service biology teachers' argumentation skills and metacognition remained low.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

R. D. Anazifa & P. Paidi: methodology, conducting the research and writing original article, field data collection, data analysis, and revision. **A. T. Pratama & A. Kuriniawati:** field data collection data analysis, and revision.

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