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A Mixed-Methods Analysis of Critical Thinking Skills and Contributing Factors: The Case of Indonesian Pre-service Biology Teachers

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Abstract: The purpose of this study was to measure the critical thinking skills of student teachers and the factors influencing them. The survey involved 477 participants from an Islamic university, including six lecturers. Data were collected in three stages. The level of critical thinking skills was measured using a test whose items were developed based on the Watson-Glaser Critical Thinking Appraisal (WGCTA) indicators. The study also reviewed lesson plans, student worksheets, and cognitive test questions. Interviews were conducted with four students from each year, the highest- and lowest-skilled, as well as with six lecturers. A one-way ANOVA was used to examine differences in critical thinking skills across university study lengths. Qualitative data were analyzed using content analysis methods. The study's findings indicated that four groups had critical thinking skills in the "moderate" category and showed no significant differences among themselves ($p = 0.215 > 0.05$). The ANOVA was performed separately for each indicator to identify any that differed significantly. The results indicate that the indicators of interpretation ($0.02 < 0.05$) and argument evaluation ($0.041 < 0.05$) differ significantly among groups. There was a significant difference in the interpretation indicator between freshmen and junior students. Meanwhile, there was a significant difference between freshmen (the highest average) and sophomores in terms of argument evaluation. Student learning experiences, including the use of learning models, assignments, student worksheets, and evaluation questions (learning assessments), were the main factors influencing critical thinking skills. As a potential step toward developing critical thinking skills, students are expected to read, review, and complete assignments independently. Study programs can evaluate curricula that emphasize critical thinking skills.

Keywords: contributed factor, critical thinking skills, pre-service biology teachers.

▪ INTRODUCTION

Producing graduates who are experts in the fields of science and/or technology is one of higher education's objectives to serve the interests of the country and boost its competitiveness (Undang-Undang Republik Indonesia Nomor 12 Tahun 2012 tentang Pendidikan Tinggi, 2012). To meet these goals, 21st-century skills are needed, which are expressed as a set of professional skills and attributes (Chalkiadaki, 2018). The ability to compete in the workplace, engage with a society that is becoming increasingly diverse, utilize new technology, and adapt to a rapidly changing workplace are all examples of 21st-century abilities (APEC, 2008). According to research conducted by Hart Research Associates (2013), nearly all respondents, particularly employers (93%), agreed that a college degree is not nearly as valuable as the capacity to think critically, communicate properly, and handle challenging situations. It is nevertheless criticized that when college graduates enter the workforce, they lack these abilities (Goodman et al., 2015). Thus, it is clear that developing students' 21st-century abilities is crucial for workforce readiness and long-term success.

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One of the most important skills for success in the workplace and in school in the twenty-first century is the ability to think critically (Murawski, 2014; van Laar et al., 2017; Rios et al., 2020). One of the four skills that should be fostered in the learning framework is critical thinking (Joynes et al., 2019; Nganga, 2019), especially in higher education (Goldsmith, 2013). This is supported by Halpern (1999) and Bassham et al. (2001), who state that developing critical thinking skills should be a priority in higher education and that the higher education curriculum, educational activities, and policy-making should emphasize honing these skills. Consequently, encouraging critical thinking is one of higher education's essential foundations and enables institutions to train students to develop their capacity for analysis and reasoning.

Identifying, analyzing, and evaluating arguments and truth claims effectively involves a variety of cognitive skills and intellectual dispositions. These abilities also include identifying and overcoming personal biases and prejudices, formulating and presenting compelling arguments to support conclusions, and making sound, informed decisions about what to believe and do. These abilities are collectively referred to as critical thinking (Bassham et al., 2011). According to Facione (2011), some examples of these critical thinking skills are interpretation, analysis, evaluation, inference, explanation, and self-regulation.

The ability to switch from a "normal" thinking model to an advanced one is a hallmark of someone with strong critical thinking skills. Compared to weak thinkers, critical thinkers generate more and better ideas (Ruggiero, 2012). By using various probing tactics, they can improve their ability to generate fresh, often better ideas. More specifically, before deciding on a plan of action, critical thinkers often evaluate alternative investigative options, consider different points of view on an issue, and generate many ideas (Murawski, 2014).

Making critical distinctions between choices, testing initial assumptions, and drawing conclusions based on facts rather than emotions; being aware of one's own limitations; assessing reasons and proposed solutions; anticipating negative responses; and refining their ideas are characteristics of critical thinkers. In addition, focus is one of the skills critical thinkers have. They do not face any less frequent disturbances than others; on the contrary, compared to ineffectual thinkers, they handle them more swiftly and effectively. They hone their skills independently, just as those taught during the learning process (Murawski, 2014).

Paul and Elder (2002) state that having a fair mind and evaluating each argument to determine its merits and shortcomings are among the characteristics of critical thinkers. Ruggiero (2012) asserts that critical thinkers are typically interested in other people's ideas, acknowledge their own limitations, regard difficulties as exciting challenges, think before they act, avoid emotionalism, have an open mind, and are willing to listen actively.

Cottrell (2020) adding to the benefits of someone having good critical skills, namely being able to recognize one's own assumptions and those of others; detect discrepancies and possible errors that require additional study; reduce the likelihood of being misled or mislead; focus on what is important and relevant, saving time and effort; bring greater accuracy and precision to different aspects of the activity; be more lucid in their thoughts and communication; have superior problem-solving abilities, such as in recognizing potential areas for improvement and assessing pre-service solutions; to analyze complex material more quickly and accurately; to have more confidence when tackling more difficult difficulties and tasks, adopt a systematic approach to guarantee that crucial details are not missed. The ability to think critically, on the other hand, is linked to academic success (Changwong et al., 2018; Orhan & Bülent, 2022). In contrast, non-critical thinkers usually have little perspective when looking at a problem, judge quickly and uncritically, are not able to listen actively, have the idea that their ideas are the best while other people's ideas are considered inappropriate, resist change, and have conventional thinking (following stereotypes) (Ruggiero, 2012).

One goal of science education is to encourage critical thinking (Bailin, 2002). For students to reason properly and choose the most appropriate action, it is essential to teach these skills (Geng, 2021). Through an effective learning process, students' critical thinking skills can be improved (Setyowati et al., 2020). However, various studies have shown that most students have poor or insufficient critical thinking skills (Nickname & Royafar, 2019; Qing et al., 2010). A similar finding was also found by Utami et al. (2018), who showed that most students had weak or low critical thinking skills, particularly in analysis, evaluation, explanation, and self-regulation. This finding aligns with previous research, which found that students' skills in inference, assumption, and interpretation were low. 83% of students said they found it challenging to analyze complex information, because they are not used to solving problems. Students also stated that the difficulty in solving problems stems from difficulties in distinguishing between problems and problem phenomena, breaking problems down into smaller parts, and finding cause-and-effect relationships. Meanwhile, Marhamah et al. (2014) stated that students' low critical thinking skills are due to their lack of training in problem-solving in their surroundings.

Various studies have shown that critical thinking skills are influenced by several factors, which can be synthesized into main categories. First, individual factors that determine students' readiness to engage in critical thinking, including motivation, personal attributes, subject mastery, self-efficacy, attitudes and beliefs, emotional intelligence, reading skills, and critical thinking (Mahapoonyanont, 2010; Slameto, 2017; Akmam et al., 2019). Second, pedagogical factors, including teaching strategies and methods, teaching activities, reinforcement, and assignments, contribute to the development of critical thinking processes by providing structured and meaningful learning (Bustami & Corebima, 2017; Nganga, 2019; Purvis, 2009). Third, curriculum and learning resource factors, such as curriculum design, credit systems, and the quality of textbooks and other references, determine the extent to which critical thinking skills are integrated into learning (Green, 2005; Thongnuypram & Sopheerak, 2013). Furthermore, contextual and environmental factors, including educational policies, learning management, and community culture and traditions, also influence the development of these skills (Thongnuypram & Sopheerak, 2013). Finally, the use of educational technology, particularly web tools, has been reported to enhance various dimensions of critical thinking dispositions (Sendag et al., 2015).

It is undeniable that critical thinking is important in education and that teachers are essential to helping students develop this skill (Hemming, 1997; Serin, 2013; Changwong et al., 2018). The findings of a study by Taghva et al. (2014) shows students' academic achievement and teachers' critical thinking abilities are significantly correlated. Therefore, teachers significantly contribute to the development of students' critical thinking skills (Slameto, 2017), so it is important to prepare pre-service science teachers with strong critical thinking skills (Fikriyati et al., 2022). To successfully teach science and cultivate critical thinkers, pre-service science teachers must graduate from an institution that equips them with strong critical thinking skills. The claim by Burks and Huffman (2019) supports this, who suggest that pre-service teachers need education that offers opportunities to strengthen their critical thinking abilities. Learning is one way to accomplish this (Akmam et al., 2019).

Although a variety of factors may affect critical thinking skills, higher education institutions can support the learning and teaching process to help educate pre-service biology teachers. Changes to the teaching methods and courses offered in teacher preparation programs are one potential step toward fostering the development of critical thinking skills in the classroom (Khalid et al., 2021). Learning strategies such as JiRQA (Bustami & Corebima, 2017), inquiry-based experiment (Qing et al., 2010), blended learning (Prafitasari et al., 2021; Suana et al., 2020), project-based learning and group investigation (Astutik & Wijayanti, 2020), research-based learning (Yanti et al., 2017), inquiry (Mustika, 2019), problem-based learning (Narmaditya et al., 2018) proven to enhance students' capacity in critical thinking.

As mentioned, lecturers can employ a variety of teaching models to help students hone critical thinking skills. It should be noted that not all academics utilize these models. This study focuses on pre-service biology teachers' critical thinking skills and analyzes potential contributing factors, notably the learning environment in which students are placed. This research will specifically answer the research questions, namely, what is the level of critical thinking skills of pre-service biology teachers', is there a difference in the critical thinking skills of pre-service biology teachers' based on the attendance year, is there a difference in the achievement of critical thinking indicators, and what factors contribute to pre-service biology teachers' critical thinking skills?

▪ METHOD

This study employed a survey method using three approaches: tests, document reviews, and interviews to measure students' critical thinking skills and identify contributing factors.

Participants

477 pre-service biology teachers took part in this study. The participants were chosen at random from various semester levels. Four students from each semester level were selected to participate in interviews after receiving their critical thinking test results. Using a purposive sampling strategy, four students in each grade with the greatest and least amount of skills were chosen as the respondents. Six lecturers also participated in this research to express their opinions on critical thinking.

Research Design & Procedures

This study was carried out in the following three steps.

Stage 1 (Test). The purpose of this test is to measure the critical thinking skills of pre-service biology teachers. Students are given test materials and have 50 minutes to complete the test.

Stage 2 (Document Review). The objective of the document review is to validate the students' test findings. The lesson plan (Rencana Pembelajaran Semester, RPS) paper, student worksheets, and questions to measure student cognitive skills in the form of quizzes, mid-semester exams, and end-semester exams are reviewed. Documents were gathered in advance of the review with the authorization of several lecturers.

Stage 3 (Interview). An interview will be conducted to learn more about the contributing factors to critical thinking skills. Prior to the interview, the date, time, and location were approved and authorized. The typical findings regarding the level of critical thinking skills across generations were shared with the students throughout the interview. The next step is to verify students' comprehension by asking them questions about the lecture. Perceptions of students and lecturers about critical thinking skills are also explored through interviews.

Instruments

Quantitative data were collected through tests administered to four groups of students, while qualitative data were collected through document review and interviews with lecturers and students. The Watson-Glaser Critical Thinking Appraisal (WGCTA) indicators were used as the research instrument to design a critical thinking test (Watson & Glaser, 2012), which was adapted from Saefi et al. (2017). The 26-item critical thinking test was presented as an objective test. The 26 items are classified into five categories, namely deduction (six items), interpretation, inference, assumption, and argument evaluation, each consisting of five items. The test items used have a p-value> 0.05 based on bivariate correlation (Pearson's R), with a Cronbach's Alpha reliability of 0.771. This test has a 40-minute time limit, but during the study, we allowed 50 minutes to ensure students could focus on completing it.

The document review is completed by reviewing student worksheets, the RPS, and cognitive assessment questions, and comparing them with graduate learning outcomes and study materials. Structured interview questions developed independently focus on techniques, learning models, tasks, and practices used during lectures as part of the student learning experience.

The validity of the interview questions was tested by two experts in educational learning and evaluation. The results showed that after revision, all questions were valid and could be used for data collection. Reliability testing was conducted by interviewing four non-participating students, with clear instructions provided at the outset. The duration, timing, and location of the interviews, as well as the transcribed interviews, were consistent, allowing the production of reliable instruments. The following are a few examples of interview questions.

To lecturers: "*Do you strive to develop students' critical thinking skills? If so, how? If not, what are your reasons?*" "What learning models do you often use when teaching in class?"

To students: "*Do you always read the material and generate critical questions before class?" "Do you try to hone your critical thinking skills by answering questions in the textbook?*" "What learning models are often used by lecturers?"

Data Analysis

Calculations are made to determine each capability's average and standard deviation (SD). Very high ability students receive scores that are higher than the average plus 1.5 SD; High ability students receive scores between the average plus 0.5 SD and the average plus 1.5 SD; moderate ability students receive scores between the average minus 0.5 SD and the average plus 0.5 SD; low ability students receive scores between the average minus 1.5 SD and the average minus 0.5 SD; and very low ability students receive a score less than the average minus 1.5 SD. As a result, we will examine how pre-service biology teachers across years rated their critical thinking skills as medium, high, low, very low, or very high. It was also investigated, using a one-way Analysis of Variance (ANOVA), whether there were any changes in the three groups' abilities across year grades. Additionally, we examine the category that appears most frequently across all indicators of the critical thinking variable using the mode. With reference to Schutt and Chambliss (2013) stages of documentation, organization / categorization, connection, corroboration / legitimization, and content analysis, approaches were used to examine data from interviews and document reviews. Interview transcripts and document review results were carefully read, followed by data categorization. Similar data were grouped into specific categories. The categorization results were then identified as related, and their relationship was analyzed. Interview results were verified with the document review results, and vice versa. This method ensures accurate and consistent results.

▪ RESULT AND DISSCUSSION

Descriptive Analysis

The study's findings will be presented in three sections: critical thinking skill is considered first, followed by the contributing factors determined through document checks and interview confirmation. The mean formula is used to obtain the descriptive analysis findings, and Sudrajat's (2020) classification criteria are used to classify the forwards. The top score is 26, which is possible. Freshmen scored an average of 14,03 (moderate), Sophomores scored an average of 14,12 (moderate), Juniors scored an average of 14,86 (moderate), and 14,81 for Seniors. Figure 1 contains the findings of the descriptive analysis.

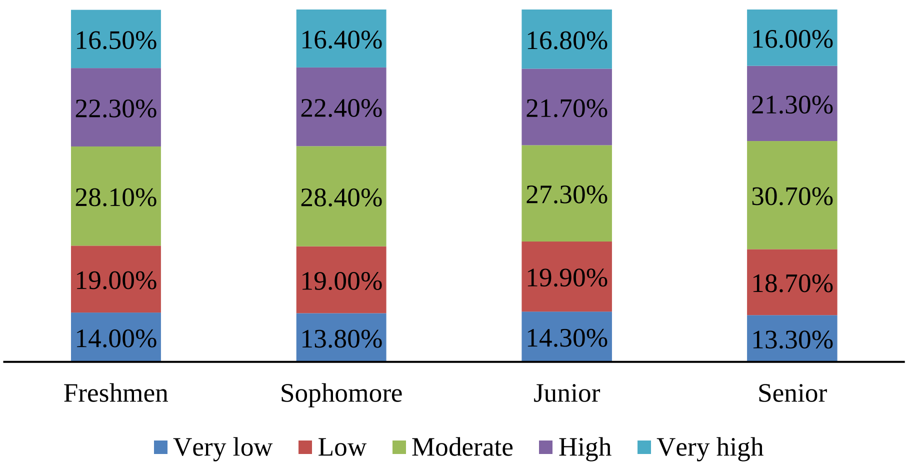

Figure 1. Critical thinking skills level results and categorization

All generations of pre-service biology teachers fall into the “moderate” group in terms of their critical thinking abilities. These results are consistent with research by (2022), which shows that students' critical thinking skills are relatively low. However, it differs from the research by Basri et al. (2018) and Serin (2013), which found that the critical thinking skills of students who intend to become teachers fall in the medium range. Additionally, Saefi et al. (2016) discovered that Sophomores' critical thinking abilities are likewise in the moderate range.

Based on Figure 1, it can be concluded that pre-service student teachers still don't have critical thinking skills to a suitable level, as also found by Fadhlullah and Ahmad (2017) and Fikriyati et al. (2022), due to the fact that in order to foster critical students, they must possess "excellent" critical thinking skills. This is supported by Allamnakhrah (2013), who stated that if teachers are to impart critical thinking and higher-order thinking skills to their students, whether openly or implicitly, they must competent in these areas.

Critical Thinking Skills of Pre-Service Biology Teachers Based on the Attendance Year

To determine whether there is a significant difference between generations, an ANOVA test is used. An ANOVA test of the overall critical thinking score yielded a p-value of 0.215 (> 0.05), indicating no significant difference in critical thinking skills among pre-service biology teacher candidates across grades. This study showed no significant difference between grades. The results obtained are similar to those of Aktaş and Ünlü (2013) and Akgun and Duruk (2016), which show that, in terms of critical thinking skills, year grade is not significant. Similarly, no statistical differences were found by Ekinci and Aybek (2010) and Bakir (2015).

Students' diverse backgrounds can influence critical thinking skills (Algharaibeh & Almomani, 2020). The sample used in this study was diverse in terms of high school educational background, with some coming from religious and general schools, some living in Islamic boarding schools, and some not, as well as diverse extracurricular activities. Secondary education prior to higher education can influence critical thinking skills (Gadzella et al., 1996). This diversity can contribute to students' critical thinking skills, without being limited by attendance year. In general, it is expected that pre-service teachers' critical thinking abilities will improve over time as they continue their education. According to Ay and Akgöl (2008), students' critical thinking skills will develop as they get older.

The Achievement of Critical Thinking Indicators

The ANOVA analysis was performed separately for each indicator to identify any that might be significantly different, even though the overall ANOVA results did not show any statistically significant differences. The significance of the ANOVA test results for each indicator is as follows. Deduction is 0.088 > 0.05, interpretation is 0.02 < 0.05, inference is 0.776 > 0.05, assumption is 0.947 > 0.05, and argument evaluation is 0.041 < 0.05. Based on this, it can be concluded that indicators of argument interpretation and evaluation differ significantly by the number of years spent at the university, as shown in Table 1. However, because all eta-squared values are low ($\eta^2 < 0.03$ across indicators), the influence is small.

Table 1. Anova results for each indicator of critical thinking skills

Indicator	Sig.	η^2
Deduction	0.088	0.014
Interpretation	**0.02**	0.021

Inference	0.776	0.002
Assumption	0.947	0.001
Argument Evaluation	**0.041**	0.017

Post hoc tests corrected with the Bonferroni test were conducted on indicators with significant differences ($p < 0.05$), namely interpretation and evaluation of arguments, to identify which groups differed significantly. The test results are shown in Tables 2 and 3.

Table 2. Post hoc test for interpretation indicator

Year	N	Notation	
1	121	a	
2	120	a	b
4	75		b
3	161		b

Table 3. Post hoc test for argument evaluation

Year	N	Notation	
2	121	a	
4	120	a	b
3	75		b
1	161		b

Table 2 shows that Juniors demonstrate a significant difference in interpretation compared to sophomores and freshmen, but not compared to senior students. Based on the biology education curriculum at UIN Walisongo Semarang, junior students have taken various courses, including religious studies, education, and biology. The expected learning outcomes for junior and senior students include analysis, evaluation, and creation. Meanwhile, the learning outcomes for first-year courses are limited to “describing,” not interpreting.

Facione (2011) defines interpretation as the capacity to comprehend and elucidate the significant features of a variety of elements, including circumstances, information, experiences, events, judgments, beliefs, rules, or procedures. Students should be able to deconstruct material into smaller components and comprehend how they relate to one another at this point. Understanding meaning, evaluating the gathered data, and making connections among ideas to reach conclusions are all part of the interpretation process. The following paragraph will explain the skills of interpreting and evaluating arguments based on post hoc results.

Interpreting involves understanding data or text. As indicated by Medranda-Morales et al. (2023), to better grasp the meaning of the data, it is helpful to distill it into simpler components. Learning experiences play a pivotal role in refining interpretive skills. With the increased difficulty of the learning experiences, students improve their ability to understand and interpret. This can be exemplified by the differences between a freshman and a senior. Sophomore students, for instance, are primarily concerned with acquiring basic concepts and introductory skills. With time, however, students can learn more intricate and advanced content, which in turn enhances their ability to interpret.

The student learning experience is designed by the lecturers in accordance with each course's learning outcomes. Through various assignments, lecturers create opportunities for students to actively participate in learning by doing mini-research projects, reflections, group discussions, and other activities. Moreover, students build on experiences from previous semesters to develop new interpretative skills over time. In addition to designing the student learning experience, the lecturers prepare corresponding unit teaching materials (RPS) for each lesson, making the course more coherent and purposeful in guiding students' learning. This is consistent with Alhassan (2023), whose emphasis on structured learning resources aimed to help students understand information and the logical connections among concepts.

In biology practicum courses, learning also emphasizes observing, recording, and analyzing practicum data. Students are required to examine practicum results, compare them with theory or the latest research results, and draw conclusions from the data, beginning with data interpretation. These activities not only strengthen critical thinking, as interpretation is one aspect of critical thinking according to Facione (2011), but also help connect biological knowledge to students' real-world situations. Many questions are raised in the practicum instructions, which students must answer based on their practicum results, so that what students are facing is real, not just limited to theory. Some questions in the practicum instructions also direct students to connect the results to real-world problems. This approach not only deepens students' understanding of biological concepts but also equips them with critical analytical skills to address academic challenges, as noted by Wahyuni & Analita (2017). Writing lab reports helps students learn to evaluate information and draw evidence-based conclusions through reading scientific literature, analyzing data, and participating in critical discussions. Based on this description, interpretation is not simply about reading results; it also builds a deeper understanding of complex concepts.

In education courses, developing interpretive skills is crucial for helping students understand pedagogical concepts and relate them to biological concepts, which are then used to design and solve problems in biology education. Several courses related to pre-service teachers' interpretive skills include curriculum review, learning methodologies, lesson planning, learning evaluation, microteaching, educational statistics, and research methodology. Students have many opportunities to interpret a variety of information. For example, when reviewing various pedagogical approaches, students are tasked with interpreting relevant research findings and case studies to assess the application of specific learning models. Collaborative discussions and projects conducted on digital platforms also provide students with opportunities to share perspectives, raise questions, and draw conclusions using their interpretive skills. Various pedagogical courses teach students that learning objectives can be optimally achieved when balanced with appropriate planning, implementation, and evaluation. Ulferts (2019) added that teaching relies not only on relevant knowledge but also requires noticing, interpreting, and reacting to important aspects in the classroom. Students can further develop their interpretive skills to better prepare them to face challenges in education, particularly by becoming responsive teachers who can reflect on their learning. This will ensure meaningful evaluation and continuous improvement.

Because understanding and interpreting meaning is a fundamental part of any interpretation process, developing interpretive skills should emphasize both the techniques used and the time allocated for practice (Petrescu, 2014). In a biology course, a deep understanding of meaning not only helps explain information but also forms the basis for analysis, evaluation, and logical conclusions. Furthermore, according to Prinz (2024), because biology contains a lot of information related to codes, the ability to interpret and understand is important in biology learning. This is reinforced by Kennedy (2023), who stated that abstract materials also require strong interpretive skills because they contain symbolic information, thereby requiring students to rely on these skills to better understand the information.

As shown in Table 3, freshmen and juniors demonstrated similar abilities in evaluating arguments, and both groups significantly outperformed sophomores and seniors. The superior performance of freshmen and juniors is likely related to differences in coursework and learning experiences. First-year students' courses focus on building foundational skills, including the ability to evaluate arguments. For example, freshmen take the course "Islam and Religious Moderation." This course is designed to help students understand various perspectives on religion and moderation, while also developing their ability to analyze and evaluate arguments on complex and sensitive religious issues. Students learn to consider multiple viewpoints in religious debates, identifying and assessing the strengths and weaknesses of each argument. Students are encouraged to think critically and actively, building arguments based on evidence, rather than passively absorbing information.

Freshmen gain argument evaluation skills from various courses. Based on the curriculum document of the biology education study program at UIN Walisongo Semarang, the Indonesian Language and Scientific Writing courses encourage students to learn how to construct effective sentences, assess how main ideas and supporting sentences can create cohesive paragraphs, and analyze sources/references that can be used to construct scientific papers, all of which require comparison and logical reasoning. This will familiarize students with the practice of stating claims based on evidence, a key component of argument evaluation. Two key points developed in the Islamic Education course are analysis and evaluation skills. Students are asked to compare educational approaches through literature reviews and assess the strengths and weaknesses of Islamic educational methods, including how they are evaluated. In the Educational Psychology course, students are asked to compare various theories of learning and student behavior, drawing on robust theoretical foundations and empirical data. Comparing students' cognitive, psychological, moral, and spiritual development; learning taxonomies; learning styles; developing students' higher-order thinking skills; and learning how to accommodate students' multiple intelligences will encourage students to formulate and assess the quality of reasoning behind arguments, rather than simply agreeing or disagreeing.

Regarding argument evaluation skills, the findings above are also confirmed in the RPS, where the Islam and Religious Moderation course has sub-Course Learning Outcome (sub-CLOs) including being able to demonstrate critical thinking in solving problems related to religious moderation in Indonesia; being able to examine the genealogy and dynamics of the development of radical Islamic ideology and movements in Indonesia; and being able to analyze the phenomena of the digital disruption era and post-truth through a religious lens. To achieve these sub-CLOs, the learning experience chosen by the lecturer in this course is to ask students to conduct debates and case studies. The Indonesian Language and Scientific Writing course has sub-CLOs including being able to analyze the differences between topic sentences and explanatory sentences; being able to construct paragraphs cohesively and coherently; being able to differentiate themes, essay titles, and paragraph types; assessing the credibility of sources; and being able to identify the characteristics of plagiarism, with the selected learning experience being writing essays and critical analysis of articles. Sub-CLO in the Islamic Education course includes being able to describe aspects of the sources and foundations of Islamic education and relate them to current phenomena in the world of education; being able to describe aspects of the tasks and functions of Islamic education and relate them to current phenomena in the world of education; and being able to describe aspects of the objectives of Islamic education and relate them to current phenomena in the world of education, by selecting learning experiences in the form of writing essays and performance demonstrations. Essays, performance demonstrations, and article analysis are also carried out in the Educational Psychology course with sub-CLOs including being able to describe human intelligence capabilities by integrating them into a unified body of knowledge; being able to apply educational psychology theories in Biology learning through the review of scientific articles; and being able to analyze concepts and theories of educational psychology in the field of biology education through the review of scientific articles by integrating them into a unified body of knowledge.

Debates, case studies, essay writing, critical analysis of articles, and performance demonstrations can contribute to the development of argument evaluation skills. Debates facilitate students' ability to logically construct and refute arguments. Case studies require students to examine a phenomenon from multiple perspectives. Writing an essay not only examines existing theories but also requires a strong synthesis of arguments to ensure the resulting essay maintains relevant structure and content. Critical analysis of articles can train the ability to critique the content presented in evidence-based articles. Meanwhile, in performance demonstrations, students actively construct arguments to connect theories to contextual circumstances.

Students learn more complex and specific concepts in their third year, but still have the opportunity to develop their argument evaluation skills through discussions or practical case studies. Sophomores, on the other hand, while gaining a broader understanding, focus more on studying more specific biology material. Meanwhile, fourth-year students focus more on research and community service (KKN), which can limit the time available to practice evaluating arguments. This difference in focus and opportunity likely explains why freshmen and juniors tend to perform better at argument evaluation. The student indicators, from lowest to highest, are inference, assumption, interpretation, argument evaluation, and deduction, as shown in Figure 1.

Depending on which category each indication of critical thinking skills falls under, the study's findings are not all consistent. Basri et al. (2018) found that the highest critical thinking ability is on the deduction indicator and the lowest on the recognizing assumptions indicator. Aktaş & Ünlü (2013) also found that the recognizing assumptions indicator has the lowest average. According to Saefi et al. (2016), all measures of critical thinking ability are in the medium range. As shown in Figure 1, research by Akyüz & Samsa (2009) also indicates that the inference indicator receives the lowest score, while the interpretation indicator receives the highest. However, findings showing that deduction and argument evaluation obtained the highest scores were also found by Algharaibeh & Almomani (2020).

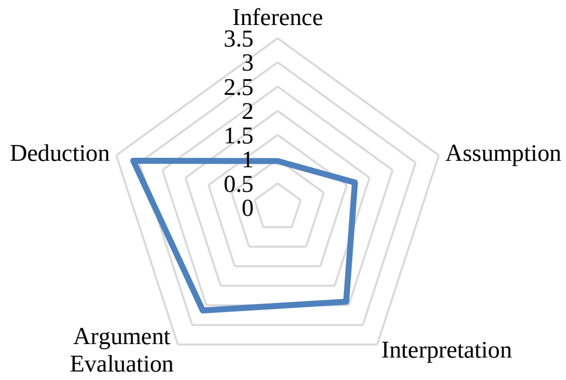

Figure 2. Mean for each indicator of critical thinking skills

Inferences are often made implicitly in the reasoning process. For this reason, inferences may be more difficult to identify. Critical thinkers try to monitor their inferences to keep them in line with what is actually implied by what they know. When speaking, critical thinkers try to use words that imply only what they can legitimately justify. They realize that certain words carry implications.

Based on Figure 2, the assumption also has a low average. Assumptions are statements that we accept as true without proof or demonstration. Assumptions are a fundamental part of the human experience. Assumptions are often challenging to identify. Usually, an assumption is something that has been learned before and is not questioned. Assumptions are part of a belief system. A person considers his beliefs to be true and uses them to interpret the phenomena around him. Low assumptions indicate limited problem-solving experience.

Interviews with students indicate that they have difficulty distinguishing between assumptions and conclusions. Students believe that personal assumptions are treated as general truths, leading to incorrect conclusions. This is reinforced by Elder & Paul (2002), who stated that conclusions are often based on incorrect assumptions, resulting in inaccurate conclusions. Furthermore, a lack of rational thinking skills, particularly in causal reasoning (Zohar & Tamir, 1991), scientific reasoning (Strode, 2015), and scientific literacy (Smith & Tanner, 2010), also contributes to errors in concluding.

An assumption is an idea or proposition considered true and often taken for granted. Even when individuals are unaware of the background of those beliefs, assumptions still influence the way they think and act (Yanchar & Slife, 2004). Moreover, by recognizing existing assumptions and their implications, and by considering alternative assumptions with different implications, scholars and practitioners can revise or replace those assumptions when necessary, thereby promoting the continuous improvement of theories and practices (Gabbitas, 2009). In this context, it is important to understand that assumptions are not always limiting; rather, they are enabling-assumptions are what make various activities, decision-making processes, and so on possible. From this perspective, it is impossible to theorize or engage in practice within any field without the guidance of assumptions; they are inevitable and shape every step of individual activity. What can be done is to first identify an inference (what do we conclude from the situation being evaluated?) and then identify the assumption that is the premise of that inference ("If the inference is true, what do I assume about the situation?"). Often, assumptions identified in this way are inferences that can be unpacked further to identify deeper core assumptions.

Factors Contribute to Pre-Service Biology Teachers' Critical Thinking Skills

To examine data related to students' critical thinking test results, a review of the RPS was conducted. The findings from this review generally align with the test results. In this review, the RPS was divided into two main categories: Theory Courses and Practical Courses. The analysis of the RPS was based on student worksheets, learning models used, and cognitive assessment questions.

Most theoretical courses employ learning methods such as lectures, presentations, question-and-answer sessions, and discussions. However, only a small portion of the learning models explicitly mention improving critical thinking skills. Examples include Reading, Questioning, and Answering (RQA) in the Biochemistry course; Project-Based Learning (PjBL) in Scientific Writing, Biology Learning Media, Natural Resource Conservation, and Ecology courses; inquiry methods in Plant Structure and Development, Biology Education Research Methodology, and Lesson Planning courses; research-based learning in the Plant Physiology course; and Problem-Based Learning (PBL) in Nutrition and Health, Natural Resource Conservation, and Toxicology courses. Nevertheless, these models are applied only in a few meetings. Meanwhile, the RPS for practical courses shows that the dominant learning model is structured inquiry. Research projects or mini-projects are typically conducted only in the final meeting and constitute a small part of the overall learning process in several courses.

Assignments given by lecturers, aligned with the learning models, include presentations, papers, concept maps, and summaries. Some assignments also require analyzing research articles. Worksheets containing critical thinking questions are only provided in Biochemistry and Plant Structure and Development courses. Although worksheets are available in other courses, the questions are usually limited to cognitive levels C1-C3, with the majority at C1 and C2 levels. This finding aligns with Ijaiya et al. (2009), who showed that C1 and C2-level questions accounted for 56.9% and 31.1%, respectively, of exam questions. Tasks such as research projects and the formulation of questions based on problem phenomena are very rarely assigned.

Regarding evaluation, most lecturer exams still focus on assessing students' content comprehension. Case study or problem-solving exercises are rarely used, although they occasionally appear in disciplines such as general biology, ecology, cell biology, nutrition and health sciences, and plant physiology. Research on practicum guides shows that structured inquiry is used for all practicum tasks, with questions at cognitive levels C2-C4 accompanied by problems, experimental procedures, and tables of research findings. However, to assess students effectively and to require critical thinking, it is necessary to provide real-life problems and situations that require solutions (Alhassan, 2023).

Through interviews, the exploration of each grade's students' learning experiences is conducted. The emphasis of the questions is on the approaches, models, tasks, and procedures used in lectures. Perceptions of students and lecturers regarding critical thinking skills are also examined through interviews. The following will describe the findings of the representative interviews.

According to students of all generations, the majority of the learning models used by lecturers in theory courses still mostly revolve around direct instruction, discussions, and presentations. Few lecturers use problem-based learning strategies to develop critical thinking abilities, such as Problem-Based Learning (PBL), inquiry, RQA, and Project-Based Learning (PjBL). Direct instruction makes the lecturer the primary learning resource, ultimately creating passive students who do not develop critical thinking skills. Information is presented without logical reasoning, and students are not allowed to develop assumptions about "what is happening behind this? Why is this?" One-way learning, the lack of activities for analysis or case studies, and the direct drawing of conclusions contribute to weak inferencing skills. In fact, to draw inferences, students need learning that involves various cognitive processes to connect concepts or phenomena. Furthermore, students should engage in active thinking processes, for example, through questions posed by lecturers, to develop inferential skills (Rice et al., 2024). Besides that, the assignments received by students are also aligned with the selected learning models. The majority of the homework that students are given involves creating theoretical academic papers, mind maps, and resumes. Only a few courses apply RQA and provide student worksheets.

Freshmen acknowledged that they had not attended many biology classes and that they had only learned about PjBL at the conclusion of their Scientific Writing (KTI) courses, in addition to attending a few general biology course meetings to learn about the issues. Inquiry learning is offered only to sophomores in select courses, such as Plant Structure and Development, PjBL in the Biology Learning Media course, and RQA in the Biochemistry course. Juniors receive inquiries in the Biology Education Research Methodology course and lesson planning, PjBL in the Natural Resources Conservation and Ecology course, research-based learning in the Plant Physiology course, and PBL in the nutrition and health sciences course. However, the implementation of some of these models is limited only to specific meetings. Only a limited number of courses use learning strategies that enhance critical thinking skills, such as inquiry, RQA, PBL, PjBL, and research-based learning, according to students' experience with models and assignments during lectures. The learning model is still dominated by lectures (direct instruction), which are theoretical in nature.

The choice of the direct instruction method is made because it can facilitate the delivery of large amounts of information, but it tends to lead students to memorize the material. To place greater emphasis on active learning, memorization, and rote learning should be abandoned. Through active learning, students can take the lead in their education and choose the most effective learning methods. While this is going on, lecturers might engage in activities that enhance their capacity for critical thought and the ability to perceive things from various perspectives.

The educational emphasis should be on the process of learning to connect critical thinking skills with content. There is too much factual material and a lack of conceptualization in traditional teaching approaches like lectures; there is also too much memorization and not enough thinking. Lectures and memorizing thereby discourage critical thought. In reality, facts and concepts interact in networks that might help students connect ideas from science with their personal experiences.

Students may align intuitive notions with scientific ones and draw meaningful connections when they have conceptual knowledge, rather than merely memorizing information. Students are able to use their conceptual understanding in a variety of circumstances as a result (Kang & Howren, 2004). In other words, memorization-based learning does not lead to long-term retention or the ability to apply that knowledge in novel contexts. In fact, the essence of critical thinking lies in the capacity to examine and respond creatively to novel contexts (Changwong et al., 2018).

The results of the interviews regarding the lecturer's assessment: each class responded that the majority of the assessments solely tested knowledge of concepts or theories presented in lectures. Case studies and other high-level thinking questions are only a small portion of the assessments that contain critical thinking content. These assessments are also restricted to specific topics. For instance, case study questions may be given to Freshmen in basic biology courses, sophomores in histology and plant structure and development courses, and Junior in plant physiology and immunology courses. Quizzes given at meetings other than UTS and UAS are also only to check students' understanding and more at the C1 level. In practicum courses, only a few questions are given to hone students' critical thinking skills.

The ability to use assessment as a foundation for successful learning makes it a crucial component of the learning process. Students' problem-solving skills do not improve as a result of assessment questions that solely test their knowledge. According to Nappi (2017), the types of questions asked have a significant impact on how people improve their critical thinking skills. It is further stated that the higher-order question design is not a natural talent. It takes careful planning to create scaffolded questions that start with recollection and progress to analysis, synthesis, and creation.

Interviews with students also demonstrated that they believed critical thinking abilities were necessary, but they claimed that neither overtly nor implicitly had they learned critical thinking. In a pre-service teacher education program, students were asked, "Do you think your lecturer is teaching you critical thinking? If so, describe how. A small number of lecturers teach critical thinking, according to the students. They further explained that the lecturer not only conveyed information, but also gave critical questions. They added that the majority of lecturers' other questions, which relied solely on memorizing textbook material, required little to no critical or analytical thought. Students agree that pre-service teacher programs do not promote critical thinking.

Students believe that lecturers play a significant role in developing critical thinking skills. However, in practice, students claimed that lecturers do not foster critical thinking and instead emphasize memorization. According to Paul et al. (1997), the majority of lecturers at both public and private universities in California failed to sufficiently teach students in critical thinking skills during teacher education programs.

Teaching critical thinking abilities in teacher education study programs is further complicated by inadequate knowledge and a reluctance to add to an already packed curriculum (Ijaiya et al., 2009). Lecturers stated they did not have enough time to implement professional development programs on critical thinking due to the high performance load and the large amount of material to be covered within a limited timeframe. Some lecturers stated that “face-to-face classes are not long enough, we cannot have in-depth discussions, and the same goes for collaborative student activities (lecturer A)." Meanwhile, another lecturer stated, "I prefer direct instruction because it is completed more quickly, compared to Student Centered Learning (SCL), which takes a long time, and the target completion of the RPS material is very large, so I cannot allow students to explore problems" (lecturer B). This shows that time and curriculum load can hinder the implementation of SCL. In addition, lecturers believe that students are not yet fully ready and capable of implementing SCL independently. The lecturer stated that "the average student today cannot learn independently, so it is difficult to implement SCL, and also students lack initiative, they prefer to have the lecturer explain it to them rather than reading the material themselves" (lecturer C). This is reinforced by another lecturer's statement, "the culture of expressing opinions and conveying ideas has not yet taken root in class discussions. Students do not seem ready to actively engage in discussions, projects, or problem-solving" (lecturer D). Lecturer A added that "one of the obstacles to implementing student-centered learning is low student motivation." This finding indicates that student readiness and ability can influence the implementation of SCL. Several lecturers highlighted how institutional support can shape students' critical thinking skills. "From the campus, there have been no periodic training and evaluation activities related to the implementation of SCL" (lecturer B). "The administrative burden on lecturers is very large and varied, so they cannot participate in off-campus training to develop strategies that lead to SCL" (lecturer C). In addition, lecturers prefer to develop knowledge in biology rather than pedagogy.

Although lecturers are seen as obstacles to critical thinking, students also say they are obstacles because they are reluctant to read much and to learn to think critically. According to Taglieber (2008) and Shihab (2011), reading is crucial for empowering critical thinking skills. Some students only want to pass classes and obtain a bachelor's degree in order to find employment. In contrast, others believe that being able to think critically requires much time, increases their study load, and makes learning difficult.

▪ CONCLUSION

The pre-service biology teacher students' level of critical thinking skills falls into the "moderate" category, which is still not adequate. The four groups of students from different years did not significantly differ from one another. However, there are significant differences in the indicators for interpreting and evaluating arguments, which are partial and limited to a certain group. Interpretation differs significantly between freshmen and juniors, while argument evaluation differs significantly between freshmen and sophomores.

The development of students' critical thinking skills can be influenced by aspects of the student learning experience, including learning models, assignments, student worksheets, and assessments. Students perceive that the learning has not provided sufficient space to hone critical thinking skills, while lecturers choose not to integrate critical thinking into the learning because they feel there is a lot of material and the workload is already high.

This research has implications for lecturers, namely, they need to determine students' critical thinking skills and implement learning using learning models, assignments, worksheets, and questions that can encourage the development of students' critical thinking skills (e.g., the application of Inquiry-Based Learning, PjBL, PBL, RQA, and so on). Specific interventions are also needed to help students develop skills in identifying assumptions and drawing inferences, for example, through data analysis, case studies, or even debates. Students can become more independent in reading, studying, and working on questions that require higher-order thinking to improve their critical thinking. Study programs can evaluate curricula that emphasize the implementation of learning processes that encourage critical thinking skills, refocus the curriculum accordingly, and change public perceptions of these skills as potential steps to advance their development in the classroom.

This study has several limitations, including the use of a WGCTA-based instrument that may not fully reflect the real-world phenomena students typically encounter. Qualitative data were limited to specific factors, and the study did not test the effectiveness of learning models on critical thinking skills. Future studies might focus on examining several different learning models designed to build critical thinking skills. Moreover, the development of prospective biology teachers' critical thinking skills could be the subject of longitudinal studies starting from the first year of their education until the final year. This may also provide more detailed information on the evolution of critical thinking skills, beginning with the assessment of these skills. Alternatively, assessments could be developed to hone and test students' critical thinking skills, specifically in targeted courses, based on critical thinking indicators from Facione or Ennis.

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