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Enhancing preservice teachers' metacognition and critical thinking through the ERIC

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Abstract. Metacognitive and critical thinking skills are essential skills for being an effective learner. However, the results of previous studies indicate that these two skills in preservice teachers still require improvement. This research aimed to investigate the potential impact of the Exploring-Resuming Integrated Criticizing (ERIC) learning strategy on enhancing the metacognitive and critical thinking skills of preservice teachers. The study employed a quasi-experimental research design with a pretest and post-test component. The research population consisted of all biology education students at a university in Magelang City, Central Java, Indonesia. The sample consisted of 54 students from two classes enrolled in Plant Physiology, selected via cluster random sampling. Data on metacognitive and critical thinking skills were collected through pretest and posttest essay assessments. The data were analyzed using Analysis of Covariance (ANCOVA). The results of this study showed that the ERIC learning strategy has a significant impact on the preservice teachers' metacognitive and critical thinking skills. We found that implementing ERIC learning led to higher metacognitive and critical thinking skills than those taught with a traditional approach. The research results recommend that ERIC be implemented as an active learning strategy to encourage the development of metacognitive and critical thinking skills.

Introduction

The 21st century is characterized by rapid advancements in information and communication technology, which have given rise to new challenges, including intensified global competition. Students' readiness to enter a post-industrial era or a complex, dynamic, and unpredictable world was expected as a learning outcome of education in the 21st century (Astuti et al., 2019). To adapt to these changes and challenges, students need to acquire 21st-century skills. Joynes et al. (2019) synthesized critical skills researchers agreed upon; one of them is individualized learning strategies, including metacognition and critical thinking. Hence, the direction of education should be to develop learners' metacognition and critical thinking to adapt to 21st-century challenges.

In the area of education, it is crucial to develop one's metacognitive skills, with teachers playing a pivotal role in preparing graduates to adapt and actively contribute to our rapidly changing world. Metacognitive skill refers to being aware of one's learning and thinking processes and making conscious decisions to improve one's own growth and development (Flavell, 1979), thereby eventually enhancing cognitive skill. However, to effectively impart and nurture metacognition to their students, teachers, including preservice teachers, must possess these skills themselves. Matsumoto-Royo et al. (2022) stated that enhancing metacognitive skills is pertinent to preservice teachers. Teachers with strong metacognitive skills are responsible for their thoughts, behaviors, and continuous learning, consequently fostering attributes such as self-confidence, self-determination, and direction (Blömeke, 2017); (Callan & Shim, 2019); (Dignath & Büttner, 2018). Additionally, teachers' metacognitive skills can significantly enhance students' achievements (Perry et al., 2019). When teachers are aware of how they think and learn, it enables them to plan their lessons effectively, teach more efficiently, and assess their students' learning progress (Evi & Widana, 2023). Moreover, Duman (2018) explained that increasing metacognitive skills through learning activities will produce advantages in learners' entrepreneurship characteristics. Despite the necessity for educators, including preservice teachers, to have adequate metacognitive skills, studies indicate that they struggle in these areas. Research by Fauzi & Sa'diyah (2019) and Purwati (2022) showed that preservice Biology teachers often had poor metacognitive abilities, highlighting the need for improvement.

Along with metacognition, encouraging critical thinking is a key educational goal at all grade levels, and preservice teachers should prioritize developing their critical thinking skills. Critical thinking is defined as self-regulatory judgments leading to interpretation, analysis, evaluation, and conclusions, as well as explanations of the evidence and considerations on which these judgments are based, making it a crucial inquiry tool (Andreucci-Annunziata et al., 2023; Widana et al., 2023). Critical thinking skills involve cognitive, analytical, rational, and logical processes that encourage students to reflect on problems (Syahrial et al., 2019). Therefore, critical thinking is part of higher-order thinking skills (HOTS) (Chusni et al., 2022), required for making deliberate, reflective, and fair judgments about beliefs or predictions regarding future practical issues. A critical thinker can logically and rationally search for, understand, and evaluate relevant statements during problem-solving or decision-making processes, and tends to engage in exploratory and reflective thinking activities (Shaw et al., 2020). For this reason, critical thinking needs to be emphasized within teacher education curricula to enhance professional teaching practices.

Preservice teachers also exhibit similar challenges in acquiring critical thinking skills. Many teachers were aware of the importance of critical thinking; however, they felt that they lacked the necessary training or resources to teach the skills to their students effectively (Innabi & El Sheikh, 2007). This idea was supported by research by Fikriyati et al. (2022) who found that critical thinking skills among preservice science teachers were consistently rated as low or still in the developmental stage. Additionally, the indicators of identifying the problem and defining the context were in the medium categories, while the indicators of reasoning, analyzing options, and enumerating the choices were in the low categories (Astuti et al., 2019). Consequently, preservice teachers' critical thinking skills should be developed before they begin to educate students on 21st-century learning skills.

By mastering creative thinking and metacognitive skills, individuals can adapt and contribute to the rapid development of the world. Metacognitive skill is closely linked to critical thinking, which involves making well-informed decisions based on a thoughtful analysis of facts and ideas by carefully examining, combining, and assessing information (Lewin & Mcnicol, 2015). Both competencies can be enhanced by implementing a student-centered learning strategy. Moreover, contextual, constructive, and student-centered learning strategies have the potential to empower students' scientific thinking skills and achievement in science (Qarareh, 2016). However, preservice

teachers in universities experienced distance learning using e-learning during the COVID-19 pandemic. Educational activities have to be conducted in various circumstances, such as teaching online via multiple platforms and multiple ways during the pandemic, and teachers should be ready to adapt to the situation (Kadir et al., 2021). Allowing adaptation to current and future unpredictable situations should be a differentiating component in training future teachers to enhance education quality (Fuertes-Camacho et al., 2021). Consequently, it was crucial to enhance and investigate the implementation of student-centered learning strategies in the post-pandemic classroom to develop preservice teachers' metacognitive and critical thinking skills.

In previous related studies, researchers implemented student-centered learning strategies to develop metacognitive and critical thinking skills. However, some limitations were found and should be investigated. (Kyriakides et al., 2020) found that only four teaching factors of the dynamic model of educational effectiveness were associated with two aspects of metacognition, namely prediction and evaluation. Mahanal et al. (2019) in their study of RICOSRE (reading, identifying a problem, constructing the solution, solving the problem, reviewing the solution, and extending the solution) learning strategy, which focused on problem-solving activity, suggested focusing more on metacognition at the university level. Hence, the metacognitive and critical thinking skills of preservice teachers should be improved and investigated in the learning process using appropriate learning strategies. One of the learning strategies that potentially fosters creative thinking and metacognitive skills at the university level for preservice teachers is the Exploring-Resuming-Integrated-Criticizing (ERIC) strategy. This learning strategy consists of two main learning stages: (1) Exploring or looking for reading sources/journal articles, followed by conducting surveys quickly in each chapter, and (2) Resuming Integrated Criticizing by making a summary based on an in-depth study of the content, for asking high-level questions (why and how). The stages and activities outlined in the ERIC strategy are designed to encourage learners to enhance their critical thinking abilities, decision-making skills, and time management. This strategy provides learners with the freedom to seek information based on their prior knowledge and encourages them to select important information and concepts needed to understand the material. This is in line with the theory of constructivism, which states that individuals learn best when they actively construct their understanding from newly acquired knowledge (Clark, 2018).

In constructivist learning theory practices, learners become self-directed and construct knowledge based on experiences and social interaction, while instructors act as mentors (Chuang, 2021). Moreover, learning in constructivist learning theory involves acquiring information, constructing meaning, and understanding through exploration and discovery processes (Marougkas et al., 2023). However, Hof (2021) explained that humans are not only receptive beings but the creators of their environment, where the boundary between human, machine, and the environment is dissolved. This learning theory will be essential to understand how students learn in the investigated classroom and how this strategy affects preservice teachers' metacognitive and critical thinking skills. Therefore, this study aims to investigate the impact of the ERIC strategy on metacognitive and critical thinking skills. Hence, the contributions of the ERIC strategy on both skills will be clarified by answering these research questions: 1) Is there any significant difference between the ERIC strategy and Lecture-Based Learning on preservice teachers' metacognitive skills?, 2) Is there any significant difference between the ERIC strategy and Lecture-Based Learning on preservice teachers' critical thinking skills?.

Method

To investigate the impact of the Exploring-Resuming Integrated Criticizing (ERIC) learning strategy on the metacognitive and critical thinking skills of preservice teachers, this study employed

a quasi-experimental design with a pretest-posttest control group, as shown in Table 1. In a quasi-experimental design, researchers are unable to assign participants to groups due to various constraints randomly. Consequently, existing groups within the natural educational environment are utilized as control and experimental groups (Creswell, 2019). The experimental group in this study was taught using the ERIC learning strategy, while the control group was taught using lecture-based learning (LC).

Table 1. Quasi-Experimental Research Design

Class	Pretest	Treatment	Posttest
Experiment	O1	X1	O2
Control	O2	X2	O4

Information:
O1, O3: pretest
O2, O4: post-test
X1: ERIC learning strategy (ERIC)
X2: Lecture-based learning (LC)

Sample

The research population consisted of all biology education students at a university in Magelang City, Central Java, Indonesia. The sample consisted of 54 students from two classes enrolled in Plant Physiology courses during the 2023-2024 academic year. Via cluster random sampling, a group of 26 students was selected for the experimental group, where the ERIC strategy was implemented. In contrast, another group of 28 students was designated as the control group, utilizing the LC strategy.

Intervention Procedure

To assess the effects of the ERIC learning strategy on the metacognitive and critical thinking skills of preservice teachers, an intervention was implemented over four weeks during plant physiology lectures, with each session lasting 150 minutes. Prior to the intervention, a pretest was administered concurrently to both the experimental and control groups to gauge the students' baseline competencies. After that, the researcher implemented the intervention process by preparing and implementing a lesson plan using the ERIC learning strategy in the experimental group. In this case, the ERIC learning strategy is implemented in two main stages, including (1) Exploring, where the students search for learning resources/scientific articles, then conduct a quick survey on each material, and (2) Resuming Integrated Criticizing, where the students resume the information through the in-depth study of the material and then asking high-level questions (why and how), answering questions, and discussing on heterogeneous groups during classroom learning. Meanwhile, lecturers monitor students' experiences during the discussion process and encourage discussion activities in a constructive direction, providing additional feedback and explanations at the end of the lesson. The control group was treated using traditional lecture activities followed by questioning and answering. The lecture method is a form of learning widely used in Indonesia (Irnidayanti et al., 2020). Finally, after the intervention was implemented, both the experimental and control groups completed the identical posttest at the same time to assess the treatment effect.

To ensure consistency across the experimental and control groups, the researcher served as the instructor in both classes. Standardized lesson plans and observation sheets were developed and used to deliver instruction with minimal variation, except for the instructional model applied. To minimize potential researcher bias and maintain procedural integrity, five peer observers were involved throughout the study (Image 1). These observers participated in three key phases: (1) planning, by reviewing and validating the lesson plans and learning materials; (2) implementation,

by observing classroom activities using observation checklists; and (3) reflection, by providing feedback on the teaching process. Their presence served to strengthen the objectivity and credibility of the instructional procedures applied in both groups. Observations and informal assessments were conducted from the first to the fourth week of learning.

(a) (b) (c)

Image 1. Involvement of peer observers during the research process to minimize potential researcher bias and maintain procedural integrity. The observers contributed during the planning phase (a), the implementation phase (b), and the reflection phase (c).

Data Collection and Instruments

This research data includes metacognitive and critical thinking skills from each group, which were collected before the learning process (pretest) and after learning (post-test). Data was obtained through the same essay test on the topic of photosynthesis, which includes sub-topics on the role of sunlight and the products produced from light reactions, the relationship between light reactions and dark reactions, and the role of enzymes involved in the dark reaction of photosynthesis, conditions that influence photosynthesis, and adaptation processes and photosynthesis mechanisms in C3, C4, and CAM plants. Experts examined the instrument in the fields of Learning Evaluation and Plant Physiology to verify its content validation.

To evaluate students' metacognitive skills, the responses from the essay test were assessed using a rubric designed for metacognitive skills assessment. Based on Corebima (2009), this rubric comprised seven scales ranging from 0 to 7, and the scores were calculated using a specified Formula (1). On the other hand, critical thinking skills were evaluated using a rubric initially developed by Finken & Ennis (1993), which was later adapted by Zubaidah & Corebima (2015) Into five scales ranging from 0 to 5. The components of this rubric encompass focus, reasoning (including reasons or ideas), organization (referring to the structure of thought), conventions (about grammar), and integration of student responses. Scores from metacognitive and critical thinking skills data were then converted into a 0-100 score range to simplify the data analysis process.

$$y_2 = \frac{y1+2xy1+2x}{3 \quad 3} \qquad (1)$$

Descriptions:
y1 = concept understanding score
y2 = combined score between conceptual understanding and metacognitive skills
x = metacognitive skills score

To determine the difference in mean scores between the pretest and posttest in the two classes, the Analysis of covariance (Ancova) was carried out at a confidence level of 95%. Ancova was selected because the use of pre-test scores as a control variable allowed researchers to account for initial differences in student knowledge as statistical covariates thus providing a more accurate

estimate of the effects of the treatment and eliminating potential bias. Prior to this, a normality test was conducted using the One Sample Kolmogorov-Smirnov and data homogeneity using the Levene test as an assumption test.

Results and Discussion

The results showed that the metacognitive skills scores of preservice teachers in both classes increased from the pretest to the posttest (Table 1). The metacognitive skills score in the class implementing the ERIC strategy increased from 62.036 at the pretest to 76.121 at the posttest. Pretest to posttest scores in the class that implemented the LC strategy were lower than those in the ERIC class, from 64.168 in the pretest to 71.967 in the posttest. Thus, the results of the study indicate that although both learning strategies improve metacognitive skills at the end of learning, the application of the ERIC strategy is more effective in training metacognitive skills.

Table 2. Results of Descriptive Statistics on Metacognitive skills

Treatment	X Metacognition		Y Metacognition	
	Mean	Std. Deviation	Mean	Std. Deviation
ERIC	62.0362	13.16820	76.828	1.836
LC	64.1686	14.12964	71.312	1.769

In line with these results, critical thinking abilities in both learning strategies increased from pre-to posttest (Table 2). The average critical thinking ability of the ERIC class increased from 65.604 to 82.966, while in the LC class, it increased from 68.264 to 79.795. However, the comparison of the mean score of the experimental and the control group showed that the experimental group students recorded a higher mean score, with 17.362 mean differences between pre- and posttest, but the control group students recorded relatively low mean score with 11.531 mean differences between pre- and posttest. Based on these results, experimental group students benefited more than control group students in improving their' critical thinking skills.

Table 3. Results of Descriptive Statistics on Critical Thinking Skills

Treatment	X Critical Thinking		Y Critical Thinking	
	Mean	Std. Deviation	Mean	Std. Deviation
ERIC	65.6046	8.10103	82.9665	7.93782
LC	68.2646	10.41373	79.7957	10.45932

Prior to conducting the hypothesis test, a prerequisite test, namely the normality test, was conducted using the one-sample Kolmogorov-Smirnov (Table 3). Additionally, the results of another assumption test, specifically the Levene test for homogeneity, are also presented in Table 4.

Table 4. Results of Normality Test

		Kolmogorov-Smirnov[a]		
Class		Statistic	df	Sig.
Metacognition_Pre	ERIC	.147	26	.153
	LC	.157	28	.076
Metacognition _Post	ERIC	.098	26	.200
	LC	.122	28	.200
	ERIC	.143	26	.184

Critical Thinking_Pre	LC	.095	28	.200
Critical Thinking_Post	ERIC	.139	26	.200
	LC	.112	28	.200

Table 5. Results of Homogenity Test

	Levene Statistic	df1	df2	Sig.
Metacognition_Pre	.596	1	52	.444
Metacognition_Post	2.373	1	52	.130
Critical Thinking_Pre	1.371	1	52	.247
Critical Thinking_Pos	.326	1	52	.571

Based on Table 3, it can be seen that the significance value for the Kolmogorov-Smirnov test is higher than 0.05. This is in line with Table 4, where the results of the Levene test show a significance value higher than 0.05. The results showed that the data were distributed normally and homogeneously. Since all the data on dependent variable meet the criteria of normality and homogeneity, hypothesis tests through Ancova can be carried out to find out the difference in pretest and postest scores from the experimental and control groups. The results of the Ancova test on the metacognitive and critical thingking variable are presented in Table 5.

Table 6. ANCOVA Results of Metacognitive and Critical Thinking Skills on ERIC and LC learning

Variable	Learning Strategy	Corrected Mean	Standard Deviation	F-Count	Sig.
Metacognitive	ERIC	76.828	1.836	4.663	.036
	LC	71.312	1.769		
Critical Thinking	ERIC	83.932	1.321	7.450	.009
	LC	78.899	1.273		

Based on Table 5, the results of Ancova test to metacognitive skill variable showed a calculated F value of 4.663 and a significant value of 0.036. Since the sig. value is less than 0.05, we have enough evidence to accept the research hypothesis that there was a significant difference between ERIC strategy and Lecture-Based Learning on preservice teachers' metacognitive skills. In addition, the result of Ancova test to critical thingking skill variable showed a calculated F value of 7.450 and a significant value of 0.009. This clearly indicates that there is a significant difference between the ERIC strategy and Lecture-Based Learning on preservice teachers' critical thinking skills. As a result, the increase of preservice teachers metacognitive and critical thinking skills are significantly higher in the ERIC strategy compared to the lecture method.

The Impact on Preservice Teachers' Metacognitive Skills

The result of the study revealed that after the intervention, there is a significant difference in the students' metacognitive scores between the pretest and post-test. This suggests that ERIC has a significant impact on the metacognitive skills of preservice teachers. In the first step of ERIC namely Exploring, the students find and explore journal articles of other resources. Thus, they are trained to identify key details and concepts necessary to comprehend the subject matter. As they analyze and synthesize information, they might use a range of reading strategies. This activity allows them to empower their metacognitive skills and cognitive approach (Yurdakal, 2019). Moreover, through this activity, the students learn how to regulate their cognitive process, which can help them understand and make sense of the information in the materials. In this learning stage, the students investigate topics and work through the challenges. In this manner, students are

encouraged to think critically, make informed decisions, and manage their time effectively. These activities significantly enhance their metacognitive skills. This finding agrees with a study conducted by Djamahar et al. (2019). Their research reported that during the exploring stage, in which the reading process is encouraged, the students actively manage their learning by being responsible for their own learning process, and modifying their learning approach to meet assignment demands; and this is a part of metacognitive skills.

The students' metacognitive skills are further developed in the next stage of ERIC, namely Resuming. At this stage, students identify important details and create a summary of the source. The activity requires a profound understanding of the topic, as it involves selecting and organizing information to facilitate comprehension. In this learning process, the lecturer plays a role as a facilitator, while the students develop their own understanding and concepts. This process enhances students' memory, problem-solving skills, and learning strategies. In this way, the students are aware of and control their thinking process. In other words, students manage their own learning, which has a beneficial impact on their metacognitive skills. The finding is similar to the study of Winarti et al. (2022), which found that the students who regulate their own learning strategy improve their metacognitive skill. As students take control of and evaluate their own learning and task completion, they develop their metacognitive skills.

Following the Resuming stage of ERIC, in the Criticizing stage, the students ask high-level questions (why and how) related to the subject matter, answer the questions, and discuss the topic in heterogeneous groups. This activity allows the students to analyze their learning resources with peers; that is why they use their higher-order thinking. This is consistent with the statement of Fuad et al. (2017), that asking questions is one of the most common ways to encourage higher-order thinking. Besides, through the group activities, the students are exposed to different perspectives and learning processes. Ultimately, it can help students make more informed decisions about how to complete learning tasks by enhancing their understanding of their own learning strategies. This is how all activities in ERIC impact the students' metacognitive skills.

The Impact on Preservice Teachers' Critical Thinking Skills

The findings of this study demonstrate a notable improvement in students' critical thinking skills following the implementation of the ERIC learning strategy. The experimental group exhibited significantly enhanced critical thinking abilities compared to students in conventional learning environments. This finding is attributed to the ERIC syntax, which consists of exploring and resuming integrated criticizing stages.

In the exploring stage, learners searched for reading sources/journal articles before surveying each chapter quickly. Based on the findings of this study, this activity supported the improvement of preservice teachers' critical thinking skills. Engaging in reading experiences contributes to the development of critical thinking by expanding perspectives, altering cognitive frameworks, and stimulating analytical thought through various avenues (Hollis, 2023; Widana & Ratnaya, 2021). Moreover, students reflect on and evaluate the reading contents, helped by critical thinking skills (Babashamasi et al., 2022). In conclusion, the first stage of the ERIC learning strategy activates the mind and facilitates the development of critical thinking skills.

In the second stage, resuming integrated criticism, learners summarized the content based on in-depth study to ask high-level questions using "why" and "how" questions. The results of this study demonstrated the role of this stage in the development of preservice teachers' critical thinking skills. Learners' critical thinking skills improvement was contributed to by asking questions; critical thinking students are creators of critical questions (Mahanal et al., 2019). When asking high-level questions, students enhance their intellectual abilities, enabling them to develop critical thinking

skills, problem-solving capabilities, the ability to seek information independently, and advanced cognitive processes (Pejchinovska-Stojkovikj, 2015). The finding of this research aligns with Bezanilla et al. (2021), who explained that reading, analyzing, and synthesizing information are the most effective methodologies to develop critical thinking skills based on university teachers' views. However, teachers need to train students in techniques for creating high-level questions because quality questions may help students to solve problems and make informed decisions.

The implementation of the ERIC strategy refers to the constructivist learning theory. Constructivism posits that learners actively engage in constructing new knowledge based on their prior knowledge (Jaleel & Verghis, 2015). This theory asserts that humans build knowledge and meaning from their experiences (Bada & Olusegun, 2015). According to Tanjung et al. (2023), the constructivist learning theory highlights how individuals form knowledge through mental activities, which are facilitated by their learning experiences. Based on the constructivist learning theory, the ERIC strategy encourages thinking activity to improve preservice teachers' metacognitive and critical thinking skills. This strategy habituates learners to read numerous sources and evaluate pivotal information, aligning with constructivist learning theory, which posits that individuals construct their own knowledge through mental activities supported by learning experiences. Learners actively construct new knowledge and meaning from their experiences during the ERIC learning phases. Therefore, the ERIC learning strategy stages provide learners with the opportunity to actively engage in regulating their cognitive processes, helping them understand, and facilitating the development of their metacognitive and critical thinking skills.

This study offers a novel contribution by being the first to investigate the implementation of the ERIC (Exploring-Resuming Integrated Criticizing) strategy in a learning context, specifically focusing on its effectiveness in enhancing metacognitive and critical thinking skills. Unlike previous studies that have generally examined active learning models in broader terms, this research uniquely situates ERIC within the framework of constructivist theory. By aligning ERIC's reflective and interpretive components with the principles of knowledge construction, the study demonstrates how structured information processing through active learning can facilitate deeper cognitive engagement and learner autonomy. This theoretical integration not only reinforces the relevance of ERIC as a pedagogical approach but also opens new pathways for applying constructivist-based strategies to promote the empowerment of students' metacognitive and critical thinking skills.

Conclusion

Based on the current study, it can be concluded that there is a significant impact of the ERIC strategy on preservice teachers' metacognitive and critical thinking skills ($p < 0.05$). It aligns with the constructivist learning theory and provides opportunities for learners to actively engage in regulating their cognitive processes, ultimately facilitating the development of critical thinking skills. The first stage of ERIC, namely exploration, trains students to think critically by examining various sources relevant to the concepts being studied, enabling them to identify key terms and concepts that facilitate comprehension of the material. The next stage, where students create resumes and ask high-level questions, not only hones intellectual capacity that stimulates critical thinking skills, but also encourages students to control and evaluate their thinking processes to solve given problems. This process also fosters the development of metacognitive skills. Based on the research findings, it is recommended that the ERIC strategy can be implemented as an active learning approach to promote the empowerment of students' metacognitive and critical thinking skills in various instructional settings.

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