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Learning Styles' Role in Enhancing Metacognition and Biology Achievement Using RQAAD

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Abstract

Modern education requires students to develop high metacognitive awareness for effective learning management, which supports applying the RQAAD model based on learning styles. This study investigates the effect of learning styles on metacognitive awareness and biology learning outcomes using a quasi-experimental method with a pre-test-post-test design at SMAN 3 Jember. Unlike previous research, which primarily explores learning styles and metacognitive awareness separately, this study investigates their combined impact on student learning outcomes. A more comprehensive comparison with prior studies is provided to emphasize the findings' academic contribution and contextual significance. The sample consisted of 72 students from classes XI-1 and XI-2, analyzed using ANACOVA in SPSS 26. The results showed that learning styles, especially kinesthetic learners, significantly affect metacognitive awareness ($p = 0.007$). However, learning styles did not significantly affect cognitive learning outcomes ($p = 0.104$) or psychomotor learning outcomes ($p = 0.312$). One-way ANOVA test significantly affected affective learning outcomes ($p = 0.039$), especially in visual learners. This study collected data through standard learning style assessments, metacognitive awareness inventories, and biology learning outcome tests. Findings emphasize the role of learning styles in improving metacognitive awareness and affective learning in the RQAAD model, underscoring the importance of personalized teaching strategies to optimize student learning experiences.

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INTRODUCTION

Education nowadays is rapidly evolving, one indication being the growing importance of students to possess high metacognitive awareness and achieve optimal learning outcomes, especially in science and biology. A 2023 UNESCO study found that 78% of global educational institutions have adopted metacognitive-based learning strategies to improve outcomes. In Indonesia, the Merdeka Curriculum also emphasizes the importance of metacognitive awareness, with students possessing high metacognitive skills tending to achieve better academic performance (Hariyadi et al., 2023; Jumanto & Mustofa, 2023; Wulandari et al., 2022). Metacognitive awareness is related to an individual's ability to recognize what they understand and do not, allowing learners to identify how they learn

and understand their own learning capacity. Additionally, metacognition includes planning learning strategies, monitoring learning processes, and evaluating the effectiveness of those strategies (Marantika, 2021; Sari & Paidi, 2019; Stanton et al., 2021). Thus, metacognitive awareness enables learners to control and adjust their learning methods to achieve optimal comprehension.

Furthermore, metacognitive awareness is critical to learning success by allowing students to manage cognitive skills effectively (Abdelrahman, 2020; Anggraini et al., 2021; Smith et al., 2020). Studies show that students with high metacognitive awareness achieve better learning outcomes because they can plan, monitor, and evaluate their learning strategies. There are also differences in metacognitive awareness based on learning styles, indicating the need for learning approaches tailored to students' styles to optimize academic performance (Ismarani et al., 2023). A questionnaire-based observation at SMAN 3 Jember found that only 65% of students demonstrated metacognitive awareness. This observation, conducted using the Metacognitive Awareness Inventory (MAI), involved 72 11th-grade students in the 2024/2025 academic year. For comparison, a study by Rohmania et al. (2021) at SMAN 1 Kediri with 48 students showed a metacognitive awareness level of 70%, indicating that many SMAN 3 Jember students still struggle with time management, understanding unfamiliar material, and evaluating their learning methods.

The primary goal of education is to achieve learning outcomes across three domains: attitude, knowledge, and skills. In the knowledge domain, memory is a fundamental skill that students must master to improve conceptual understanding (Dakhi, 2020). Metacognitive awareness is vital in developing all three domains by helping students plan, monitor, and evaluate their learning strategies. Hence, metacognition impacts cognitive achievement, shapes positive attitudes toward learning, and enhances problem-solving skills. Therefore, educators must design creative, innovative, and motivating instruction to avoid monotonous learning processes, enabling students to be more engaged in acquiring knowledge (Maulana, 2021; Serdyukov, 2017).

Learning outcomes consist of three main areas: cognitive, affective, and psychomotor, affecting students' academic achievement (Owan et al., 2022; Ulfah & Arifudin, 2021; Yasmin et al., 2023). Students who achieve good outcomes are more likely to stay motivated and continue improving their performance (Gulo, 2022). Metacognitive awareness is positively correlated with learning outcomes—the more aware students are of their learning process, the better their academic results (Asaidah et al., 2022). When metacognitive awareness is achieved, students know how to gain knowledge independently by reflecting on what they have understood and identifying what still needs improvement (Marhaendra et al., 2023). This awareness includes three types of metacognitive knowledge: declarative, procedural, and conditional, as well as five aspects of metacognitive regulation: monitoring comprehension, evaluation, prediction strategies, planning, and information management (Putera et al., 2021).

Learning styles affect how students acquire knowledge and shape their metacognitive awareness. Visual learners use diagrams or concept maps to monitor their understanding, auditory learners prefer discussions or voice recordings to review material, and kinesthetic learners benefit from hands-on practice and simulations. By understanding their learning styles, students can develop more effective metacognitive strategies to improve their outcomes (Siswati & Suratno, 2024). Learning styles are especially important in biology, where students have different preferences for processing information and interacting with the content (Supit et al., 2023). Visual, auditory, and kinesthetic styles help determine how well students can absorb and master material, making it easier for them to learn (Aprilia et al., 2022). By recognizing each student’s learning style, teachers can tailor instructional methods to suit their characteristics and personalities (Wardi & Kartika, 2019).

In order to develop learning skills effectively, an appropriate model is needed—one such model is RQAAD. This model was chosen because it is more effective at encouraging

active student engagement than traditional, passive learning models. Research by Siswati et al. (2021) shows that RQAAD can enhance students' metacognitive awareness by helping them independently plan, monitor, and evaluate their learning processes. The RQAAD syntax—Reading, Questioning, Answering, Analyzing, and Discussing—can be adapted to various learning styles. This approach improves conceptual understanding and fosters critical thinking, discussion, and reflection skills (Siswati et al., 2021).

One topic that can be taught using this model is the circulatory system, which involves transporting substances from one organ to another (Kurniasih, 2018). Applying the RQAAD model in biology education can align with learning styles to enhance metacognitive awareness and student outcomes (Larasati & Widyasari, 2021). Based on this explanation, this study aims to analyze the influence of learning styles on metacognitive awareness and biology learning outcomes using the RQAAD model. The study examines learning styles (visual, auditory, and kinesthetic) as independent variables and metacognitive awareness and learning outcomes as dependent variables. It also aims to fill gaps in previous research by exploring how the RQAAD syntax can be adapted to different learning styles to optimize students' understanding. The hypothesis tested is that learning styles significantly affect metacognitive awareness and biology learning outcomes within the RQAAD instructional model.

METHODS

This study is categorized as a quasi-experimental research type. This method was chosen because it is more suitable in educational contexts where random student grouping is difficult to implement. The research design used is a pre-test and post-test with only an experimental group. However, without a control group, the study has limitations in ensuring that learning outcomes are solely influenced by the treatment applied in the classroom. The research was conducted in a class that implemented the RQAAD learning model, divided into three learning styles. The research design can be seen in Table 1.

Table 1 Research design

Learning Style	Pre-test	Post-test	Pre-Metacognitive Awareness	Post-Metacognitive Awareness	Affective	Psychomotor
Auditory	O_1	O_2	K_1	K_2	A	P
Visual	O1	O2	K1	K2	A	P
Kinesthetic	O_1	O_2	K_1	K_2	A	P

Information:

O_1	: Pre-test results	K_2	: Post-questionnaire results
O_2	: Post-test results	A	: Affective learning outcomes
K_1	: Pre-questionnaire results	P	: Psychomotor learning outcomes

Source: Abraham & Supriyati (2022)

Data were collected through observation using several assessment instruments, including a learning style questionnaire, metacognitive awareness questionnaire, pre-test and post-test questions, RQAAD model syntax, and learning style assessment rubrics. This study's dependent variables were biology learning outcomes and metacognitive awareness, while the independent variables included learning styles and the RQAAD learning model.

The study was conducted on the Circulatory System in Grade XI biology class at SMA Negeri 3 Jember in the 2024/2025 academic year. This school was chosen due to adequate facilities, infrastructure, and curriculum support. The study involved 72 students from classes XI-1 and XI-2 to obtain more representative data regarding students' understanding of the topic.

The results were analyzed using ANCOVA to test students' metacognitive awareness and cognitive learning outcomes, as this method allows for controlling covariates that may affect the outcomes. Meanwhile, affective and psychomotor outcomes were analyzed using one-way ANOVA to examine differences between groups. Before the analysis, statistical assumption tests (normality and homogeneity) were conducted. The significance level was 0.05 to determine whether learning styles significantly influenced students' metacognitive awareness and biology learning outcomes using the RQAAD learning model. Data analysis was performed using IBM SPSS Statistics 26 for Windows.

RESULTS AND DISCUSSION

Metacognitive Awareness

After conducting the research, data were collected on students' metacognitive awareness based on eight indicators obtained through a metacognitive awareness questionnaire completed by students before and after the learning process. The scores were analyzed using ANCOVA to determine whether learning styles influenced students' metacognitive awareness. The ANCOVA results are presented in Table 2.

Table 2 ANCOVA results for metacognitive awareness

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	8103.606[a]	3	2701.202	107.038	0.000
Intercept	415.635	1	415.635	16.470	0.000
Pretest	7265.563	1	7265.563	287.905	0.000
Class	272.661	2	136.330	5.402	0.007
Error	1716.047	68	25.236		
Total	474307.000	72			
Corrected Total	9819.653	71			

Table 2 confirms the effect of learning styles on students' metacognitive awareness. The ANCOVA results show a significance value of 0.007, indicating a statistically significant difference before and after applying the RQAAD learning model. This means H0 is rejected, and H1 is accepted, as the p-value is less than 0.05. Therefore, learning styles significantly affect metacognitive awareness when the RQAAD model is applied.

These findings align with those of Hamda et al. (2024), who state that auditory, visual, and kinesthetic learning styles enhance students' metacognitive awareness in planning, monitoring, and evaluating their tasks accurately. Similarly, Siswati et al. (2023) found that metacognitive awareness helps students organize strategies, time allocation, orientation, planning, and evaluation processes.

A Post Hoc test was conducted to identify which learning styles significantly differed in metacognitive awareness levels. The results are shown in Table 3.

Table 3 Post hoc test results for metacognitive awareness

No	Learning Style	Pre-test	Post-test	Difference	Notation
1	Auditory	77.45	83.55	6.10	a
2	Visual	74.82	81.44	6.62	a
3	Kinesthetic	61.67	74.61	12.94	b

The results show significant differences in metacognitive awareness levels based on auditory, visual, and kinesthetic learning styles, as analyzed through the Post Hoc test. While visual and auditory learners did not significantly differ from each other, the kinesthetic learning style showed a notable difference, with a much higher increase in metacognitive awareness.

This indicates that kinesthetic learners experienced a greater improvement in metacognitive awareness compared to other styles within the RQAAD-based learning process. The model emphasizes active student involvement in understanding and reflecting on the material. Kinesthetic students are more engaged through physical activities, direct exploration, and interaction with the learning environment (Siswati et al., 2021). They are more likely to develop metacognitive awareness through hands-on experiences, particularly during the Discussing phase, which allows them to concretely understand information and reflect on it in a practical context. Activities involving movement and direct practice help kinesthetic learners become more aware of their thinking strategies and comprehension (Lamowa et al., 2022).

In contrast, auditory and visual learners tended to be less actively involved in RQAAD-based learning. Auditory learners relied more on listening during the Questioning, Answering, and Discussing stages, which limited their deeper reflection (Suratno et al., 2023). Meanwhile, visual learners focused on visuals and diagrams during the Reading and Analyzing stages, which supported conceptual understanding but offered fewer opportunities for deep reflection. Thus, students with visual and auditory learning styles developed lower metacognitive awareness than kinesthetic learners in RQAAD-based classes (Yanti, 2024).

Metacognitive awareness is crucial in helping students plan optimal learning strategies that align with their individual needs (Suratno et al., 2023). It enables students to identify areas they have not yet mastered, encouraging them to become more independent and active in their learning process. Prior to identifying their learning styles, students often followed general teaching methods without considering their effectiveness (Hamsyah et al., 2021). However, once they understand their learning preferences, they can more easily adapt strategies to improve outcomes. Therefore, recognizing learning styles and applying the RQAAD learning model becomes a strategic step in developing students' metacognitive awareness and supporting more effective and personalized learning (Wardana et al., 2021).

Cognitive Learning Outcomes

Data on students' cognitive learning outcomes were analyzed using ANCOVA to determine whether the applied treatment had any effect. These outcomes were obtained through pre-test and post-test scores. The values were analyzed using covariance (ANCOVA) analysis to assess whether learning styles influenced students' cognitive performance. The ANCOVA results are presented in Table 4.

Table 4 ANCOVA results for cognitive learning outcomes

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	2790.928[a]	3	930.309	38.331	0.000
Intercept	6201.546	1	6201.546	255.518	0.000
Pretest	2768.587	1	2768.587	114.072	0.000
Class	113.413	2	56.707	2.336	0.104
Error	1650.392	68	24.270		
Total	567125.000	72			
Corrected Total	4441.319	71			

The ANCOVA analysis in Table 4 shows no significant difference in students' cognitive learning outcomes based on learning styles, with a significance value of 0.104. This indicates that H_0 is accepted and H_1 is rejected, meaning that learning styles do not significantly influence cognitive learning outcomes.

This finding may be due to other, more dominant factors, such as student motivation, classroom environment, or the teacher's instructional strategies. These results contrast with the findings of Lestari and Djuhan (2021), who stated that students' learning styles could contribute to improving their cognitive achievement. However, as Nurnaifah et al. (2022) pointed out, many other factors can affect learning outcomes, so learning styles do not always significantly impact students' cognitive achievement.

One contributing factor is the learning model used. In this study, the RQAAD learning model improved students' cognitive performance regardless of differences in learning styles—whether auditory, visual, or kinesthetic.

The RQAAD model, which emphasizes Reading, Questioning, Answering, Analyzing, and Discussing, creates a balanced learning atmosphere that accommodates students with various learning preferences (Siswati et al., 2020). Auditory learners benefit most from the Questioning, Answering, and Discussing stages, where verbal communication enhances understanding through listening and speaking, boosting confidence and critical thinking. Visual learners are supported during Reading and Analyzing, as textual and diagrammatic content strengthens their conceptual grasp, contributing to positive character development (Fatimah et al., 2023). Meanwhile, Kinesthetic learners benefit from the Discussing stage, where hands-on activities and real-life simulations help them internalize concepts through movement and physical interaction (Derici & Susanti, 2023).

These results support the view that learning success is influenced by learning styles and the effectiveness of teaching strategies that actively engage students (Puspita & Tirtoni, 2023). Thus, the success of the RQAAD model in enhancing cognitive learning outcomes demonstrates its reliability as an inclusive and adaptive instructional approach to meet diverse student needs.

Affective Learning Outcomes

Data analysis of students' affective learning outcomes was derived from assessing five character values: 1. Religious devotion and piety, 2. Honesty, 3. Discipline, 4. Cooperation, and 5. Courtesy. These values were evaluated through observational assessments conducted by observers. The affective learning scores were analyzed using a One-Way ANOVA test to determine whether learning styles significantly affected students' affective outcomes. The One-Way ANOVA results are presented in Table 5.

Table 5 One-way ANOVA results for affective learning outcomes

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	514.859	2	257.429	3.407	0.039
Within Groups	5214.252	69	75.569		
Total	5729.111	71			

The One-Way ANOVA results in Table 5 show a significant influence of auditory, visual, and kinesthetic learning styles on students' affective learning outcomes, with a significance value of 0.039 (< 0.05). This indicates the rejection of H0 and acceptance of H1. This result can be attributed to the fact that affective learning outcomes are more closely related to emotional involvement, motivation, and interest in learning, which are influenced by how students receive and process information in accordance with their learning style. This finding aligns with Irawati et al. (2021), who stated that applying learning styles that match students' characteristics can increase their enthusiasm and participation in the learning process, ultimately affecting their attitudes and values developed during learning.

Subsequently, a Post Hoc test was conducted to determine the differences in affective learning outcomes among learning styles. The results are presented in Table 6.

Table 6 Post hoc test results for affective learning outcomes

No	Learning Style	Score	Notation
1	Auditory	88.82	a
2	Kinesthetic	84.78	a
3	Visual	82.70	b

According to Table 6, the Post Hoc test shows no significant difference between the auditory and kinesthetic learning styles but a significant difference between the visual learning styles. One factor that influenced these results is the implementation of the RQAAD learning model syntax throughout the learning process. Visual learners benefit more during the Reading and Analyzing stages, where information is presented in text or diagram formats. These formats suit their preferences and allow them to read and analyze thoroughly and accurately, directly contributing to the development of positive character traits that support academic success (Fatimah et al., 2023).

In contrast, auditory learners may focus more on the questioning, answering, and discussing stages, where they can more easily comprehend material through verbal input and reflection. Activities that involve verbal communication can enhance their understanding of the content and learning process.

Kinesthetic learners are often more engaged in the Discussing stage, responding more actively through physical activities and hands-on experiences (Widodo et al., 2020). These interactions may have a stronger emotional impact, though they lean more toward exploration and direct action rather than deep reflection. This difference indicates that learning styles uniquely affect students' affective engagement, depending on how they best absorb and interact with learning content.

Psychomotor Learning Outcomes

Data related to psychomotor learning outcomes were obtained through assessments of students' ability to present analysis accurately and engage in group discussions. These values were collected from observational assessments carried out by observers.

The data were analyzed using a One-Way ANOVA to determine whether learning styles influence psychomotor learning outcomes. The results are presented in Table 7.

Table 7 One-way ANOVA results for psychomotor learning outcomes

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	116.881	2	58.441	1.184	0.312
Within Groups	3406.396	69	49.368		
Total	3523.278	71			

According to Table 7, the significance value is 0.312, indicating that H0 is accepted and H1 is rejected, meaning that learning styles do not significantly influence psychomotor learning outcomes. This result differs from Hanifah and Mulyaningrum (2021), who found that each learning style impacts psychomotor learning differently. However, other factors, such as the learning model applied, can influence outcomes, making learning styles not the dominant factor.

In this study, the RQAAD model effectively enhanced psychomotor learning regardless of students' learning styles. Its effectiveness lies in its syntax, which actively involves students in activities that encourage interaction and participation, accommodating different learning preferences. Auditory learners benefit from the Questioning, Answering, and Discussing stages, where verbal communication enhances comprehension and critical thinking (Sunarya & Atmazaki, 2024). Visual learners are supported during Reading and

Analyzing, where textual or visual information aids their understanding. Kinesthetic learners gain the most from discussing, as hands-on experiments or simulations boost comprehension through movement. This model can be applied universally without major adjustments for each learning style. Its comprehensive structure supports balanced psychomotor development, reinforcing that active learning strategies are key to student success (Puspita & Tirtoni, 2023).

CONCLUSION

Based on the research findings, it can be concluded that learning styles significantly influence students' metacognitive awareness when using the RQAAD learning model, as indicated by a significance value of 0.007 (sig < 0.05). Additionally, learning styles significantly influence affective learning outcomes with a significance value of 0.039 (sig < 0.05). However, no significant influence was found on cognitive and psychomotor outcomes, with significance values of 0.104 and 0.312, respectively (sig > 0.05). These findings demonstrate that applying the RQAAD learning model supports the development of metacognitive awareness and affective learning tailored to students' learning styles. However, learning styles do not directly affect cognitive or psychomotor outcomes, suggesting additional instructional strategies are needed to optimize those areas. This study has some limitations, including a restricted sample size from a single educational institution and not accounting for external factors such as intrinsic motivation, learning environment, and prior experience, all of which may influence learning outcomes.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, AS and BHS; methodology design and development, BHS; formal analysis and data interpretation, S; writing—original draft preparation, AS and BHS; review and editing, ALARL and S; supervision and project administration, BHS; all authors have read and agreed to the published version of the manuscript.

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