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The influence of multimodal learning strategies on prospective biology teachers' literacy-numeracy learning outcomes

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Abstract

This study examines the influence of multimodal learning strategies on total learning achievement and literacy-numeracy in prospective biology teacher students. Using the quasi-experimental matching-only pretest-posttest control group design, we tested sixth-semester students enrolled in the biology education program for the odd semester of 2022/2023. One group (class A) received multimodal learning strategies, while the other group (class B) received conventional methods through random sampling. The results indicate that multimodal strategies significantly improve total learning outcomes and literacy-numeracy, regardless of students' VAK learning styles. In particular, learning styles do not significantly affect learning outcomes, demonstrating the effectiveness of multimodal strategies in hydrobiology courses.

Keywords: multimodal, learning outcomes, numeracy literacy, learning styles

INTRODUCTION

The Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia, hereafter referred to as Kemendikbud-ristek RI (2022a), has established process standards, which are the minimum criteria for the learning process managed by teachers in the implementation of the new curriculum referred to as *Kurikulum Merdeka Belajar* (freedom to learn curriculum). These minimum criteria include providing quality learning experiences to students with diverse characteristics by delivering material in real-life problem or context, encouraging interaction and active participation, considering students' readiness, prior knowledge, learning styles, interests, and psychological factors, using various techniques and/or assessment instruments. The goal of this differentiated learning is to ensure that each student can achieve the expected learning objectives. Teachers are required to have the ability to manage learning that can accommodate the diversity of characteristics and skills of each student in the class.

Implementing differentiated learning is not a simple task. Many teachers face obstacles due to time constraints in designing different learning based on the needs of each student, grouping students based on learning styles, identifying the initial readiness of many students, organizing additional learning programs for students not ready to learn according to the phase in their class, and limited learning facilities (Kemendikbud-ristek RI, 2022b). One concern is the grouping of students based on their learning style, which is one of the most common myths found in education (Dekker et al., 2012).

The study by Riener and Willingham (2010) emphasizes that teachers should present information in the most appropriate way based on differences in students' levels of knowledge, abilities, and interests. However, the study argues against tailoring teaching to learning styles, as there is insufficient evidence that meeting these preferences leads to better learning outcomes. Several other studies (e.g. Farkas et al., 2015; Martinez & Tuesca, 2019; Newton, 2015; Rohrer & Pashler, 2012) reported a lack of accurate data supporting style-based teaching. Despite the widespread acceptance of learning styles, more methodological research tends to reject the hypothesis, questioning its validity (Cuevas, 2016).

Researchers like Rogowsky et al. (2015), and Aslaksen and Lorås (2018) found no statistically significant empirical support for matching learning methods to

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Contribution to the literature

- This study enhances biology teacher education through multimodal learning, leading to stronger literacy and numeracy skills for effective science instruction.
- This study highlights the link between literacy, numeracy, and science with multimodal learning, promoting a more integrated science education approach, and benefits students by equipping future biology teachers (via multimodal learning) to design lessons fostering stronger literacy and numeracy in their classes.
- This study demonstrates the effectiveness of multimodal learning in training STEM educators, potentially influencing its use in other disciplines.

individual learning styles. According to Morse (2014), and Willingham et al. (2015), the simplistic premise of identifying a dominant learning style and adjusting teaching accordingly lacks empirical support. Lawrence et al. (2020) argues that the neuromyth of learning styles oversimplifies the learning process, emphasizing that teaching is more complex than just matching students with learning styles. Clements (2022) suggests that students discovering their learning styles is unnecessary in 21st-century education.

Nguyen et al. (2022) propose involving children in multimodal learning experiences since learning styles lack strong evidence of effectiveness and are often difficult to test. Aslaksen et al. (2020) question the psychometric aspects of reliability and validity in modality-specific learning style inventories, suggesting further research on the overall applicability of multimodal learning strategies in various learning situations.

Researchers such as Rohrer and Pashler (2012) recommend focusing on developing effective ways to present specific material, combining various teaching forms, while Shaidullina et al. (2023) emphasize considering various learning patterns or techniques to accommodate students' unique knowledge acquisition.

Challenges in Indonesian Education

Research studies suggest that student achievement in Indonesia falls below expectations at both national and international levels. Results from the Programme for international student assessment 2018 (OECD, 2019), for example, show that Indonesia's PISA scores are approximately 100 points below the OECD average. The results of the national assessment, 2021 (Kemendikbud-ristek RI, 2022c) indicate that around 50% of elementary to middle school students do not meet minimum literacy standards, while approximately 75% do not achieve minimum numeracy competence.

Multimodal Learning as an Alternative Solution

To address these challenges, the study proposes multimodal learning strategies as an alternative solution for teachers and prospective teachers to effectively manage diverse classrooms without burdening themselves with additional tasks, such as determining learning styles or grouping students based on their initial readiness. The research suggests that multimodal learning strategies, which integrate various instructional techniques, can enhance the quality of the learning process and outcomes in hydrobiology courses.

The study also reviews various multimodal teaching strategies applied in science education, highlighting their positive effects on students' cognitive skills and learning outcomes. However, it points out a gap in the literature, as there is a lack of research on multimodal learning strategies integrating dual-code theory, questioning techniques, and weekly quizzes within a direct teaching model.

Experimental Design and Future Research Directions

The present study employs an experimental design to examine the influence of multimodal learning strategies on both total learning outcomes and literacy-numeracy outcomes based on different learning styles. A control group is taught using conventional methods, such as group discussions and question-and-answer sessions. The research aims to fill the gap in experimental studies testing the hypothesis and learning outcomes related to learning styles.

Simply put, the study emphasizes the need for alternative solutions, such as multimodal learning strategies, to improve the quality of teaching and learning in diverse classrooms, especially in the context of Indonesian education. It advocates for further research on multimodal learning strategies that integrate various instructional techniques to enhance student learning outcomes in different subject areas.

LITERATURE REVIEW

Multimodal Learning

Multimodal learning involves the application of diverse teaching models creatively within a lesson or teaching unit (Arends, 2007). According to Woolfolk (2008) and Joyce et al. (2009), presenting information using multiple models in a learning program is crucial and highly beneficial. Teachers who implement varied teaching through multisensory and varied models successfully maximize strengths and minimize students' learning weaknesses (Tomlinson, 1999). Shihusa and Keraro (2009) emphasize that effective learning approaches should employ multiple teaching methods to enhance motivation and actively engage students in biology learning.

Hydrobiology Course

The Hydrobiology course is a mandatory subject in the Biology Education Department at Halu Oleo University, Kendari, Sulawesi Tenggara, Indonesia. This course aims to equip students with a comprehensive understanding of various aspects. These include the history and development of limnology and the sea, characteristics of different aquatic habitats, measurement of water quality parameters, knowledge of aquatic biota and their interactions, understanding water properties in relation to biodiversity and human-environment interactions, and the ability to conduct bioassay experiments and analyze aquatic communities.

Learning Outcomes and Numeracy Literacy

Learning outcomes represent students' abilities after experiencing learning and are expressed through scores obtained from tests reflecting their level of success (Sudjana, 2017). Numeracy literacy refers to the knowledge and skills needed to acquire, interpret, use, and communicate various numbers and mathematical symbols to solve practical problems in various everyday contexts (Han et al., 2017). Success in any learning field depends on the ability to use numeracy literacy, providing the foundation for learning more complex skills (NSW Department of Education, 2016). Numeracy literacy also contributes to the development of critical and creative thinking skills (State of Victoria, 2018). Understanding the factors that influence literacy and numeracy skills is crucial, as they statistically impact workforce outcomes (Shomos, 2010).

Learning Styles

The concept of learning styles suggests that each student processes information differently. Proponents argue that optimal learning requires diagnosing individual learning styles and adjusting instruction accordingly (Pashler et al., 2008). The common premise is the matching hypothesis, stating that learning is more effective when students receive instruction in a way that aligns with their learning preferences (Rogowsky et al., 2015). Oliveira et al. (2023) stress the importance of adjusting teaching materials and strategies to meet students' learning style needs. Learning style preferences often classify students into categories such as visual, Auditory, kinesthetic, and mixed types based on VAK methods (Rose & Nicholl, 2009).

The research aims to answer the following questions:

RQ1: How does the improvement in total learning outcomes (N-gain) and numeracy literacy of each learning style type differ between students taught with multimodal learning strategies (treatment group) and those taught conventionally (control group) in hydrobiology lectures?

RQ2: What are the differences in N-gain for total learning outcomes and numeracy literacy between the treatment and control groups?

RQ3: To what extent do differences in N-gain for total learning outcomes and numeracy literacy exist among students of different learning style types between the treatment and control groups?

RQ4: How do differences in N-gain for total learning outcomes and numeracy literacy manifest within the treatment and control groups and among different learning style types?

RESEARCH METHOD

Population and Sample

The study population comprised all sixth-semester students enrolled in the biology education program during the odd semester of 2022/2023. The sample specifically targeted students participating in the hydrobiology course, encompassing two classes: class A (treatment group) with 63 students and class B (control group) with 62 students. The selection of students for each group utilized the random sampling technique. Furthermore, informed consent was obtained from all participants, who were informed of their right to withdraw from the study at any time without the need to justify their decision.

Research Design

The research design utilizes a quasi-experimental approach, specifically employing the matching-only pretest-posttest control group design (Fraenkel et al., 2018), structured as follows in **Figure 1**.

Instruments and Data Collection Techniques

Research instruments

The instruments employed in this study include written tests used in both the pretest and posttest to assess overall learning outcomes. These tests cover fundamental concepts from the course material and consist of completion sentences, selecting a single answer with a justification, and matching items. The literacy and numeracy tests are based on the framework developed by Han et al. (2017) and involve calculations related to the analysis of water community activities. This includes interpreting information presented in various formats such as graphs, tables, and charts, followed by drawing conclusions.

Treatment Class	M	O	X_1	O
Control Class	M	O	C	O

Description

Treatment Group (X1) : This group comprises students whose lectures are conducted through the multimodal learning strategy.

Control Group (C) : This group consists of students who are taught using conventional methods, involving discussions and question-answer sessions.

Figure 1. Research design structure (Source: Authors' own elaboration)

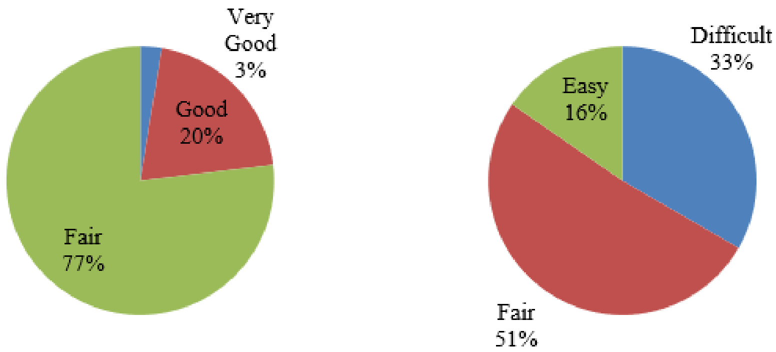

Figure 2. Discriminative power (A) and difficulty level (B) percentage (Source: Authors' own elaboration)

Table 1. Pretest score differences between treatment and control groups in hydrobiology course

	Levane's Test for equality of variances		t-test for equality of means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95 % confidence interval of the difference: Lower	95 % confidence interval of the difference: Upper
Equal variances assumed	12.741	.007	-.233	124	.816	-.45025	1.93147	-4.27317	3.37268
Equal variances not assumed			-.233	103.624	.816	-.45025	1.93147	-4.28059	3.38010

The test instrument is categorized into three levels of thinking skills: lower order thinking skills (C1-C2), middle order thinking skills (C3-C4), and higher order thinking skills. Lower order thinking skills account for approximately 41% of the test, middle order thinking skills represent about 41%, and higher order thinking skills constitute approximately 18%. These categories were determined through a trial to ascertain item sensitivity, specifically the discriminative power and difficulty level, based on Arikunto's criteria (2018). The percentages are outlined in **Figure 2**.

An instrument employed to ascertain the VAK learning style of each participant in the Hydrobiology course was adapted from DePorter et al. (2010).

Data collection technique

The technique for collecting data involves the administration of a pretest, followed by the analysis and interpretation of results to identify any differences using the t-test statistic. The test results, as indicated in **Table 1**, revealed no significant variance in pretest scores between the treatment group and the control group (significance value 0.816 > α = 0.05). This suggests that the initial knowledge levels of students enrolled in the Hydrobiology course, within both the treatment and control groups, did not exhibit significant discrepancies.

Referring to the Semester Syllabus (RPS) of Hydrobiology from the Department of Biology Education, Faculty of Teacher Training and Education, Halu Oleo University, both groups received identical lecture materials. In the treatment group, the lecturer initially employed direct teaching, which involved:

(a) providing a PowerPoint model of the core material using the dual coding theory technique and demonstrating its presentation.

(b) guiding students through exercises to emulate the presentation model, with direct corrections provided for any deviations.

(c) facilitating advanced exercises for each group to create a PowerPoint presentation based on the provided model.

(d) requiring each group to submit a PowerPoint draft and accompanying paper three days prior to the presentation via a WhatsApp group, allowing for feedback from the lecturer and peer review.

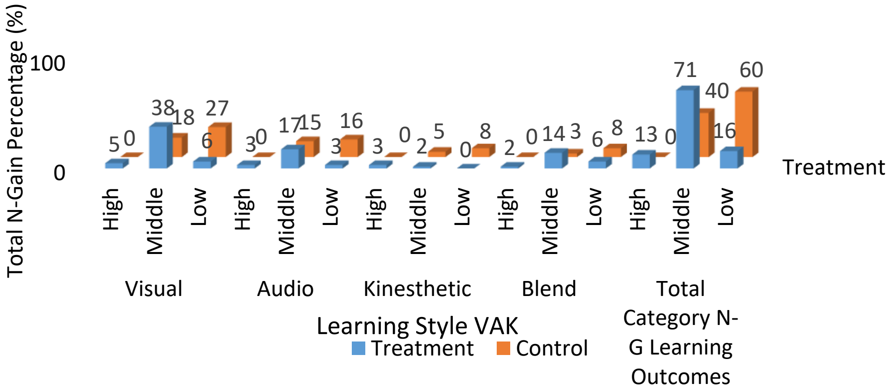

Figure 3. Percentage of total N-gain for each learning style in the treatment and control groups (Source: Authors' own elaboration)

(e) conducting presentations by each group, followed by Q&A sessions involving students from other groups and the lecturer, and

(f) administering weekly quizzes consisting of basic written questions at the end of each core material presentation or before the introduction of new material.

Conversely, in the control group, each presenting group was tasked with creating a PowerPoint presentation and paper on specified core material for presentation and discussion, like previous lectures but without modeling, specific questions, or weekly quizzes.

Following the lectures, post-tests were administered to both the treatment and control groups. Additionally, the learning style of each student participating in the Hydrobiology course was determined using the VAK instrument adapted from DePorter et al. (2010).

Data Analysis Techniques

The data analysis for this research encompasses two main components:

1. Descriptive analysis:
   a. Identification of students' VAK learning styles, adapted from DePorter et al. (2010).
   b. Calculation of total N-gain and numeracy-literacy N-gain for each student, following the methodology outlined by Hake (1998).
   c. Presentation of N-gain percentage categories for each learning style in graphical format, followed by a descriptive analysis aligned with the research objectives.
2. Inferential analysis:
   a. Assessment of data normality and homogeneity using the online SPSS version 29 application.
   b. Evaluation of the significance of differences in total N-gain and numeracy-literacy N-gain through two-way analysis of variance:
      i. Between students in the treatment group and the control group.
      ii. Among different types of learning styles within both the treatment and control groups.
      iii. Between learning style types and other forms of learning within each group.

Steps in hypothesis testing are undertaken as follows:

H_0: No significant difference was found in total learning outcomes and numeracy-literacy between the treatment and control groups, as well as within the internal groups of both the treatment and control groups (significance value $> \alpha = 0.05$).

H_1: A significant difference was observed in total learning outcomes and numeracy-literacy between the treatment and control groups, as well as within the internal groups of both the treatment and control groups (significance value $< \alpha = 0.05$).

FINDINGS

The analyzed results of the study encompass descriptive analyses of the categories of total N-gain and numeracy-literacy N-gain for each learning style within both the treatment and control groups, along with inferential statistics.

To begin with, descriptive analysis of the categories of total N-gain and numeracy-literacy N-gain for each learning style in both the treatment and control groups is conducted. The categories of total N-gain are depicted in **Figure 3**.

Referring to **Figure 3**, it is evident that in the treatment group, the total N-gain for the high and moderate categories reaches 13% and 70%, respectively, while the low category N-gain reaches 16%. Conversely, in the control group, the total N-gain for the low and moderate categories is 60% and 40%, respectively, with no high category N-gain observed. Moreover, when considering learning style types, the total N-gain is

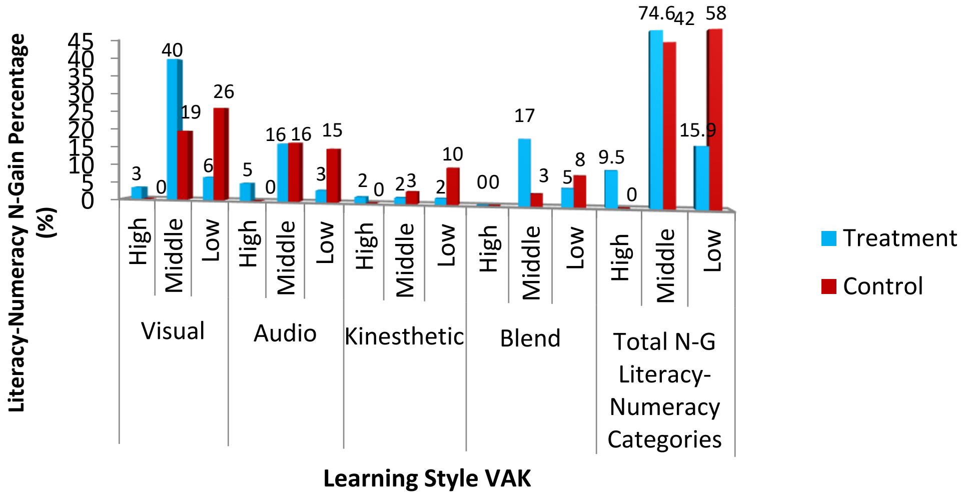

Figure 4. The percentage of literacy-numeracy N-gain for each learning style in both groups (Source: Authors' own elaboration)

Table 2. Analysis of N-gain difference: treatment vs. control

	Levane's Test for equality of variances		t-test for equality of means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95 % confidence interval of the difference	
								Lower	Upper
Equal variances assumed	.647	.004	7.154	124	.000	.20150	.02817	.14575	.25726
Equal variances not assumed			7.154	121.809	.000	.20150	.02817	.14574	.25727

generally higher in the treatment group, except for the mixed learning style.

Figure 4 illustrates the literacy-numeracy N-gain, providing a detailed depiction of the observed trends and changes.

Based on Figure 4, it appears that in the treatment group, high and medium literacy-numeracy N-gain categories reach 9.5% and 74.6% respectively, and the low N-gain category is 15.9%. Conversely, in the control group, literacy-numeracy N-gain is dominated by the low N-gain category at 58% followed by the medium N-gain category at 42%. In general, the literacy-numeracy N-gain categories have the same pattern as the total learning outcomes N-gain, i.e., higher in the treatment group except for the mixed learning style.

The results of the analysis of the differences in total N-gain and literacy-numeracy N-gain between students taught with multimodal learning strategies (treatment group) and those taught conventionally through group discussion and question-and-answer methods (control group) are presented in the following Table 2.

Based on the results of the difference analysis in Table 2, it appears that the total N-gain of biology teacher candidates who were taught with multimodal learning strategies is significantly higher than those taught conventionally (significance value 0.000 < α = 0.05). This suggests that the teaching method using multimodal learning strategies seems to have yielded notably higher N-gain compared to conventional teaching methods. The significance value of 0.000 indicates that the probability of this difference occurring by chance is extremely low, further reinforcing the conclusion that the multimodal approach is more effective in enhancing the candidates' learning outcomes in biology.

Results of the analysis of the difference in literacy-numeracy N-gain between the treatment group and the control group are presented in the following Table 3.

Based on the results of the difference analysis in Table 3, it appears that the literacy-numeracy N-gain of biology teacher candidates who were taught with multimodal learning strategies is significantly higher than those taught conventionally (significance value 0.000 < α = 0.05). This finding indicates a similar trend to the previous one but focuses specifically on the literacy-numeracy N-gain and underscores the effectiveness of multimodal learning strategies in not just overall N-gain, but also in enhancing literacy and numeracy skills and reinforces the notion that incorporating multimodal approaches can lead to more substantial improvements in various facets of learning outcomes.

The following Table 3 presents the results of the analysis comparing total N-gain and literacy-numeracy

Table 3. Literacy-numeracy N-gain: treatment vs. control

	Levane's Test for equality of variances		t-test for equality of means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95 % confidence interval of the difference	
								Lower	Upper
Equal variances assumed	7.386	.002	6.139	124	.000	.15918	.02593	.10786	.21050
Equal variances not assumed			6.139	111.319	.000	.15918	.02593	.10780	.21056

Table 4. Total N-gain by learning style, treatment vs. control

(I) Learning style class A	(J) Learning style class B	Mean difference (I-J)	Std. error	Sig.	95% confidence interval	
					Lower bound	Upper bound
Visual	Visual	.17600*	.02772	.000	.1214	.2306
	Auditory	.15637*	.02772	.000	.1018	.2110
	Kinestetic	.18390*	.02772	.000	.1293	.2385
	Mixed	.18296*	.02772	.000	.1284	.2376
Auditory	Visual	.22831*	.02772	.000	.1737	.2829
	Auditory	.20868*	.02772	.000	.1541	.2633
	Kinestetic	.23621*	.02772	.000	.1816	.2908
	Mixed	.23528*	.02772	.000	.1807	.2899
Kinesthetic	Visual	.46003*	.02772	.000	.4054	.5146
	Auditory	.44040*	.02772	.000	.3858	.4950
	Kinestetic	.46793*	.02772	.000	.4133	.5225
	Mixed	.46700*	.02772	.000	.4124	.5216
Mixed	Visual	.18980*	.02772	.000	.1352	.2444
	Auditory	.17018*	.02772	.000	.1156	.2248
	Kinestetic	.19770*	.02772	.000	.1431	.2523
	Mixed	.19677*	.02772	.000	.1422	.2514

*The mean difference is significant at the 0.05 level

Table 5. Literacy-numeracy N-gain by learning style, treatment vs. control

(I) Learning style class A	(J) Learning style class B	Mean difference (I-J)	Std. error	Sig.	95% confidence interval	
					Lower bound	Upper bound
Visual	Visual	.15772*	.02596	.000	.1066	.2089
	Auditory	.12366*	.02596	.000	.0725	.1748
	Kinestetic	.21901*	.02596	.000	.1679	.2701
	Mixed	.17042*	.02596	.000	.1193	.2216
Auditory	Visual	.19256*	.02596	.000	.1414	.2437
	Auditory	.15850*	.02596	.000	.1074	.2096
	Kinestetic	.25385*	.02596	.000	.2027	.3050
	Mixed	.20527*	.02596	.000	.1541	.2564
Kinesthetic	Visual	.24096*	.02596	.000	.1898	.2921
	Auditory	.20690*	.02596	.000	.1558	.2580
	Kinestetic	.30225*	.02596	.000	.2511	.3534
	Mixed	.25366*	.02596	.000	.2025	.3048
Mixed	Visual	.11362*	.02596	.000	.0625	.1648
	Auditory	.07956*	.02596	.000	.0284	.1307
	Kinestetic	.17491*	.02596	.000	.1238	.2260
	Mixed	.12632*	.02596	.000	.0752	.1775

*The mean difference is significant at the 0.05 level

N-gain for each learning style type between students in the treatment group and the control group.

Results in **Table 4** indicate that the total N-gain for each learning style type among students taught with multimodal learning strategies is significantly higher than those taught conventionally (significance value 0.000 < α = 0.05).

Table 5 presents the analysis of the difference test for literacy-numeracy N-gain across learning styles between the treatment and control groups.

Table 6. Total N-gain by learning style in treatment group

(I) Learning style	(J) Learning style	Mean difference (I-J)	Std. error	Sig.	95% confidence interval	
					Lower bound	Upper bound
Visual	Auditory	-.05231	.027772	.060	-.1069	.0023
	Kinestetic	-.28403*	.027772	.000	-.3386	-.2294
	Mixed	-.01380	.027772	.619	-.0684	.0408
Auditory	Kinestetic	-.23172*	.027772	.000	-.2863	-.1771
	Mixed	.03851	.027772	.166	-.0161	.0931
Kinestethic	Mixed	.27023*	.027772	.000	.2156	.3248

*The mean difference is significant at the 0.05 level

Table 7. N-gain by learning style in control group

(I) Learning style	(J) Learning style	Mean difference (I-J)	Std. error	Sig.	95% confidence interval	
					Lower bound	Upper bound
Visual	Auditory	-.01963	.027772	.480	-.0742	.0350
	Kinestetic	.00789	.027772	.776	-.0467	.0625
	Mixed	.00696	.027772	.802	-.04676	.0616
Auditory	Kinestetic	.02752	.027772	.322	-.0271	.0821
	Mixed	.02659	.027772	.338	-.0280	.0812
Kinestethic	Mixed	.00096	.027772	.973	-.0555	.0537

*The mean difference is significant at the 0.05 level

Table 8. Literacy-numeracy N-gain by learning style in treatment

(I) Learning style	(J) Learning style	Mean difference (I-J)	Std. error	Sig.	95% confidence interval	
					Lower bound	Upper bound
Visual	Auditory	-.03484	.02596	.181	-.0860	.0163
	Kinestetic	-.08324*	.02596	.002	-.1344	-.0321
	Mixed	.04410	.02596	.091	-.0070	.0952
Auditory	Kinestetic	-.04840	.02596	.063	-.0995	.0027
	Mixed	.07895*	.02596	.003	.0278	.1301
Kinestethic	Mixed	.12734*	.02596	.000	.0762	.1785

*The mean difference is significant at the 0.05 level

Results in **Table 5** indicate that the literacy-numeracy N-gain for each learning style among students taught with multimodal learning strategies is significantly higher than those taught conventionally (significance value 0.000 < α = 0.05). The following table presents the analysis of the difference between total N-gain and literacy-numeracy N-gain for each learning style within both the treatment and control groups.

The analysis in **Table 6** reveals significant differences in total N-gain among students taught with multimodal learning strategies:

- visual vs. kinesthetic (significance value < α = 0.05)
- auditory vs. kinesthetic (significance value < α = 0.05)
- kinesthetic vs. mixed (significance value < α = 0.05)

Other learning style comparisons did not show significant differences (significance value > α = 0.05).

Table 7 presents the results of the analysis of the differences in total N-gain among various learning styles within the control group. The table includes the mean difference, standard error, significance level, and 95% confidence interval for pairwise comparisons between different learning styles. The significance of the mean difference is evaluated at the 0.05 level. This analysis provides insights into the comparative effectiveness of different learning styles in terms of total N-gain within the control group context.

Based on the analysis results in **Table 7**, there are no significant differences in N-gain between the compared learning styles within the conventionally taught group (all significance values > α = 0.05).

Table 8 presents the analysis of the differences in N-gain in literacy-numeracy among the internal learning styles of the treatment group.

Based on the analysis in **Table 8**, students taught with the multimodal learning strategy show significant differences in literacy-numeracy N-gain between the following learning styles:

- visual vs. kinesthetic (significance value < α = 0.05)
- auditory vs. mixed (significance value < α = 0.05)
- kinesthetic vs. mixed (significance value < α = 0.05)

Table 9. Literacy-numeracy learning outcomes by learning style, control group

(I) Learning style	(J) Learning style	Mean difference (I-J)	Std. error	Sig.	95% confidence interval	
					Lower bound	Upper bound
Visual	Auditory	-.03406	.02596	.191	-.0852	.0171
	Kinestetic	.06129*	.02596	.019	.0102	.1124
	Mixed	.01270	.02596	.625	-.0384	.0638
Auditory	Kinestetic	.09535*	.02596	.000	.0442	.1465
	Mixed	.04676	.02596	.073	-.0044	.0979
Kinestethic	Mixed	-.04859	.02596	.062	-.0997	.0026

*The mean difference is significant at the 0.05 level

Other learning style comparisons do not show significant differences (significance value > α = 0.05).

Table 9 presents the analysis of differences in literacy-numeracy learning outcomes between various learning styles within the control group. The table displays the mean difference, standard error, significance level, and 95% confidence interval for pairwise comparisons. Significant mean differences at the 0.05 level are indicated with an asterisk (*) for easy identification.

Based on the analysis results in **Table 9**, the conventionally taught group shows significant differences in literacy-numeracy N-gain between:

- visual and kinesthetic (significance value < α = 0.05)
- auditory and kinesthetic (significance value < α = 0.05)

Other learning style comparisons do not show significant differences (significance value > α = 0.05). The pattern of significant and non-significant differences is like that observed in the treatment group taught with the multimodal strategy.

DISCUSSION

The findings of this study indicate that implementing multimodal learning strategies-comprising dual-code theory presentations, group discussions, oral questions, and weekly quizzes within a direct teaching framework-leads to a substantial improvement in student learning outcomes (measured by N-gain). This improvement is significant when compared to the results achieved through conventional learning methods, which primarily involve traditional presentations and group discussions. Moreover, when analyzing literacy-numeracy N-gain separately, the results consistently support the effectiveness of multimodal learning strategies over conventional learning.

According to the N-gain categories (Hake, 1998), the treatment group demonstrated a distribution of high and medium N-gain totals at 13% and 71%, respectively, with the low category at 16%. In contrast, the control group showed a distribution of 60% in the medium category and 40% in the low category. A similar trend was observed in literacy-numeracy N-gain, where the treatment group had 9.5% in the high category, 74% in the medium category, and 15.9% in the low category. Conversely, the control group had 58% in the low category and 42% in the medium category.

Thus, it is evident that the treatment group exhibited higher N-gain percentages across all categories compared to the control group. Specifically, the treatment group had a significant proportion of students with high and medium N-gain scores, indicating substantial improvement in their learning outcomes. On the other hand, the control group had lower percentages of high and medium N-gain scores, with a notable portion of students in the low category. This suggests that the intervention or method applied in the treatment group had a more pronounced positive impact on students' learning outcomes, particularly in literacy and numeracy skills.

This study highlights several key benefits of implementing multimodal learning strategies. Firstly, the use of PowerPoint modeling (PPT), demonstrated by the instructor at the beginning of the lecture, empowers students to organize content for their tasks effectively. This approach aligns with Bandura's social learning theory, which emphasizes that students learn efficiently through modeling without extensive trial and error. Learning through modeling involves four crucial phases: attention, retention, reproduction, and motivation (Arends, 2007; Woolfolk, 2008). Nicol and Macfarlane-Dick (2006) noted that providing high-quality information as a model helps clarify expectations and standards for students, enabling them to directly compare their work to model standards. Additionally, Endres et al. (2021) found that guiding students through step-by-step procedures (scaffolding) significantly enhances the implementation of expected learning strategies compared to scenarios without scaffolding.

Secondly, providing feedback and corrections for PowerPoint assignments before presentations emerged as a critical factor in motivating student groups to improve their work. Wisniewski et al. (2020) emphasize that constructive feedback enhances learning strategies, prompting students to be more careful and attentive in their efforts. This feedback mechanism also helps students understand crucial aspects of their performance, guiding them toward further improvement (Hattie & Clarke, 2018). Moreover, Kubik et al. (2021) reported that using retrieval techniques and feedback are effective tools for enhancing learning. Previously, Vollmeyer and Rheinberg (2005) found that feedback improves learning strategies because students tend to work more diligently when they know their learning outcomes are being monitored by teachers.

Thirdly, the implementation of the dual-code theory technique during presentations requires students to master basic concepts before effectively delivering them using visual aids such as diagrams, tables, graphs, or images, supported by concise explanations. This approach is particularly beneficial for complex topics, such as community analysis of aquatic ecosystems, which are often challenging in hydrobiology courses. Dual-code theory posits that combining verbal and nonverbal channels enhances learning outcomes (Najjar, 1995).

Lastly, interactive elements play a crucial role in this learning strategy. Questions asked during presentations serve as indicators of students' understanding levels, and unanswered questions are transformed into group tasks for further assessment. Correct answers are shared among classmates through platforms like WhatsApp groups, encouraging collaboration and motivating each group to prepare thoroughly. In contrast, the control group relies on more traditional and less interactive presentations. Pesovski and Klashninovski (2022) reported that students in frequently tested groups have a 13.3% higher chance of achieving better final exam results than students who only take the final exam. Conversely, in the control group, PowerPoint presentations created by each presenting group generally consist of complete sentences read during the presentation, which lessens the motivation for each group member to master the background material before presenting.

The analysis of N-gain, encompassing both overall and literacy-numeracy aspects based on learning styles, indicates that each learning style benefits more from multimodal learning than from traditional presentations and group discussions alone. Examining the differences in N-gain and literacy-numeracy N-gain in the treatment and control groups reveals a consistent pattern, with no significant differences among most learning styles. Exceptions arise in the treatment group for visual vs. kinesthetic learning style, auditory vs. kinesthetic, and kinesthetic vs. mixed, as well as in the control group for visual vs. mixed and kinesthetic vs. mixed. These exceptions indicate significant variation in total N-gain and literacy-numeracy N-gain, highlighting the effectiveness of multimodal learning approaches compared to individual learning styles.

This study reinforces previous research findings by Cuevas (2016), Liew et al. (2015), Papanagnou et al. (2016), Pashler et al. (2008), Riener and Willingham (2010), and which concluded that there is no significant relationship between learning styles and student learning outcomes. Scott (2010) further argues that advocating for learning styles wastes valuable time and perpetuates detrimental stereotypes, hindering the development of evidence-based best practices. Riener and Willingham (2010) emphasize that educators should adjust their teaching approaches based on students' knowledge, abilities, and interests rather than relying on learning styles. Despite students' potential preferences for specific learning styles, there is no strong evidence that accommodating these preferences improves learning outcomes. Rohrer and Pashler (2012) also report a lack of reliable data supporting the efficacy of teaching based on adult learning styles, and Rogowsky et al. (2015, 2020) found no statistically significant empirical support for adjusting teaching methods to the learning styles of adults and school-age children. Allcock and Hulme (2010) assert that, aside from the lack of credible empirical evidence, the persistent focus on learning styles is counterproductive.

A comprehensive study by Cuevas (2016) and Cuevas and Dawson (2018) examining the interaction between cognitive models, learning styles, and dual coding revealed no significant interaction effects between style and learning conditions. This finding challenges the basic premise of learning style theory. Specifically, none of the four learning styles (visual, auditory, reading/writing, or kinesthetic) showed predictive strength related to material retention. Instead, a highly significant main effect of the visual condition emerged, with students in the visual condition retaining information twice as effectively as those in the auditory condition, regardless of their learning style, strongly supporting dual coding theory. These results cast doubt on learning based on learning styles and suggest that dual coding principles offer greater benefits for student learning. Samburskiy (2020) reported that dual coding techniques are effective at all levels of student competency, particularly in metaphor and metamorphosis competence in interpreting idioms in ESL/EFL learning. However, students with lower metaphor competence benefited more from dual coding techniques.

Although the N-gain in total learning outcomes and literacy-numeracy in the treatment group increased significantly compared to the control group, the percentage of high N-gain achieved was still low, ranging from 9.5% to 13%. This indicates a need for more training and habituation for students to effectively apply dual coding techniques beyond hydrobiology lectures.

Like general biology books, current school textbooks in the independent learning curriculum context include various images, diagrams, icons, symbols, graphic organizers, infographics, timelines, and concept maps. These features support the implementation of multimodal learning with dual coding techniques. Therefore, intensive and measured training for teachers is needed to familiarize them with applying dual coding techniques in various learning strategies/models tailored to the material's characteristics, enhancing student literacy-numeracy learning outcomes. As a follow-up to the National Assessment results by the Kemendikbud-ristek RI. (2022c), it is recommended that teachers focus on training students in numeracy literacy skills. The biology learning implementation plan study in Kendari city high schools shows that about 97% of learning is still monomodal, mostly employing discovery learning, with only around 3% using problem-based Learning (Arifin et al., 2024).

Interestingly, teachers often use learning styles as a primary parameter to accommodate student diversity in learning. However, Kemendikbud-ristek RI (2022a) no longer includes learning styles as a parameter to accommodate student diversity. Nevertheless, teachers continue to use them based on differentiation learning guidelines available on various websites by the Ministry of Research and Technology and private institutions, such as Adisaputra (2012a, 2012b) and Kumar et al., (2005).

CONCLUSIONS

The implementation of multimodal learning strategies, incorporating dual coding presentation techniques with group discussions, oral questions, and weekly written quizzes within a direct teaching framework, has proven significantly effective in enhancing overall learning outcomes and literacy-numeracy compared to conventional learning methods. This improvement is particularly evident among students in hydrobiology courses, where multimodal learning surpasses the outcomes of conventional presentations and group discussions. Across Visual, Auditory, and Kinesthetic (VAK) learning styles, students engaged in multimodal learning demonstrated substantial increases in both overall learning outcomes and literacy-numeracy compared to those in conventional learning settings. However, the comparison of learning outcomes between multimodal and conventional groups for each learning style consistently showed a uniform pattern. This suggests that the improvement in learning outcomes is more attributed to the overall implementation of multimodal learning strategies than to individual learning styles. These findings align with the recommendations of Rohrer and Pashler (2012), advocating for higher education educators to focus more on developing effective and cohesive ways to present material, utilizing various teaching forms that mutually reinforce each other, rather than relying on the concept of learning styles. Furthermore, the suggestions from Cuevas and Dawson (2018) assert that style-based teaching is less effective and should be replaced by the application of dual coding principles in student learning.

LIMITATIONS AND FUTURE RESEARCH

This study's limitations include the relatively small sample size of kinesthetic learners, particularly in the treatment group, which may affect the generalizability of the findings. Moving forward, future research should aim to include larger and more diverse sample sizes across all learning styles to validate the findings and ensure they are representative of the broader student population. Additionally, incorporating dual coding techniques into a wider variety of multimodal learning strategies tailored to the characteristics of each specific topic would provide deeper insights into the most effective teaching methods. Longitudinal studies assessing the long-term impact of multimodal learning strategies on student outcomes, comparative studies comparing their effectiveness with other innovative teaching approaches, and exploration of their implementation in diverse educational contexts would further advance our understanding of optimal teaching practices. Furthermore, investigating the role of technology in enhancing multimodal learning strategies could provide new opportunities to engage students and improve learning outcomes.

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