Evaluating the Effectiveness of the Learn-before-Lecture Approach on Biodiversity Education for Pre-University Students

Azlinah Matawali, Johannah Jamalul Kiram, Megawati Mohd Yunus, Huzaikha Awang, Sitty Nur Syafa Bakri, Fadzilah Awang-Kanak, Nur Ramziahrazanah Jumat, and Siti Nazirah Butai*

Preparatory Centre for Science and Technology, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia
Email: azlinah@ums.edu.my (A.M.); johannah612@ums.edu.my (J.J.K.); megawati@ums.edu.my (M.M.Y.); huzaikha.ikha@ums.edu.my (H.A.); syafa@ums.edu.my (S.N.S.B.); akfadzil@ums.edu.my (F.A.-K.); nramziah@ums.edu.my (N.R.J.); siti.nazirah@ums.edu.my (S.N.B.)
*Corresponding author
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Abstract—**Biodiversity conservation is dependent on human knowledge and understanding of nature and society. Conventional teaching created a formalism in students' interpretations of biodiversity. This study evaluated the effectiveness of a Learn-before-Lecture (LBL) approach through pre-lecture activities on biodiversity topics among pre-university students. A total of 80 pre-university students were randomly assigned to the Treatment Group (TG) and the Control Group (CG). Pre-lecture interventions included organizing materials and activities for TG a week before the scheduled lecture class, while CG followed the conventional teaching method. Both groups completed pre- and post-test quizzes for evaluations. The result reported that while both groups showed improvements from pre-test to post-test, the post-test mean score of the CG (13.16) was significantly higher than the TG (10.77). Statistical analysis confirmed a significant difference in post-test performance between the two groups, favouring the CG. This suggests that the CG outperformed the TG after the LBL intervention. The questions distributed to students were observed with excellent difficulty (53.125±5.473) and a fair discriminative index (0.296±0.049). These results show that the LBL method, as implemented in this study, did not enhance student performance compared to conventional teaching. Hence, the findings suggest that although the LBL approach is pedagogically promising, it may require improved design with better integration, support mechanisms, or motivational components to be effective in pre-university biodiversity education.**

Keywords—**learn-before-lecture, biology, biodiversity, pre-university, Universiti Malaysia Sabah**

I. INTRODUCTION

Biodiversity is traditionally characterized as the variety of all living organisms, measured on various scales (from genes to species to ecosystems) and dimensions (morphological, phylogenetic, and functional). However, the lack of clarity on the definition of biodiversity as understood in science leads to a communication gap between science and the public, including decision-makers charged with designing and implementing biodiversity policies. Hence, Meinard and Quétier proposed biodiversity as a learning experience that can serve as a proxy for the scientific concept of biodiversity while remaining understandable to non-scientists [1]. This surrogate of biodiversity for communication is particularly important in education, as it emphasizes experiential understanding and personal engagement with biodiversity. By framing biodiversity as a learning process rather than a static concept, students are more likely to connect with the subject matter, fostering deeper awareness, critical thinking, and a stronger sense of stewardship for the natural world. This pedagogical framing is particularly relevant to education, as it promotes conceptual engagement, supports the development of ecological literacy, and fosters meaningful connections between learners and biodiversity [1].

Biodiversity education is key to promoting biodiversity conservation. The lack of awareness of the importance of biodiversity, especially among students, is a major concern because biodiversity conservation efforts need widespread public support [2]. The preservation of biodiversity relies on humans who are equipped with knowledge about species, as well as ecosystems, and understand the connection between nature and species with society [3]. However, there is still limited research investigating the teaching methods concerning the variables that promote biodiversity learning and understanding particularly at the pre-university level in Malaysia. While tertiary-level studies have begun integrating local knowledge into biodiversity teaching with positive learning outcomes, similar efforts at the pre-university level remain rare [4]. Musa and co-workers integrated local knowledge from farmers and indigenous people in their teaching and learning method to enhance students' understanding of biodiversity-related subjects. In this study, there were significant differences between pre-and post-test of 20 Diploma of Science students in identifying plant species [4]. Internationally, Yli-Panula and co-workers review of 317 studies found that only 12 explicitly addressed biodiversity teaching methods, with an even smaller subset focusing on targeted pre-university instruction or advanced cognitive aims [5]. Hence, this underscores a critical gap in the literature regarding the application of innovative pedagogical strategies for biodiversity education at the pre-university level, highlighting the need for further localized research to evaluate their effectiveness and contextual relevance.

Traditional teaching, which is normally practiced in a large group of lectures, begins with the introduction of new material during each class, and students review the information later. A summative exam will then be used to assess students' understanding. In contrast, more student-centered learning activities might enhance student participation in class, promote critical thinking, and improve student attitudes. For instance, Learn-before-Lecture (LBL) strategies implemented with interactive exercises among

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students in introductory biology were found to enhance learning gains in large introductory biology classes [6]. Pre-lecture activities can help to provide a platform to encourage further learning, which can counteract issues with prior knowledge. Lecturers can also get a more realistic estimation of the student's prior knowledge for future lectures, especially on content that might be difficult or ambiguous for students based on the performance observed on the resources provided [7]. Hence, the implementation of LBL in biodiversity education is highly warranted. Implementing LBL is expected to foster deeper cognitive engagement, strengthen conceptual understanding, and enhance academic outcomes. The strategy enables students to arrive at lectures better prepared, thus increasing participation and reinforcing long-term knowledge retention, both of which are critical outcomes for foundational topics such as biodiversity. This study aimed to evaluate the effectiveness of the Learn-before-Lecture (LBL) approach in improving students' understanding and learning of biodiversity concepts.

A. LBL in Science, Technology, Engineering and Mathematics (STEM) Education

The integration of Learn-before-Lecture (LBL) strategies, often associated with the flipped classroom model, has gained traction in STEM education due to its potential to enhance academic performance. In this approach, students engage with instructional materials before class sessions, allowing in-class time to focus on active learning activities that reinforce and apply the previously learned content. Implementing LBL strategies in STEM education has become increasingly prevalent due to their positive impacts on academic performance. A meta-analysis of 225 studies comparing traditional lecturing to active learning in undergraduate STEM courses found that active learning increased examination scores by approximately 6% and reduced failure rates from 32% to 21% [8]. Additionally, active learning has been shown to narrow achievement gaps for underrepresented students, promoting equity and inclusivity in STEM education [9].

The adoption of LBL and active learning strategies varies across educational institutions. While some universities and colleges have embraced these methods, others continue to rely on traditional, lecture-based instruction. Factors influencing the extent of implementation include institutional support, faculty training, and the availability of resources. In fact, several challenges might hinder the implementation of LBL strategies, such as the instructor's lack of preparation time. Nguyen and co-workers reported that there are at least eight strategies based on three major categories (explanation, facilitation, and planning) to support instructors in the implementation of active learning in undergraduate students [10]. Instead of instructors, students resist learning due to unfamiliarity or discomfort with non-traditional teaching methods. In an interview of 17 engineering professors in the United States of America (USA), effective use of strategies to mitigate student resistance towards active learning are such as clearly explaining the purpose and benefits of active learning activities and facilitating the class by approaching non-participating students, inviting questions, and using humor as engagement techniques [11]. In addition, implementing LBL may require technological resources and classroom spaces conducive to interactive activities, which may not be available in all educational settings. Therefore, while LBL strategies have demonstrated positive impacts on academic performance in Science, Technology, Engineering and Mathematics (STEM) education, further research is needed to understand the extent of their implementation and to address the challenges associated with their adoption.

B. LBL in Biology Education

The Learn-before-Lecture (LBL) approach, often implemented through flipped classrooms, has garnered attention in biology education for its potential to enhance student engagement and academic performance. In biological education, mastering complex concepts and engaging in systems-level reasoning are essential, providing students with foundational content prior to class enhances their ability to engage in higher-order tasks during lessons, including data analysis, problem-solving, and collaborative exploration. By introducing students to foundational material prior to formal instruction, LBL aims to foster deeper understanding and prepare students for active participation during class. Studies have indicated that in biology and related STEM fields, flipped classroom strategies can lead to improved learning outcomes and critical thinking skills. For instance, research has demonstrated that students in flipped courses exhibited significant gains in critical thinking, particularly in intermediate and upper-level courses, thereby suggesting the potential of flipped approaches for enhancing cognitive development in biology learning [11]. Similarly, the study conducted at a college in Alabama reported improvements in both student engagement and academic performance following the adoption of an active learning model [12], reinforcing the argument for exploring such models in other contexts, including pre-university biology education. Importantly, LBL has also shown promise in biodiversity education specifically. A recent classroom-based study involving secondary school students used a flipped model integrated with interactive multimedia focused on biodiversity topics finding that this method promoted better conceptual understanding and active engagement with ecological content [13, 14].

Given the inherently applied nature of biology and the growing emphasis on inquiry-based learning, the LBL model presents a strong framework for fostering scientific reasoning, ecological literacy, and learner autonomy. Nevertheless, empirical research examining its effectiveness in pre-university biodiversity education remains scarce. This study aims to address that gap by evaluating the applicability and outcomes of LBL within this specific educational context.

C. Theoretical Framework for LBL

The Learn-before-Lecture (LBL) approach is grounded in educational theories that advocate for active learning and the systematic development of cognitive skills. In the theory of education, constructivism posits that learners actively construct their understanding and knowledge through experiences and reflection [15]. This perspective emphasizes the importance of engaging students in activities that require them to connect new information with their existing knowledge base, thereby fostering deeper comprehension and retention.

In the context of LBL, constructivist principles are operationalized by encouraging students to engage with learning materials before formal instruction. This pre-lecture engagement allows students to build preliminary understandings, which can then be expanded and refined during interactive classroom activities. Such a strategy aligns with the constructivist emphasis on active participation and the co-construction of knowledge, as students are better prepared to contribute meaningfully to class discussions and collaborative exercises. A recent study on 189 sample populations used to develop a constructivist e-learning module based on the 5E Instructional Model (engage, explore, explain, elaborate, and evaluate) and evaluated its effectiveness among senior high school STEM students. The findings indicated significant improvements in students' content mastery and cognitive skills, highlighting the potential of constructivist approaches in enhancing biology education [16]. Investigating factors such as student and instructor preparedness, the nature of pre-lecture materials, and the integration of in-class activities is essential to fully realize the potential of LBL in enhancing learning outcomes in biology. Despite the theoretical alignment, there is a notable gap in the literature regarding the empirical validation of LBL's effectiveness, particularly within STEM disciplines like biology. While constructivist approaches provide a solid theoretical foundation, further research is needed to explore how LBL strategies can be effectively implemented and tailored to the specific demands of biology education.

II. Materials and Methods

A. Learn-before-Lecture Intervention

The LBL activity was designed to equip students with prior knowledge that could stimulate their curiosity and encourage independent learning before attending formal lecture sessions. By engaging with core content in advance, students were expected to arrive better prepared for in-class activities, thereby promoting deeper understanding, stimulating curiosity, and fostering self-directed learning. These skills are essential for long-term academic success in biology education.

This study enrolled 80 pre-university students from the Preparatory Centre of Science and Technology, Universiti Malaysia Sabah, Malaysia, and assigned them into two groups: the Treatment Group (TG) and the Control Group (CG). The students in both groups were told that they were involved in activities to enhance the teaching and learning process, but details about the study and their particular roles were not discussed. The intervention design was based on the framework proposed by Moravec and colleagues, with adaptations to suit the local learning environment (Fig. 1) [6]. Pre-lecture interventions for the TG included the distribution of curated study materials one week in advance of the scheduled lecture. The lecturer provided recorded lectures and maintained regular communication through structured activities on the university's official Learning Management System, SmartUMS. The use of SmartUMS was essential to the implementation of LBL for several reasons: it centralized all instructional resources for consistent access; it allowed students to easily retrieve materials at their convenience; it enabled instructors to monitor student engagement through activity tracking; and it supported the integration of multimedia elements such as videos, quizzes, and interactive modules to enhance the learning experience [17–20].

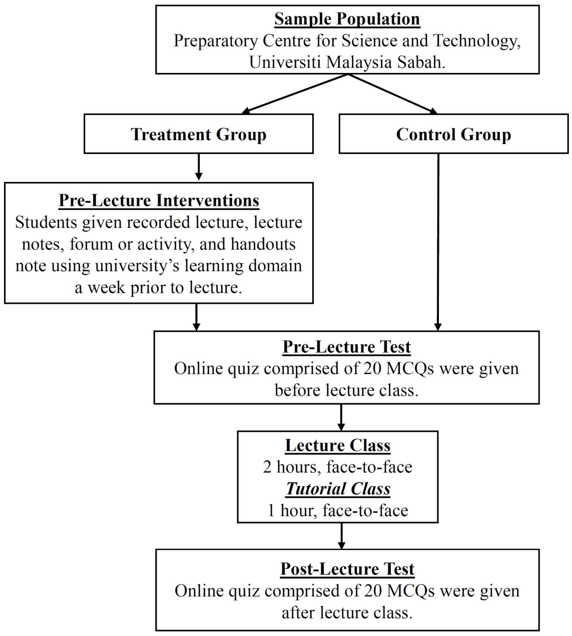

Fig. 1. Schematic representation of interventions applied to pre-university students.

B. Data Collection

A pre-test and post-test quiz with a similar set of questions was given to both TG and CG. Approximately 20 questions were prepared in Multiple-Choice (MCQ) format, with a 20-minute time limit per session. The mean of the pre-and post-test scores for both groups were calculated and compared to determine any group differences. The effects of pre-lecture treatment can be evaluated based on the mean comparisons.

C. Item Analysis

Post-validation of the test by item analysis consists of 3 parameters: Difficulty Index (DI), Discrimination Index (DSI), and Distractor Efficiency (NFD) [21, 22]. The difficulty index was calculated using the formula as follows:

$$DI = \left(\frac{(H+L)}{2n}\right) \times 100 \quad (1)$$

where:

H = number of students in higher ability group correctly answering the item;

L = number of students in lower ability group correctly answering the item;

N = total number of students;

The discrimination index was calculated using the formula as follow:

$$DSI = \frac{H-L}{n} \quad (2)$$

The number of Non-Functional Distractors (NFD) per item and the number of items with non-function distractors were calculated to determine the distractor efficiency. Those options selected by <5% of students are referred to as the NFDs. A decrease in NFDs, coupled with high DI and DSI values, indicates effective item construction. The interpretations (Table 1) made following Burud and co-workers are as follows [23]:

Table 1. Item analysis interpretation

Parameter	Range	Interpretation
Difficulty Index (DI)	<30	Difficult
	31–40	Good
	41–60	Excellent
	61–80	Easy
	>81	Very easy
Discrimination Index (DSI)	<0.19	Poor
	0.19–0.29	Fair
	0.30–0.39	Good
	>0.40	Excellent
Non-Functional Distractor (NFD)	0	3 NFD
	33.3	2 NFD
	66.6	1 NFD
	100	0 NFD

Notes: Non-Functional Distractor (NFD) refers to a distractor that is selected by less than 5% of students. A lower number of NFD indicates more functional and plausible distractors, with 0 NFD representing items where all distractors are effective.

D. Data Analysis

Data analysis involved assessing the normality of pre-test and post-test scores using the Shapiro-Wilk test. Since the data were normally distributed, a paired t-test was employed to examine differences in mean scores between the TG and CG for both pre-test and post-test, with statistical significance set at $p < 0.05$. Data is keyed in MS Excel for item analysis, while all descriptive statistics and inferential analyses were computed using IBM SPSS Statistics version 26.

III. Result and Discussion

A. Pre and Post-Test Comparison between TG and CG

The performance analysis of both TG and CG is summarized in Table 2. The Shapiro-Wilk test revealed no significant deviation from normality for either group ($p > 0.05$), thereby fulfilling the assumption of normality. Hence, parametric tests were used in the analysis. For the TG, the mean post-test score ($M = 10.77$, SD = 2.871) was higher than the mean pre-test score ($M = 8.51$, SD = 2.853), and this difference was statistically significant based on the paired sample t-test, $t(34) = -3.787$, $p = 0.001$. However, the correlation between pre- and post-test scores within the TG was not statistically significant (r = 0.241, p = 0.163).

For the CG, the post-test mean ($M = 13.16$, SD = 3.457) was higher than the pre-test mean ($M = 9.00$, SD = 2.384), with the paired sample t-test confirming a highly significant difference, $t(44) = -8.094$, $p < 0.0001$. The correlation between pre- and post-test scores showed statistically significant week correlation ($r = 0.350$, $p = 0.018$).

Table 2. Mean pre- post-test scores for TG and CG

Group	Test	Mean ± SD	n
TG	Pre-test	8.51±2.853*	35
	Post-test	10.77±2.871*	35
CG	Pre-test	9.00±2.384*	45
	Post-test	13.16±3.457*	45

Notes: TG, Treatment group; CG, Control group; SD, Standard deviation; n, number of item; *pre-post and post-post were significant at $p < 0.05$

Further analysis comparing TG and CG post-test scores using an independent samples t-test indicated a statistically significant difference between the two groups, $t(98.88) = -3.069$, $p = 0.003$. However, the assumption of equal variances was not met, as revealed by Levene's test ($F = 4.502$, $p = 0.036$). Despite this, the adjusted t-test result remained significant. CG, which followed traditional lecture methods, achieved higher mean post-test scores (13.16±3.457) compared to the TG (10.77±2.871) using the LBL method. This finding suggests that the LBL strategy, in the context of biodiversity education for pre-university students, may not have adequately resulted in improved academic performance. While the TG showed a slight improvement from pre-test to post-test (mean difference = 2.26), the CG demonstrated a larger learning gain (mean difference = 4.16). These findings challenge the commonly reported benefits of LBL strategies in biology education [6] and point to potential limitations in implementation or student engagement within the LBL model used in this study

During informal feedback sessions, several students in the TG indicated they did not engage deeply with the pre-lecture materials due to competing academic tasks or a lack of perceived importance. Additionally, some expressed difficulty navigating the Learning Management System (LMS) interface. These observations support the notion that student engagement in LBL contexts requires structured accountability, technical literacy, and motivational incentives. Thus, despite its pedagogical potential, the implementation of the Learn-before-Lecture (LBL) approach in this study may have fallen short due to several contributing factors. We speculated that students may not have taken the LBL treatment seriously, as it was not formally integrated into the overall course assessment. Without assessment-driven motivation, engagement with pre-lecture materials may have been minimal. This was supported by a study from Kilickaya [24] that identified the significance of higher scores among 27 undergraduates in an English course was mainly due to their awareness that the pre-lecture activities affected their grades at the end of the semester. Thus, students considered the task seriously, which led to better preparation, engagement, and participation. Digital tools were discussed as being frequently used in biology education experiences [25, 26]. Heo and co-workers [27] identified that literacy of learning management system and motivation are positively associated with the self-directed learning readiness in the case of 206 online college students in South Korea. However, the literacy of participants towards the selected learning management system used to support LBL may also have lacked the effectiveness required for a subject like biology, where hands-on instruction and real-time guidance are often crucial for conceptual understanding. Instead, Nguyen and co-workers highlighted that instructors are one of the main factors that affect better adoption and students' response to active learning [10]. However, instructor preparedness was not evaluated in this study. Additionally, the declining attention span of learners in this era of constant digital distraction may further compromise the success of methods that rely heavily on independent study. Moreover, while many studies highlight the benefits of pre-lecture activities, some research indicates that these methods may not always lead to improved student performance. For example, a study by Brink (2013) [28] found that the effectiveness of pre-lecture quizzes varied depending on student aptitude as students with higher GPAs benefited more from pre-lecture quizzes, while those with lower GPAs did not show significant improvement. Thus, the limited effectiveness of the Learn-before-Lecture (LBL) method in this study highlights the need for aligning several factors such as assessment integration, instructor preparedness, and engaging digital tools. Thus, strengthening students' self-directed learning skills and ensuring the preparatory materials are pedagogically sound is also crucial before fully implementing LBL in pre-university biology education.

B. Evaluation of Assessment Items Based on Difficulty and Discriminative Index

An effective assessment strategy is essential in any academic course to ensure accurate measurement of learning outcomes [29]. In this study, Multiple Choice Questions (MCQs) were employed to evaluate students' understanding of biodiversity concepts. MCQs are structured assessments in which students select the most appropriate answer from provided options rather than generating their responses. Each item consists of a stem (the prompt), a lead-in question, and several alternatives including one correct answer and several distractors [29, 30]. The MCQ is commonly preferred due to its practicality in administering and ease of preparation, less discriminating than free response tools, and practicality in assessing a large bulk of knowledge in a shorter period [29, 30].

To ensure fairness and validity, the quiz items used in this study underwent a systematic quality analysis. Key metrics, including item difficulty, discrimination index, and response pattern distribution, were assessed to verify that only well-constructed items were included. The analysis focused on responses from both TG and CG who completed 20 MCQs within a 20-minute time frame. As shown in Tables 3 and 4, the mean difficulty index was 53.13±5.473, suggesting that the items were appropriately challenging, neither too difficult nor too easy. A discrimination index mean of 0.296±0.049 indicated a fair ability of the items to distinguish between high- and low-performing students, which aligns with acceptable standards for educational assessments [23]. Taken together, the assessment items used in this study demonstrated sound psychometric properties, supporting their validity and usefulness for evaluating student learning. These items may serve as a valuable foundation for future biodiversity-related assessments and the development of a standardized question bank.

Table 3. Mean values of indices in item analysis

Item Indicators	Mean score ± SD	Remarks
Difficulty index	53.125±5.473	Excellent
Discriminative index	0.296±0.049	Fair

Notes: n=35; SD, Standard Deviation

Table 4. Frequency and distributions of non-functional distractors in test items

Distractor Analysis	Numbers	Percentage (Frequency)
Total number of items	20	-
Total number of distractors	60	-
Functional distractor	46 (76.67%)	-
Non-functional distractor	14 (23.33%)	-
	0 NFD	55% (n=11)
	1 NFD	25% (n=5)
	2 NFD	15% (n=3)
	3 NFD	5% (n=1)

Notes: n= number of item, NFD, Non-Functional Distractor, refers to a distractor that is selected by less than 5% of students. A lower number of NFD indicates more functional and plausible distractors, with 0 NFD representing items where all distractors are effective.

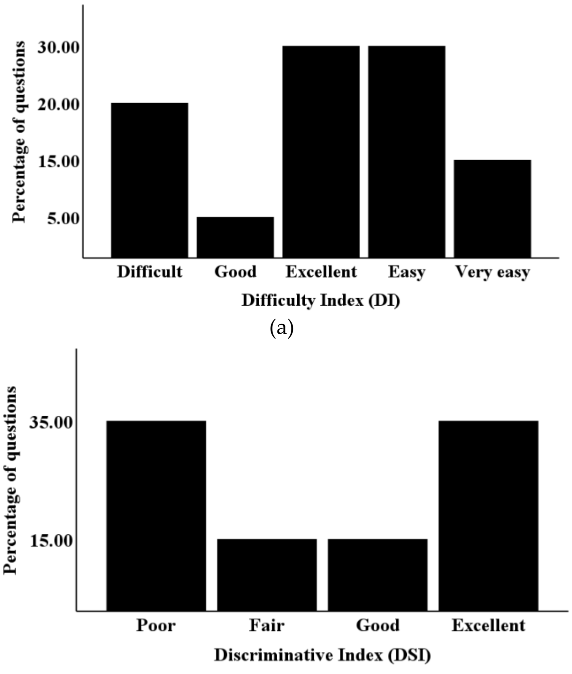

Fig. 2. Item analysis of Multiple-Choice Questions (MCQs). (a) Percentage distribution of MCQs according to their Difficulty Index (DI). The Y-axis represents the percentage of questions in each DI category. (b) Percentage distribution of MCQs byDiscrimination Index. The Y-axis represents their percentage of questions in each DSI category.

Based on Fig. 2, the most difficult questions are from the Kingdom Animalia subtopic, as the mean for DI of this question is 4.167. Meanwhile, two questions from the Kingdom Monera subtopic were the easiest, as the mean for DI for both questions is 87.5. It is speculated that, at the fundamental level, the Kingdom Animalia subtopic is discussed more extensively, and the learning outcomes include knowledge and understanding of complicated divisions and terminologies. Nevertheless, variables such as students interest in tested subtopics and hours spent by students during non-face-to-face learning time were not considered. In fact, biodiversity encompasses genetic, species, and ecosystem diversity, all of which contribute directly to human well-being and development [3, 5]. Biodiversity as a foundation-level subject at Universiti Malaysia Sabah was developed to assist students in comprehending and discussing the concept of biodiversity, species classification, and bio-conservation, particularly in Malaysia. This demonstrates how critical biodiversity education is in preserving the interdependence of human and natural resources [3]. The loss of biodiversity would jeopardize human access to food, energy, medicines, and a variety of other essential resources [3, 5]. As a result, education about biodiversity is critical for increasing awareness and conservation action. Biodiversity education has been incorporated into education beginning in early childhood and continuing through university [3]. Additionally, numerous research initiatives have been undertaken to enhance biodiversity education, as a variety of factors such as teacher knowledge and teaching methods may have an effect [3, 5, 31–33]. However, research at the university level remains relatively sparse, as previous studies predominantly addressed earlier educational stages [5]. This current study highlights an existing gap between biodiversity education and student-centered learning methods at the pre-university level in Malaysia. In the current study, the pre-test for the Treatment Group was conducted after the LBL materials were distributed, following the typical structure of LBL interventions, in which students are expected to review content in advance to activate prior knowledge. It is acknowledged that this may have resulted in a slight difference in baseline knowledge between the Treatment and Control Groups. To strengthen future study designs, it is recommended that a diagnostic test be administered before any intervention takes place, to more accurately assess the true impact of the LBL approach. Furthermore, the present study did not specifically measure supporting factors influencing the LBL implementation, potentially explaining its limited effectiveness. Additional research addressing instructor and student preparedness, motivation, and optimizing technical aspects of online learning platforms is recommended. Future studies should consider larger, varied student cohorts and technological stability enhancements to further validate and expand upon these findings.

IV. Conclusion

In conclusion, this study examined the implementation of the Learn-before-Lecture (LBL) approach in a biodiversity education context for pre-university students. Although both the treatment and control groups demonstrated improvement from pre-test to post-test, the control group achieved a significantly higher post-test mean score (13.16) compared to the treatment group (10.77), indicating that the LBL approach, as applied in this context, was less effective than the traditional learning method. The assessment items in this study were thoughtfully constructed to align with the intended learning outcomes and demonstrated acceptable levels of difficulty (mean DI = 53.13±5.47) as well as fair discriminative power (mean DSI = 0.296±0.049). These findings highlight the importance of critically evaluating the delivery and support mechanisms of active learning strategies such as LBL, particularly in ensuring that students are adequately guided and motivated during self-directed learning phases. To enhance its effectiveness, future research should focus on refining the LBL model by incorporating structured scaffolding, integrating interactive and adaptive digital platforms, and ensuring coherence between learning activities and assessment practices. It is also essential to examine how variables such as prior knowledge, learning styles, and student engagement levels influence the outcomes of LBL interventions. Additionally, longitudinal studies could explore the long-term retention and application of knowledge gained through LBL. Studies involving different cohorts or larger sample sizes, diverse academic disciplines, and varied educational contexts are recommended to validate these findings and inform the development of a more robust and context-sensitive LBL framework suitable for wider implementation in science education. Taken together, this study highlights the ongoing evolution of LBL implementation towards a more dynamic and personalized framework that responds to diverse learner needs and educational contexts.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: AM, SNB; Methodology: SNB, AM, MMY, HA, JJK; Validation and formal analysis: AM, JJK; Investigation: AM, SNB, FAK, NRJ; Resources: AM, JJK, SNB, MMY, HA; Writing original draft: AM, SNB, FAK, NRJ; Writing—review and editing: SNB, MMY, HA. All authors had approved the final version.

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