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MICRO-LEARNING-BASED FLIPPED CLASSROOM FOR ENHANCING BIOLOGY LEARNING OUTCOMES

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Abstract: This research aimed at enhancing student academic performance in biology by introducing and testing an innovative micro-learning-based flipped classroom model. The study employed a research and development (R&D) methodology, progressing through stages of designing, implementing, and refining the model based on feedback and results. The intervention involved biology students divided into two groups: the experimental group, taught using the newly developed model, and the control group, which followed traditional teacher-centered methods. The experimental group's model combined short, focused micro-learning modules with active, in-class learning designed to engage students more deeply with the content and allow for more personalized instruction. After analyzing the data, the results revealed that students in the experimental group demonstrated a marked improvement in academic performance compared to the control group. This finding suggests a positive effect that using the flipped classroom with a micro-learning-based model enhanced learning outcomes in biology. Specifically, students in the flipped classroom with a micro learning-based model experimental group demonstrated higher levels of content retention, a deeper understanding of biological concepts, and learning engagement.
Keywords: Micro-learning based; Flipped classroom model; Biology course; Learning outcome

1. INTRODUCTION

The landscape of teaching technology is continually evolving, sparking numerous discussions on teaching methodologies (AlAjmi, 2022). Despite this, many innovative teaching approaches have yet to see widespread implementation in everyday classrooms. Traditional teaching methods remain rigid, with slow information exchange, and students often engage in passive learning by merely mimicking their teachers' actions. The flipped classroom model has proven to be an effective solution to these challenges, promoting active learning, tailored instruction, and greater student participation (Busebaia & John, 2020). By moving content delivery outside the classroom and focusing on interactive activities during class, it overcomes many drawbacks of traditional lecture methods, creating a more dynamic and engaging learning environment.

Biology is a fascinating subject to teach, with continuous discoveries and innovations enhancing our quality of life (Yaki, 2022). However, as new species are identified and others near extinction, staying updated with the latest research, especially in fields such as cell and molecular biology, becomes more challenging. At an annual biology conference in the United States, organized by the National Association of Biology Teachers, several key issues faced by biology educators were brought to light. One major issue is balancing the demands of a packed curriculum and exam-focused learning with providing a meaningful education for students. Inagaki & Hatana (2002) observed that children enter school with an inherent curiosity about biology, having instinctively learned from their surroundings. This provides a valuable starting point for educators to deepen students' understanding of this vital subject, since we are also part of the living world, active student involvement typically leads to more effective learning (Ueckert & Gess-Newsome, 2006). High school biology teachers often use hands-on experiences, allowing students to engage with materials and conduct experiments (Tunnicliffe & Ueckert, 2007). However, teaching biology becomes particularly challenging when students lack access to labs for direct specimen observation, as was the case during pandemic lockdowns, which restricted movement (Nieto-Escamez & Roldán-Tapia, 2021).

Research Objectives:

Therefore, from the prior research and review, the present study aims to propose the following research objectives:

(1) To improve students' academic performance in biology;

(2) To enhance the student engagement by flipped classroom with micro-learning-based model.ion and practical application of skills. Examples of micro-learning formats include videos, quizzes, infographics, and short articles.

2. LITERATURE REVIEW

Micro-learning: Micro-learning is an instructional method that delivers content in brief, easily consumable segments, usually targeting specific learning goals (Lee, 2023). These segments, often called "learning bites," are usually short (around 2-10 minutes) and designed to be consumed in brief sessions. The objective is to improve accessibility, efficiency, and engagement in learning by simplifying complex topics into smaller, more digestible segments (Lee et al., 2021). Micro-learning is often used in corporate training, online courses, and mobile learning platforms. It supports just-in-time learning, allowing learners to access information when they need it, which can improve retention and practical application of skills. Examples of micro-learning formats include videos, quizzes, infographics, and short articles (Figure 1).

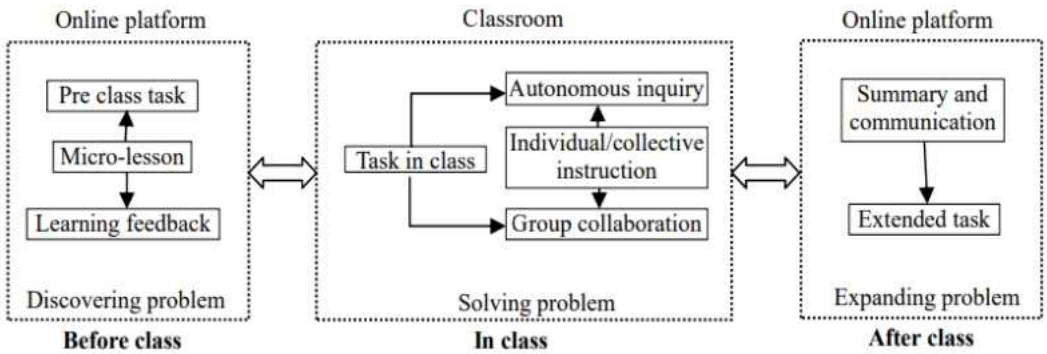

Figure 1. Implementation of Learning Model

Micro-lesson: A micro lesson for a biology course is a short, focused learning segment designed to teach a specific topic or concept in a brief period, typically 5-10 minutes. In biology, micro-lessons simplify intricate scientific concepts into smaller, more digestible units, facilitating better understanding and retention of information by students (Susanti, 2023). A micro lesson in a biology course could cover topics such as Cell Structure, A quick overview of cell organelles like the nucleus, mitochondria, and endoplasmic reticulum, explaining their functions in the cell, Photosynthesis Process, A brief explanation of how plants convert light energy into chemical energy, focusing on the key stages of the process, DNA Structure and Function, A concise lesson on the double helix structure of DNA, its components, and its role in genetic inheritance, The Circulatory System A short lesson explaining how the heart pumps blood through the body and the role of arteries, veins, and capillaries. Each micro lesson would typically include a clear learning objective, simple explanations, visual aids (like diagrams or videos), and possibly a short quiz or interactive activity to reinforce understanding. The idea is to make learning more engaging and accessible by focusing on one small topic at a time.

Flipped Classroom: A flipped classroom is an educational model that inverts the conventional teaching method. In this approach, students initially engage with new material at home—often via videos, readings, or online resources—and then dedicate classroom time to active learning activities like discussions, problem-solving, or group projects (Oudbier, 2022). This method shifts the focus from passive reception of information during class to active engagement with the material, allowing students to apply what they have learned and receive immediate feedback from the instructor. Key Components are Pre-class learning, Students engage with lecture content or resources outside of class (e.g., videos, readings); In-class activities, Class time is used for interactive activities like group work, discussions, and applying concepts through problem-solving. This approach promotes deeper understanding, critical thinking, and collaboration, as students are expected to come prepared to engage actively during class (Nugraheni, 2022).

Flipped Classroom with a Micro-Learning Model: This approach merges the concepts of the flipped classroom and microlearning, fostering a highly interactive, adaptable, and efficient educational setting (Fidan, 2023). Structure composes of 1. Pre-class Micro-learning, instead of long lectures or readings, students engage with bite-sized, focused learning materials (videos, articles, quizzes) outside of class. These micro lessons are typically 5-10 minutes long and cover key concepts or topics that students need to understand before coming to class, such as A biology class on genetics may assign students a series of micro lessons on DNA structure, gene expression, and mutations, each delivered in short, digestible formats. 2. In-class Application and Interaction, during class, students apply the knowledge gained from the micro-learning sessions through hands-on activities, group discussions, problem-solving exercises, or projects. The teacher's role shifts from delivering content to facilitating, guiding, and providing feedback, helping students deepen their understanding by working through more complex applications of the material, such as After watching micro-lessons on DNA, students might spend class time working in groups to solve genetic problems or conduct a lab experiment on gene mutations (Ridlo, 2022).

Student academic performance: Student academic performance pertains to how well an individual student meets their educational objectives, typically evaluated through a range of indicators including grades, test results, assignments, and other forms of academic assessment (Abidoye, 2021). It reflects the level of a student's understanding, skills, and knowledge in different subjects and is often used to gauge their progress, competence, and their overall success in academic pursuits. Several factors affect academic performance, such as the student's motivation, effort, learning environment, teaching quality, and individual circumstances (Alam, 2021). This performance can be assessed using quantitative measures like GPA and standardized tests.

Engagement: Student engagement refers to the degree of participation and interest that students show in classroom activities, learning projects, and other academic pursuits (Hiver, 2024). It includes their involvement in discussions, group tasks, extracurricular learning opportunities, and more. Various methods can be used to assess student engagement, such as evaluating classroom performance, how often they contribute to discussions, the quality of their involvement in group activities, and their punctuality in completing assignments (Bedenlier, 2020).

3. RESEARCH DESIGN

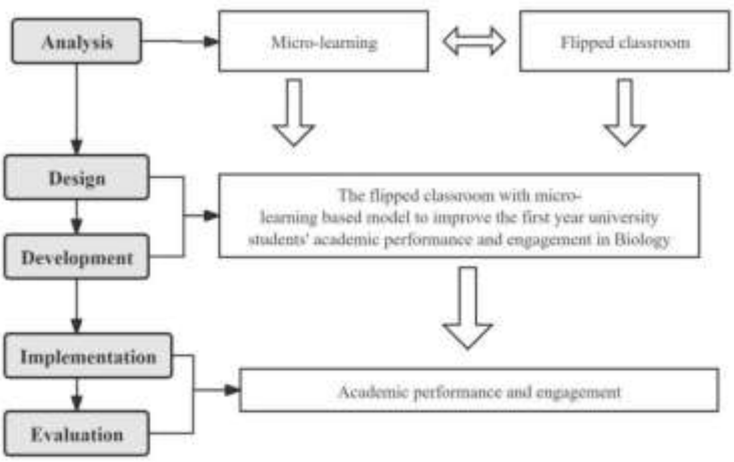

Figure 2 Research Framework Adapted from ADDIE

The ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) is a widely used instructional design framework that guides the creation of learning experiences (Figure 2). It can also be adapted as a research framework, particularly in educational and training research, to structure the process of investigation, data collection, and analysis.

(1) Analysis

Identify the research problem or question and understand the context in which the research will be conducted, define the research problem or hypothesis. Conduct a literature review to understand the current state of knowledge. Identify research gaps or areas that need investigation. Analyze and review the literature on the micro-learning-based flipped classroom. This approach integrates the flipped classroom model with micro-learning strategies, where students engage in self-directed learning prior to class through brief, focused modules. These modules, which can include videos, readings, quizzes, or interactive content, concentrate on specific topics or concepts. By arriving to class with a foundational knowledge, students can engage in deeper discussions, collaborative exercises, and hands-on activities, with the instructor facilitating a more interactive and immersive learning experience.

(2) Design

Plan how the research will be conducted, including methods, instruments, and procedures. Choose the appropriate research methodology (qualitative, quantitative, or mixed methods). Develop the research design (e.g., experimental, case study, survey). Define the data collection instruments (e.g., questionnaires, interviews, observations). Establish the sampling method and identify the target group or participants. Develop a research timeline and ensure ethical considerations are addressed. A detailed research design that outlines how data will be collected, analyzed, and interpreted, along with a clear plan for implementation.

The study's participants fall into two groups: teachers and students. Both categories are affiliated with the School of Biology and Chemistry at Minzu Normal University of Xingyi, located in Xingyi City, Guizhou Province, China, and are pursuing degrees in Biological Science.A total of 90 students were randomly chosen from a group of 180 first-year Biological Science students who had completed life science courses. and possessed foundational knowledge in the field. Additionally, 51 teachers were chosen through purposive sampling from the Biological Science department. Each teacher has over five years of experience teaching life science courses..

(3) Development

i. Development of the applications

The applications used in this research included the following mobile-based applications, which have different functions and benefits for successful micro-learning implementation:

- Chaoxing Learning Platform focusing on the student learning management, (https://apps.chaoxing.com/)
- EV screen recording focusing on the micro-videos design and recording (http://soft.cuanfeng.cn) and
- Jianying for video revision and clips (https://www.capcut.cn).

First, the application used for student learning management was the Chaoxing Learning Platform (https://apps.chaoxing.com/). Other learning management platforms, e.g., Rain Classroom (https://www.yuketang.cn/), Seewo Assistance https://www.seewo.com/) and Yunban (https://www.mosoteach.cn/) learning platforms and WebCT (1995) (World-Wide-Web Course Tools, created in 1995 in Canada), could be used:

Table 1. Learning Platform Capabilities

Learning management systems/Features	Chaoxing	Rain Classroom	Seewo	Yunban	WebCT	Zoom	Google Classroom
Classroom Administration	√	√		√	√		
Student Administration	√	√		√	√	√	√
Course Administration	√	√		√	√	√	√
Design of classroom activities	√	√	√	√			
Uploading resources	√	√	√	√	√	√	√
Cloud-based resource distribution	√						√

In summary, the present study has chosen the Chaoxing Learning Platform to facilitate the implementation of the Flipped Classroom with Micro-Learning Based Model, as evidenced by the comparative results presented in Table 1, which indicate that the Chaoxing Learning Platform possesses all the required learning management platforms/functions.

ii. Development of the micro-learning videos

The development of the model combined flipped classroom methods with micro-learning techniques to help students understand complex biology topics independently. This approach moved away from traditional lectures, encouraging students to engage with the material on their own before class. Consequently, classroom time was used for more interactive and practical activities. The researcher created a series of concise micro-videos that simplified key biological concepts, aiming to make in-class sessions more focused on hands-on learning and application. The lineup of micro-videos included the key topics, as shown in Table 2:

Table 2: Essential Topics for Micro-Learning Videos in Biology

No.	**Title**	**(Time/min)**
1	Cell Membrane Structure	(3.45)
2	Mitosis	(4.45)
3	Reproductive Organs of Plants	(5.0)
4	Plant Pigments	(4.24)
5	Adenosine Triphosphate	(3.28)
6	Gene	(3.39)
7	Mendel's Genetic Law	(5.28)
8	Catabolism	(5.0)

(4) Implementation and Evaluation

Execute the research plan and collect the data according to the designed framework. Implement the research by administering surveys, conducting interviews, or performing observations. Collect primary data from the participants or the environment under study, monitor the data collection process to ensure consistency and reliability, address any issues or adjustments needed during the implementation phase.

Analyze the collected data and evaluate the research findings in relation to the original objectives. Analyze the data using suitable statistical or qualitative analysis techniques. Interpret the results in the context of the research questions or hypotheses. Compare the results with the existing literature to identify new insights or confirmations of prior research. Evaluate the strengths and limitations of the research process.

(5) Finalization of the Model

The feedback from the quality assessment phase was used to make any final adjustments to the model. This stage ensured that the flipped classroom with micro-learning-based model was ready for implementation in a real-world educational setting and had a strong foundation for enhancing student engagement and learning outcomes (Figure 3).

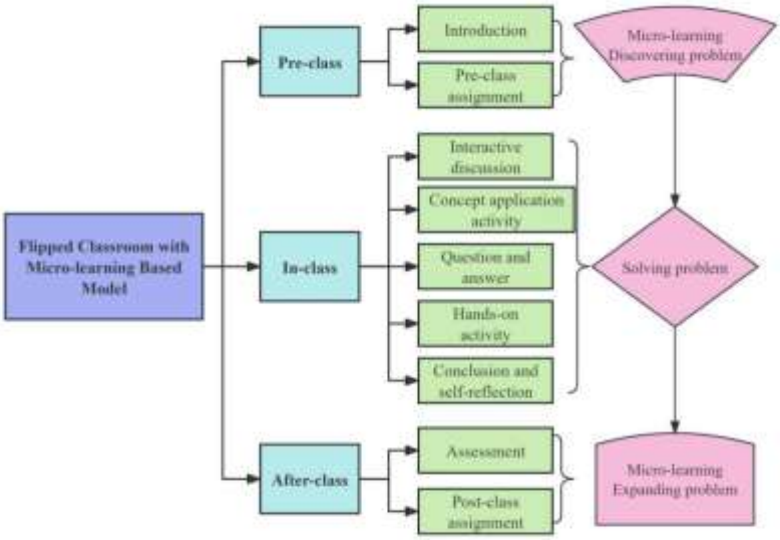

Figure 3 Flipped Classroom Utilizing a Micro-learning Based Model

4. RESEARCH RESULTS

The researcher employed cluster random sampling to select an experimental group and a control group from 180 first-year Biological Science students at Minzu Normal University of Xingyi in Guizhou Province, China. Class comprising 45 students, was designated as the experimental group, while Class 2, also with 45 students, served ,1 as the control group. Within the experimental group, male students were divided into two age categories: 11 were ,aged 18-20 (24.50%) and 12 were aged 21-25 (26.50%). Female students in this group were similarly divided with 11 in each age category (18-20 and 21-25), also representing 24.50% each. In the control group, there were male students aged 18-20 (28.50%) and 12 aged 21-25 (26.50%). Female students in this group included 10 13 in each age range (18-20 and 21-25), each accounting for 22.50%. Both the experimental and control groups each .consisted of 45 students, making up 50% of the total sample size for their respective groups

Table 3: The Normality of The Pre-test Score

	Group	Shapiro-Wilk		
		Statistic	**df**	**Sig.**
Pre-test	CG	0.973	45	0.378
	EG	0.961	45	0.132

Table3 shows that since both the control and experimental groups each had fewer than 50 participants, the Shapiro-Wilk test was used to assess data normality. The Sig values for the control and experimental groups were and 0.13 0.37, respectively. Both values exceed 0.05, suggesting that the score distributions for both groups are .normally distributed

Table 4: *Pre-test Scores: Control and Experiment Groups*

IV	n	X̄	S.D.	Levene's test		t	df	Sig.
				F	**Sig.**			
Group	CG 45	6.93	6.750	0.425	0.516	0.000	88	1.000
	EG 45	6.93	6.390					

.DV was Pre-test score*

Table4 reveals that the control and experimental groups both had mean scores of 66.93, with standard deviations of 6.750 and 6.390, respectively. Levene' s test yielded a Sig value of 0.516, indicating homogeneity of variance between the groups, as this value exceeds 0.05. Furthermore, the pre-test results for biology academic performance showed no significant difference between the two groups, with a Sig value of 1.000, also above the .threshold 0.05

Table 5: *N*ormality for the Post-test and Engagement

	Group	Shapiro-Wilk

		Statistic	df	Sig.
Engagement	CG	0.975	45	0.441
	EG	0.971	45	0.310
Post-test	CG	0.920	45	0.104
	EG	0.947	45	0.140

As shown in Table 5 ,since both the control and experimental groups had fewer than 50 students , Shapiro-Wilk' s test was applied. The post-test Sig. values were 0.104 for the control group and 0.140 for the experimental group, while the engagement Sig. values were 0.441 for the control group and 0.310 for the experimental group. All values exceeded 0.05, indicating that the distributions for both post-test scores and .engagement levels were normal.

Table 6: Testing the Dependent Variables

	Box's Test of Equality of Covariance Matricesa					Bartlett's Test of Sphericitya			
	Box's M	F	df1	df2	Sig.	Likelihood Ratio	Approx. Chi-Square	df	Sig.
Post-test and Engagement	0.479	0.156	3	1393920.000	0.926	<0.01	200.736	2	<0.001

To evaluate potential differences in academic performance and engagement in Biology between the experimental and control groups, a MANOVA was conducted on the post-test scores and engagement levels. Table 6 shows the Box M test yielded a Sig value of 0.926, indicating the covariance matrices were equivalent as it exceeds 0.05. Furthermore, Bartlett's test of sphericity returned a Sig value of <0.001, confirming a significant correlation between the two dependent variables.

Table 7: Multivariate Tests

Effect		Value	F	Sig.
Group	Pillai's Trace	0.341	22.463b	<0.001
	Wilks' Lambda	0.659	22.463b	<0.001
	Hotelling's Trace	0.516	22.463b	<0.001
	Roy's Largest Root	0.516	22.463b	<0.001

According to Table 7, the Box M test yielded a Sig value of 0.926, which is greater than 0.05, indicating that the covariance matrices were equal. In the Wilks' Lambda row, the Sig value was <0.001, which is less than 0.05, suggesting that there is a significant difference in at least one of the dependent variables between the experimental and control groups. Detailed MANOVA results are provided in Table 8.

Table 8: Comparison the Result of Post Test Score and Engagement

DV	IV	n	M	S.D.	Levene's test		ANOVA				Compare between groups
					W	Sig.	SS df	MS	F	Sig.	
Post-test	CG	45	75.51	4.69	0.212	0.646	313.61	313.6	13.98	<0.001	CG<EG
	EG	45	79.24	4.77			1971.55	22.4			
Engage ment	CG	45	13.82	0.81	0.004	0.952	12.47	12.47	19.73	<0.001	CG<EG
	EG	45	14.57	0.78			55.69	0.62			

According to Table 8, Levene's test yielded significance values of 0.646 for post-test scores and 0.952 for engagement, both above 0.05, confirming variance homogeneity. The ANOVA results returned Sig. values of <0.001 for both post-test scores and engagement, indicating significant differences between the groups. The control group had a lower post-test score (M = 75.51, S.D. = 4.69) compared to the experimental group (M = 79.24, S.D. = 4.77). Similarly, the control group's engagement score (M = 13.82, S.D. = 0.81) was lower than that of the experimental group (M = 14.57, S.D. = 0.78). These findings suggest that the flipped classroom with micro-learning notably improved student performance and engagement in Biology, while pre-test results revealed no significant differences.

5. DISCUSSION AND CONCLUSION

Expert validation plays a key role in refining the flipped classroom with a micro-learning model, ensuring it aligns with academic standards and supports independent learning. Nikou (2019) emphasizes how expert feedback enhances motivation and engagement in educational frameworks. At Minzu Normal University of Xingyi, the flipped classroom combined with micro-learning significantly improved student performance and participation compared to traditional teaching methods. The experimental group demonstrated higher post-test scores and engagement, consistent with findings by Jamaludin & Osman (2014), who also observed the model's effectiveness in promoting active learning and interest, especially in complex subjects like biology. Similarly, Ayçiçek and Yelken (2018) found positive effects of the flipped classroom model on biology student engagement, echoing their results in English education. This illustrates the model's versatility across disciplines, encouraging more student interaction and learning ownership, thus enhancing engagement beyond conventional classrooms.
The flipped classroom with micro-learning model offers a significant improvement over traditional teaching methods by creating a student-centered environment where learners review material independently before class and engage in interactive, problem-solving activities during class. This approach enhances both teaching and learning by promoting deeper understanding and active participation. In comparison to traditional methods, the model has shown clear advantages in boosting student performance and engagement, demonstrating its potential to transform education through technology and innovative pedagogical strategies, making a strong case for more interactive and student-centered learning environments.

6. RECOMMENDATIONS

When comparing the flipped classroom with micro-learning to traditional teaching methods, several factors must be evaluated to optimize their impact. These include assessing student performance through formative and summative metrics, long-term knowledge retention, and student engagement through surveys, participation, and feedback. Instructional efficiency can be measured by analyzing classroom time utilization and teacher preparation. Consideration should also be given to how each model accommodates different learning styles, preferences, and accessibility needs. Professional development for educators, including training in micro-learning content creation and technology use, is crucial. Encouraging peer collaboration, conducting comparative studies, and measuring academic achievement and skill development across both models can provide further insights. Continuous improvement and possibly hybrid approaches that integrate the strengths of both methods should be explored to maximize learning outcomes.

Declaration of Conflicting Interests
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The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.
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