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The Effect of Flipped Classroom Model on Student Achievement in Biology Lessons

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Abstract

The aim of this study is to examine the effect of the technology-enhanced flipped classroom (TEFC) model, applied to the experimental group, on the academic achievement of 7th-grade students in the "Zoology" unit of the biology course, compared to the traditional teaching method used in the control group. The research was designed using a quasi-experimental pretest-posttest control group model, which is a type of experimental design. The study group consists of 51 students attending the 7th grade at a state school in Azerbaijan during the 2023-2024 academic year. In the study, the TEFC model was implemented in the experimental group, while the traditional teaching model was used in the control group. The experimental procedure lasted for a total of 8 weeks. As a data collection tool, the Zoology Achievement Test (ZAT) was administered to both groups as a pretest and posttest. For data analysis, the Mann-Whitney U test and the Wilcoxon signed-rank test were employed. According to the findings of the study, there was no statistically significant difference between the pretest scores of the experimental and control groups. However, a significant difference in favor of the experimental group was found in the posttest ZAT scores between the experimental group (which received the TEFC model) and the control group (which received the traditional model). Furthermore, in both the experimental and control groups, posttest scores significantly increased compared to pretest scores. These results suggest that the flipped classroom model is more effective than traditional methods in enhancing academic achievement in 7th-grade biology lessons on zoology topics. In this context, it is recommended that future researchers include variables such as motivation, higher-order thinking skills, and affective outcomes in their studies. Additionally, teachers are encouraged to use the flipped classroom model effectively in their classrooms.

Keywords: Science education, biology teaching, academic achievement, zoology.

Introduction

Rapid developments in educational technologies necessitate continuous review and renewal of teaching methods. In line with these developments, it is observed that traditional teaching approaches have been replaced by more student-centered, interactive and technology-effective methods. Especially since science education inherently requires student participation and active learning, the need for contemporary teaching approaches is increasing day by day. In this context, the flipped classroom (TYES) model stands out as one of the prominent innovative approaches in technology-oriented education (Chebotib, Too, & Ongeti, 2022).

TRYES is a model that replaces traditional classroom teaching with homework practices, aiming to provide students with early access to basic concepts and to devote more classroom time to high-level cognitive activities such as analysis, discussion, and problem-solving. This model is particularly student-centered, as it allows students to take a more active role in their learning process (Adonu, Nwagbo, Ugwuanyi, & Okeke, 2021).

Biology course, as a discipline where abstract and micro concepts are intense and observational information is frequently included, is a field where students are open to misconceptions. For this reason, it is important that the method used in biology teaching contributes to the student's structuring of knowledge, establishing relationships and making knowledge permanent. TYES can be considered as an effective model for science and biology courses, as it offers a structure where students are prepared with video and digital content that students can watch in advance, and in-class time is devoted more to discussion and practice (Malto, Dalida, & Lagunzad, 2018; , Ebrahim & Naji, 2021). Another important contribution of TYES is that it allows the student to learn at their own pace during the learning process (Dorji & Dorji, 2022). Since each student's learning style and duration differ, this model helps students take on their own learning responsibilities. This offers a significant advantage, especially in courses with high conceptual content such as biology (Sletten, 2017).

This research aims to examine the effect of BYES on student academic achievement in the context of biology course. The data to be obtained as a result of the research are expected to guide biology teachers in innovative teaching methods and contribute to further studies in the field of science education.

Today, education systems focus on providing 21st century skills, aiming not only to enable students to access information, but also to analyze, evaluate and use information creatively. In this context, traditional teacher-centered teaching methods are insufficient to meet these new expectations (Sletten, 2017). Biology course is a basic science course aimed at enabling students to understand living things, nature and environmental systems. However, many students have difficulties due to the abstract and memorization-based structure of this course and move away from the learning process. This situation not only negatively affects students' academic achievement levels but also reduces their interest in science (Çakır & Yaman, 2017).

Zoology topics are one of the most comprehensive and detailed subfields of biology. These subjects are generally perceived by students as abstract, complex and based on rote memorization; In particular, contents such as invertebrates, vertebrates, classification of the animal kingdom, life cycles and roles in the ecosystem are among the main topics that students have difficulty in making sense of. It is clear that students need experiment, observation, visual material and interactive learning environments in order to embody these abstract structures (Sletten, 2017; Arslanhan, Bakırcı, & Altunova, 2022). In traditional teaching practices, such content is generally based on teacher lectures and textbooks, and the student's participation in the active learning process is limited. In particular, the one-way and teacher-centered teaching process prevents students from actively participating in the learning process (Ceylan & Hamzaoğlu, 2022). This situation makes it necessary to reconsider teaching strategies.

In fields that require plenty of visual and experimental content, such as zoology, it is possible to create an effective teaching environment by taking advantage of the opportunities offered by technology. At this point, the TYES model provides students with access to course content in advance, providing them with the opportunity to spend class time with higher-level cognitive activities such as practice, analysis and interpretation. This model, which is especially focused on video-supported content, can contribute to a better understanding of the classification, structure and behavior of animals (Sletten, 2017). Students' ability to access pre-class content, repeat the lesson, and actively participate in activities such as discussion and practice in class facilitates understanding, especially in complex zoology subjects (Ebrahim & Naji, 2021). In this context, student-centered approaches such as the TYES model offer solutions to these problems, which are the weak point of the traditional teaching approach. This model, which enables students to participate more actively in the learning process and learn content at their own pace and by repetition, has been effectively implemented in many countries in recent years (Malto et al., 2021).

Despite the increasing interest in the TYES approach in terms of related research, the number of studies conducted specifically for biology courses is quite limited (Ceylan & Hamzaoğlu, 2022; Tanrıverdi, 2024). In Azerbaijan, the flipped teaching technique is becoming more and more common. It is observed that this model is used both at the university level and in secondary education institutions. The school where the research was conducted is among the institutions that implement the flipped classroom model, and the academic outputs obtained in these institutions reflect the success of the method. However, an important shortcoming is that these practices are not adequately supported by scientific measurement and evaluation processes.

Factors such as the fact that technological equipment is not available equally in every school in Azerbaijan, the digital competencies of teachers differ, and student motivation is directly affected by the teaching method necessitate detailed examination in order to implement these methods effectively. Experimental studies carried out in the local context are of great importance in order to eliminate these deficiencies. For this reason, the effect of flipped teaching practice on academic success within the scope of biology course in the Azerbaijani sample should be revealed.

The rapid development of digital technologies and learning environments has also led to radical transformations in education systems. Today, students can access information not only through teachers but also from many sources such as the internet, video content and digital platforms. This situation makes it necessary to redefine the roles of teachers and reorganize learning environments according to students' expectations and needs (Koray, Çakar, & Koray, 2023). In this context, the active use of technology in teaching processes both increases the quality of learning and allows students to participate in the learning process at a higher level (Yavuz, 2016).

Especially in courses such as biology, which have a high conceptual level and a high need for visual materials, traditional methods are often insufficient for students to achieve permanent and meaningful learning. Zoology topics consist of abstract content such as classifications of living things, structural features and systematics, which may cause students to be content with rote learning approaches (Lage, Platt, & Treglia, 2000). At this point, contemporary approaches such as the technology-supported TYES model enable students to actively participate in learning and support meaningful learning (Taşkın & Aksoy, 2019).

The TYES model enables students to access the course content in advance through online environments, and to allocate in-class time to practice, discussion, and reinforcement activities (Kozikoğlu & Camuşcu, 2019). In particular, the ability of students to re-watch the course content in accordance with their individual learning paces, to repeat the parts they do not understand, and to actively participate in the classroom environment shows that this model deepens the learning process (Yavuz & Karaman, 2021; Yurtlu, 2018).

Although the flipped classroom model is applied at various levels in Azerbaijan, experimental studies are limited, especially at the secondary school level and for the zoology unit of biology courses. In this context, this study is important in terms of examining the effect of the TYES model on the academic achievement of 7th grade students in biology course for the first time experimentally and statistically. This situation both contributes to the existing literature and reveals original findings that will guide the practices in the context of Azerbaijan.

The aim of this study is to examine the effect of the technology-oriented TYES model applied in the experimental group of 7th grade students in the "zoology" unit of the biology course on the academic achievement of the students compared to the control group in which the traditional method was applied. In this context, answers to the following research questions were sought;

1. Is there a statistically significant difference between the pre-test scores of the students in the experimental group where the TYES model was applied and the control groups in which the traditional learning model was used?
2. Is there a statistically significant difference between the post-test scores of the students in the experimental group where the TYES model was applied and the control groups in which the traditional learning model was used?
3. Is there a statistically significant difference between the pre-test scores of the "Zoology Achievement Test" before the experimental application and the post-test scores of the "Zoology Achievement Test" after the experimental application?
4. Is there a statistically significant difference between the pre-test scores of the "Zoology Achievement Test" before the experimental application and the post-test scores of the "Zoology Achievement Test" after the experimental application of the students in the control group using the traditional learning model?

Method

Research Model

In this study, a quasi-experimental design with pretest-posttest control group was preferred in order to determine the effect of the TYES model on academic achievement in biology course (Karasar, 2009).

Table 1

Research Design

Group	Pre-Test Instrument	Instructional Process	Post-Test Instrument
Experimental Group	Pre-ZAT	Instruction based on the Flipped Classroom Model (8 weeks)	Post-ZAT
Control Group	Pre-ZAT	Textbook-based instruction (8 weeks)	Post-ZAT

Study Group

This study was conducted in the 2023-2024 academic year in a public school in Azerbaijan determined by convenience sampling method. It was carried out with students attending the class. Classes 7/A and 7/B in the school were determined as experimental and control groups with random assignment. In this context, group 7/A was assigned as the experimental group and group 7/B as the control group. The critical conclusion made regarding whether the experimental and control groups are suitable for experimental application in terms of their characteristics;

- The experimental group students had access to mobile internet (including mail, WhatsApp) in the home environment,
- The practices in the experimental and control group were carried out by the researcher, who is also a teacher, and in this context, the validity of the practitioner was ensured,
- The technological skills of the experimental group students were sufficient for the research purpose (determined according to the criteria in the basic computer course applications)

Data Collection Tool

As a data collection tool in the research, "Zoology Achievement Test (ZAT)" was applied to the experimental and control groups in the form of pre-test and post-test. The achievement test was developed by the researcher in line with the achievements in the Azerbaijan 7th grade curriculum. In the first stage, 25 multiple-choice questions were prepared for the outcomes classified according to Bloom's taxonomy, and these questions were examined by 2 expert teachers and 1 assessment and evaluation expert. Then, a pilot application was made to 76 students and item analyzes were carried out.

Pilot application data were analyzed with SPSS 26, item difficulty indices were found to be between 0.32-0.82 and distinctiveness indices were found to be between 0.42-0.85. As a result of 27% lower-upper group comparisons and item-total correlation analyses, 5 items (7, 17, 23, 24, 25) that did not meet the discrimination criteria were excluded from the test. As a result of the analysis, the number of questions in the ZAT was reduced to 20 items. The KR-20 reliability coefficient of the final 20-item test was calculated as 0.786, which showed that the ZAT provided a high level of reliability. There are 4 distractors and 1 correct answer for 20 questions in the test.

Implementation Process and Data Collection

In the research, the necessary permissions for the "Flipped classroom model" that I used in my research to be implemented in the school were obtained in advance. These permits were given with the official approval of the public school No. 3 named after Nariman Narimanov with the demonstration of the Karabakh Regional Directorate in Azerbaijan. In the implementation of the program, the curriculum of the 7th grade and school books were taken as a basis and the lessons were applied accordingly.

While teaching the courses in the control group, the researcher acted in accordance with the achievements and instructions in the biology teaching program and the courses were carried out within the framework of the program. Some of the experiments in the biology curriculum were carried out in accordance with the course.

As required in the TYES model, a group was created via WhatsApp in the experimental group and the necessary materials were sent there. The TYES model was explained to the students in the experimental group and they were told to watch the video materials thrown to them before the lesson, solve the questions given to them and take notes of the necessary parts in the video.

During the research process, the students in the Experimental and Control groups were followed step by step. In these two groups, the same program was taught, but lessons were given with different models. It was also regularly monitored whether they watched the videos sent to the experimental group students. Reminders were made by message at 2-3 different times of the day. The main materials to be used in the application were determined by the researcher in advance of the application. Although the courses were given with traditional methods in the control group, TYES was applied to the experimental group. At the end of the unit, posttests were performed in both groups and the process was completed. During the ZAT application process, the groups were given 40 minutes each for the HEE pre-test and post-test. The application took 8 weeks in total.

Data Analysis and Ethical Procedures

This study approved by the University Scientific Research and Publication Ethics Committee with the permission of the institution dated 24/06/2024 and numbered 2025/315.

In the study, the normal distribution assumptions of the Zoology Achievement Test (IQT) measurements applied to the experimental and control groups were first tested. As a result of the Shapiro Wilk test analyzes performed for this purpose, it was seen that the measurements of the experimental and control groups did not meet the normal distribution assumptions. For this reason, the Mann Whitney U test was used to compare the IQT measurements of the students in the experimental and control groups. Wilcoxon test was used to compare the pretest and posttest scores of the experimental and control groups.

Findings

In this part of the collected research, the findings reached as a result of the analysis of the data are presented.

The descriptive findings for the *"ZAT" pre-test scores* of the students in the experimental and control groups are presented in Table 2.

Table 2

Descriptive Analysis of "ZAT" *Pre-test Scores of* Students in Experimental and Control Groups

	Experimental group			Control group		
	N	$\bar{X}$	Ss	N	$\bar{X}$	Ss
ZAT Pre-test	26	30,96	2,46	25	26,80	1,31

Table 3 presents descriptive statistics on the "ZAT" *pre-test scores of students in the experimental and control groups* . Accordingly, the arithmetic mean of the ZAT pre-test scores of 26 students in the experimental group was calculated as 30.96 and the standard deviation was calculated as 2.46. The mean pre-test score of the 25 students in the control group was 26.80 and the standard deviation was 1.31. The results of the Mann Whitney U test performed between the two groups are given in Table 3.

Table 3

Mann Whitney U Test Results Regarding the *"ZAT" Pre-test Scores of* the Students in the Experimental and Control Groups

	Group	N	Rank Avg.	Rank Total	Mann-Whitney U	Z	p
ZAT Pre-test	Experiment	26	28,46	740,00	261,00	-1,22	0,22
	Control	25	23,44	586,00			

Table 3 shows the results of the Mann-Whitney U test, which was performed to determine the difference between the "ZAT" pre-test scores of the students in the experimental and control groups. According to the findings of the analysis, the mean rank of the experimental group was 28.46 and the total rank was 740.00; The mean rank of the control group was 23.44 and the total rank was 586.00. The Mann-Whitney U value is 261.00, the Z value is -1.22, and the resulting p-value is 0.22. This result shows that there is no statistically significant difference between the experimental and control groups in terms of pre-test scores ($p > 0.05$).

The "ZAT" post-test results *of the students after the experimental procedures* are presented in Table 4 and Table 5.

Table 4

Descriptive Analysis of "ZAT" Post-test Scores of Students in Experimental and Control Groups

	Experimental group			Control group		
	N	$\bar{X}$	Ss	N	$\bar{X}$	Ss
ZAT Post-test	26	81,73	12,24	25	60,45	1,89

Table 4 shows the descriptive statistics of the "IQT" post-test scores *of the students in the experimental and control groups* . Accordingly, the mean post-test score of 26 students in the experimental group was calculated as 81.73 and the standard deviation was calculated as 12.24. The mean post-test score of the 25 students in the control group was 60.45 and the standard deviation was 1.89. The results of the Mann Whitney U test performed between the two groups are given in Table 5.

Table 5

Mann Whitney U Test Results Regarding the *"ZAT" Post-test Scores* of Students in the Experimental and Control Groups

	Group	N	Rank Avg.	Rank Total	Mann-Whitney U	Z	p
ZAT Post-test	Experiment	26	36,21	941,50	59,50	-5,03	0,00*
	Control	25	15,38	384,50			

*p<0.001

Table 5 shows the Mann-Whitney U test results for the "ZAT" post-test scores of the students in the experimental and control groups. According to the findings of the analysis, the mean rank of the experimental group was calculated as 36.21 and the control group as 15.38 (U = 59.50, Z = -5.03, p < .001). According to the rank averages, the post-test scores of the students in the experimental group were significantly higher than the post-test scores in the control group. This result shows that the flipped teaching application applied in the experimental group significantly increased the students' Zoology achievement compared to the application in the control group.

In Table 6, the results of the Wilcoxon test performed between *the "ZAT"* pretest-posttest scores of the students in the experimental group are given.

Table 6

Analysis Results of "ZAT" Pretest-Posttest Scores of Students in the Experimental Group with Wilcoxon Test

	Rows	N	Rank Average	Sum of Rows	Wilcoxon Z	p
ZAT Pre-test-Post-test	Negative Ranks	0	0,00	0,00	-4,49	0.00*
	Positive Ranks	26	13,50	351,00		
	Even	0				
	Total	26				

*p<0.001

Wilcoxon Signed Ranks Test was applied to determine whether there was a significant difference between the pre-test and post-test scores of the "ZAT" of the students in the experimental group. According to the test results, the post-test scores of all students were higher than the pre-test scores, and no negative ranking was observed. The statistical values obtained as a result of the analysis show that this difference is significant (Z = -4.49, p < .001). This finding reveals that the applied teaching activity is effective in increasing students' Zoology achievements.

In Table 7, the results of the Wilcoxon test performed between *the "ZAT"* pretest-posttest scores of the students in the control group are given.

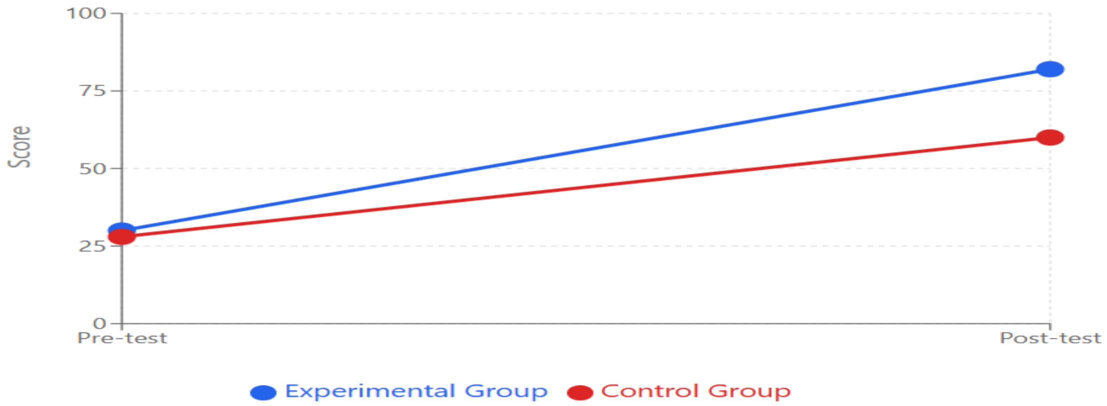
Table 7

Analysis Results of "ZAT" Pretest-Posttest Scores of the Students in the Control Group with Wilcoxon Test

	Rows	N	Rank Average	Sum of Rows	Wilcoxon Z	p
ZAT Pre-test-Post-test	Negative Ranks	0	0,00	0,00	-4,40	0.00*
	Positive Ranks	25	13,00	13,00		
	Even	0				
	Total	25				

*p<0.001

Wilcoxon Signed Ranks Test was applied to examine the difference between the pre-test and post-test scores of the "ZAT" of the students in the control group. According to the test results, the post-test scores of all students were higher than the pre-test scores and no negative ranking was found. The results obtained reveal that this difference is statistically significant (Z = -4.40, p < .001). This shows that the teaching process applied in the control group also made a significant contribution to the academic success of the students in the Zoology course.



Figrue 1

Graph of the Averages of the "ZAT" Pre-test and Post-test Scores of the Experimental and Control Groups

Discussion

In this study, the effect of the technology-oriented "flipped teaching technique" applied in the experimental group in the "zoology" unit of the biology course of 7th grade students on the academic achievement of the students compared to the control group where the traditional method was applied was investigated. The first sub-problem of the research aims to reveal the difference between the pre-test scores of the experimental and control groups. When the pre-test findings are examined, it is seen that the arithmetic means of the two groups are close to each other. Equality between groups constitutes an important prerequisite for maintaining internal validity in experimental studies. In addition, the similarity of initial success levels provides the opportunity to isolate the real effect of the flipped teaching technique.

The pre-test results show that there is no success advantage between the traditional teaching approach and the flipped teaching technique at the beginning. Therefore, it becomes possible to attribute the differences that may arise in subsequent tests to pedagogical intervention. This supports the methodological integrity in terms of the experimental design of the research (Tabachnick and Fidell, 2011). Furthermore, the relatively limited sample size may partially reduce the statistical power in detecting baseline differences (Divine et al., 2013). However, the absence of an unequal group size problem strengthens the consistency of the analyses. The data of the study indicate the initial homogeneity and thus clarify the effect of the teaching technique. (Karagöz, 2010)

The second sub-problem of the research aims to examine the difference between the post-test scores of the experimental and control groups. When the post-test findings are examined, it is seen that the success average of the experimental group is significantly higher than the average of the control group. The fact that the rank mean in the experimental group was high and the rank mean in the control group was low reveals the direction of the intervention effect. The finding shows that the flipped teaching technique increases biology success. Therefore, it is predicted that the conceptual understanding of the experimental group students deepens, their problem-solving skills improve, and their self-regulation capacities increase. In the control group, the continuation of the traditional method may have caused students to devote most of their classroom time to teacher-centered presentations and limited the level of active participation. It is thought that the experimental group students acquire basic concepts by watching pre-lesson videos and reinforce knowledge by using in-class time in interactive activities. This process allows students who have acquired prior knowledge to focus on deep learning in the course by spreading the cognitive load over time (Tanrıverdi, 2024). Additionally, peer interaction within the classroom and teacher guidance providing more personalized feedback support the increase in achievement (Kılınç, 2024).

These results coincide with the relevant literature. Research by Moravec, Williams, Anguliar-Roca, and O'Dowd (2010) in biology class indicated significant achievement elevation in the experimental group and demonstrated the effectiveness of the model. In addition, Mennella (2016) stated in his study conducted in the context of genetics course that the flipped model significantly increases academic achievement. Akgün (2015) and Çelebi (2023), among domestic studies, also stated that they found a significant increase in success in experimental groups in science courses. These findings coincide with the results of the current research and show that flipped teaching is especially effective in subjects that require conceptual depth. Zgeng (2020), in his motivation-oriented study, concluded that the flipped model indirectly contributes to academic success by increasing learning motivation. Aksoy and Aydın (2022) reported that the experimental group showed significant improvement in conceptual questions, but a more limited increase was observed in procedural questions. In the current study, an increase was recorded in the entire achievement test, which includes both conceptual and procedural elements, indicating the holistic impact potential of the model. In the literature, Bozdağ and Türkoğuz (2021) report a similar increase in fifth-grade students and state that standardized tests may not fully reflect higher-order thinking skills. Considering this criticism, the fact that no additional open-ended measurements were made in the present study constitutes a limitation.

When the reasons for the achievement difference in the post-test are examined, it can be said that the flipped teaching process strengthens the student self-directed learning cycle (Dorji & Dorji, 2022). After acquiring basic knowledge through pre-class videos, students have the opportunity to reinforce knowledge through peer collaborative activities in the classroom environment. In this process, the teacher takes on the role of a guide, focusing on individual needs and providing feedback. Classroom discussions allow students to experience cognitive conflict and correct misconceptions. Furthermore, multiple forms of representation of learning materials (video, animation, experiment kit) diversify cognitive encoding and facilitate recall (Chebotib, Too, & Ongeti, 2022). This interaction, which is not possible in the control group, leads to the activation of high-level processes in the experimental group. Technology access, which is a prerequisite for the flipped model, allows students to repeat pre-lesson materials at their own pace. Therefore, time-independent learning flexibility increases motivation (Arslanhan, Bakırcı, & Altunova, 2022).

The third sub-problem of the research is to evaluate the change between the pre-test and post-test scores of the experimental group. According to the Wilcoxon test applied, it was determined that the post-test scores of all students in the experimental group were higher than the pre-test scores. The absence of a negative ranking indicates an increase in the academic achievement of all participants (Karagöz, 2010). This finding shows that the flipped teaching technique positively affects all students. The homogeneous structure of the increase in the experimental group shows that the model has a similar effect on students with different levels of readiness.

The limited duration of the application to eight weeks may have prevented some students from reaching their full potential. Nevertheless, the comprehensive gains even in short-term intervention demonstrate the rapid impact potential of the model. The fact that students have the chance to watch pre-class videos asynchronously contributes to the allocation of classroom time to practices (Ceylan & Hamzaoğlu, 2022). These interactive applications expand the conceptual schemes in biology subjects. It is assumed that concept mapping, model building, and discussion-based activities develop students' analytical thinking skills (Sletten, 2017). In this context, Demirel and Türkmen (2025) determined in their study that the common knowledge construction model, which is a model that develops student-centered and analytical thinking skills, increases students' academic success and maintains its permanence. TAVAÇ papers and argumentation-based activities in this model have especially led to this result. Students receive peer feedback in the classroom and have the opportunity to correct their mistakes instantly. This feedback loop reinforces a culture of continuous evaluation. Therefore, the increase in success in the experimental group reflects the multi-layered gains of the learning process (Çakır & Yaman, 2017).

The increase observed in the experimental group is similar to many findings in the literature and supports the consensus that the flipped teaching model increases overall achievement in students. The statistically significant increase achieved by Moravec et al. (2010) in biology course coincides with the results of this study. Akgün (2015) stated that the motivation and cognitive load levels of the students in the experimental group improved in his science education research, thus increasing their success. Similarly, in the study conducted by Solak (2021) during the pandemic period, a significant increase was observed in the post-test scores of the students. Olakanmi (2017), one of the international studies, emphasized that there was significant progress in academic achievement in science classes. These findings indicate that the model has demonstrated consistent performance across different countries and subject areas. However, the results obtained by Bozdağ and Türkoğuz (2021) in fifth grade students indicate that performance improvement depends on understanding basic concepts. Zgeng (2020) states in his research that high motivation mediates the increase in success. Therefore, the lack of measurement of motivation in the present study creates a deficiency in explaining the exact mechanism of success increase. Yıldız et al. (2016), in their study based on teacher opinions, show that the model has a positive place in teacher perception and supports the sustainability of achievement increase.

When the reasons for the change in the experimental group are examined, the importance of a model that centers the learning process on the student can be emphasized (Malto et al., 2018). Students interact with course materials individually and share cognitive responsibility. The collaborative nature of classroom activities aligns with the social constructivist perspective. The teacher's role as a facilitator detects students' conceptual misunderstandings in a timely manner (Chebotib, Too, & Ongeti, 2022). Furthermore, the audiovisual nature of pre-class materials supports success, catering to diverse learning styles (Zgeng, 2020). The perceived benefits of the model could not be fully assessed because student feedback was not collected systematically. However, the flipped model may pose risks of technology dependency, disparities in device access and internet speed. These risks can reduce the effect size in students with low socioeconomic status. The advantage of students learning at their own pace can lead to loss of motivation in individuals with poor self-regulation skills (Kılınç, 2020).

The fourth sub-problem of the study is to reveal the difference between the pre-test and post-test scores of the control group. Wilcoxon test results show that the post-test scores of all students in the control group were higher than the pre-test scores. However, the absolute magnitude of the increase in the control group compared to the experimental group remains limited. This increase reveals that the traditional teaching method is also effective to a certain extent. It is thought that students have the opportunity to reinforce their knowledge with homework after acquiring basic concepts through face-to-face lectures in the classroom. However, it is anticipated that the passive learning environment limits student engagement. Allocating most of the classroom time to teacher lecture can develop students' high-level inquiry skills to a limited extent. Therefore, the increase in the control group is considered as the minimum achievement of one-way information transfer.

The limited increase in the control group is in line with studies in the literature reporting the partial effect of the traditional teaching approach. In the meta-review of Sharples et al. (2014), it is stated that the traditional method limits the increase in achievement and is insufficient to reduce flawed learning compared to the flipped model. In the study of Moravec et al. (2010), it was reported that the success increase of the control group was less than half of the experimental group. Akgün (2015) and Aksoy and Aydın (2022) also observed significant but limited increases in the control groups, emphasizing that the traditional learning environment does not serve deep learning.

Conclusion and Recommendations

- There was no significant difference between the pre-test scores of the experimental and control groups. In this context, the pre-application experimental and control groups are equivalent in terms of academic achievement.
- In the post-test, the success scores of the experimental group students were significantly higher than the control group. This shows that the flipped teaching technique significantly increases academic achievement in zoology subjects in the seventh grade biology course compared to the traditional model.
- In the experimental group, the difference between the pre-test and the post-test was positive in favor of all students and it was determined that the application increased student success.
- An increase was observed between pre-test and post-test scores in the control group. However, this increase is significantly less than the difference created by the flipped teaching technique.

Recommendations for Practitioners

- When planning the flipped teaching technique in biology lessons, it should be planned effectively before the lesson and the materials should be tested in advance.
- It is recommended that classroom activities include peer collaborative problem solving and experimental design.
- Students' access to videos should be monitored periodically and in-school support units should be established for those who have access problems.
- Teachers should allocate classroom time to feedback and misconception correction activities.
- In the application process, practices to increase motivation can be included in order to increase student motivation.

Recommendations for Researchers

- Future studies may examine the effect of the flipped teaching technique on permanent learning using long-term monitoring designs.
- Qualitative data collection methods will contribute to an in-depth understanding of students' model perceptions and motivation dynamics.
- Studies to be carried out in different cultural and socioeconomic contexts may be useful in testing the generalizability of the model.
- It is recommended that the measurement tools be supported by motivational tests and open-ended questions focusing on high-level cognitive skills.
- Structural equations of equity can be designed to model the effect of the flipped teaching technique on cognitive load, metacognitive awareness, and self-regulation levels.

Declarations

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