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An Investigation into the Impact of the Flipped Classroom Model in Science Education on Student Academic Performance and Attitudes[1]

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Abstract

The purpose of this study was to investigate the effectiveness of a flipped classroom model (FCM) in science education on student achievement as well as to explore student opinions, interests, and attitudes toward this instructional approach. The study cohort comprised 41 second-grade students Faculty of Education, Department of Mathematics and Science Education of a state university in Türkiye, specializing in Science during the 2017-2018 academic sessions. The experimental group consisted of 20 students, while the control group comprised 21 students. Data collection and analysis followed a mixed-methods approach encompassing both quantitative and qualitative methodologies. The analysis of the collected data involved the use of Independent Samples T-Test (pre-test post-test quasi-experimental design) to determine whether there was a significant difference in the achievement scores between groups. Upon analyzing the results, it was found that there was a substantial increase in the experimental group's pre-test mean score (Xpe = 7.05, Xle = 22.20) compared to their post-test arithmetic mean score, whereas the control group's pre-test mean (Xpc = 7.61, Xlc = 16.19) showed a lower increase in their post-test arithmetic mean score. The qualitative data analysis employed a descriptive analysis approach utilizing semi-structured interview forms. The research findings revealed a statistically significant difference in academic achievement test scores between the experimental and control groups, with the experimental group demonstrating notably higher scores. Furthermore, the semi-structured interview forms unequivocally indicated a positive trend in students' opinions, interests, and against course toward the implemented instructional model.

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Active learning, academic achievement, flipped classroom, constructive learning, semi-constructed interview form

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Introduction

In recent years, advancements in educational technology and pedagogical approaches have revolutionized traditional teaching methods, particularly in the field of science education. One such innovative approach that has garnered significant attention and interest is the flipped classroom model (FCM) (Doğan et al., 2023; Turan, 2023). The FCM represents a paradigm shift in the way content is delivered and learning is facilitated, with a focus on active engagement, student-centered learning, and the integration of technology into the educational process (Cabı, 2018). The Flipped Classroom Model involves a fundamental inversion of the traditional instructional sequence, where students are introduced to foundational content through pre-class assignments such as video lectures, readings, or online simulations. The essence of the FCM lies in the inversion of traditional teaching methods, where students are first exposed to instructional content through pre-recorded lectures, videos, or online materials outside of the classroom, typically as homework assignments. This pre-class engagement enables students to acquire basic knowledge independently, allowing for more interactive and collaborative activities during face-to-face classroom sessions. In the context of science education, where conceptual understanding and practical application are paramount, the FCM holds significant potential for transforming the learning experience and improving student academic performance (Long et al., 2017). This pre-class preparation allows students to familiarize themselves with the fundamental concepts and theoretical frameworks independently, at their own pace, and provides them with the foundational knowledge necessary for deeper exploration and application during in-class activities (Ozdamli & Asiksoy, 2016). Within the context of science education, the FCM has demonstrated great potential for enhancing student learning outcomes, fostering critical thinking skills, and promoting a deeper understanding of scientific principles. By utilizing digital resources, interactive simulations, and multimedia tools, educators can create engaging and interactive pre-class materials that cater to diverse learning styles and preferences.

Numerous studies have investigated the impact of the FCM on various aspects of science education, including student achievement, attitudes toward learning, engagement levels, and retention of knowledge (Baytiyeh, 2017; Güler et al., 2023; Assi & Cohen, 2024). While some research has reported positive outcomes and significant improvements in learning outcomes among students exposed to the FCM, others have highlighted challenges related to implementation strategies, technological barriers, and student readiness (Ajmal & Hafeez, 2021; Bakırcı & Kılıç, 2021; Han et al., 2024). Additionally, the interactive nature of the FCM fostered greater student engagement, motivation, and enthusiasm for learning, as evidenced by enhanced participation rates and positive attitudes toward science subjects. However, challenges and considerations regarding the effective implementation of the FCM have also been documented in the literature. These include technological constraints, student readiness and access to resources, instructional design complexities, and the need for ongoing assessment and feedback mechanisms to monitor learning progress (Larcara, 2015; Arslanhan vd., 2022; Aksoy & Aydın, 2022). That study is to shed light on the FCM's effects on student academic performance and attitudes in science education. By presenting key findings, identifying best practices, and discussing potential challenges associated with the FCM, the study aims to offer valuable insights to educators and researchers. These insights can help in utilizing innovative teaching methods effectively to improve student learning experiences and outcomes, particularly in the field of science education. For this aim is to focused on the impact of the FCM on student academic performance and attitudes in science education. By revealing key findings, this study seeks to provide valuable insights for educators, and researchers interested in leveraging innovative teaching methodologies to optimize student learning experiences and outcomes in science education, as well.

Method

Research Design

Quantitative data were gathered using a pretest-posttest methodology. Qualitative data were gathered using a semi-structured interview format, which served to complement and enhance the research findings (Steiner et al., 2009; Campbell &Stanley, 2015). Given the challenges associated with achieving unbiased participant assignments in research settings, quasi-experimental designs are frequently utilized. In this study, a quasi-experimental design with a pretest-posttest control group was implemented to investigate the impact of the FCM model on the academic performance of prospective science teachers and their attitudes in the General Chemistry IV course. The outcomes were assessed using semi-structured interview forms to ascertain student opinions.

Study Group

This study was conducted with science teacher candidates enrolled in the 2nd Grade 1st Education Department in a state university in Türkiye during the 2016-2017 academic years. A preliminary pilot program utilizing a blended learning model was implemented in the preceding academic year (2015-2016) to facilitate the categorization of students into experimental and control groups and to acclimate them to the intervention process. Based on the insights gained from the pilot study, the application of the FCM was continued with a total cohort of 41 students, evenly divided into 20 participants in the experimental group and 21 participants in the control group, with comparable baseline scores.

Design and Administration of Pre-test and Post-test Measures

To ensure accurate data collection concurrent with the intervention, a pretest-posttest methodology was adopted using an academic achievement measurement test focused on aliphatic hydrocarbons (alkane, alkene, and alkyne) topics within the Science General Chemistry IV course. The development of this achievement test involved consultation with two subject matter experts in chemistry, including a lecturer specialized in the field of chemistry and an experienced educator with 15 years of teaching experience in the Ministry of Education. A question bank specifically addressing hydrocarbons was created based on their expertise. The test questions were administered to a sample of 40 students who had previously completed the course. The reliability of the test was assessed using Cronbach's Alpha, resulting in a value of 0.94, indicating high internal consistency (Cetin & Akkus, 2016). As the students had encountered hydrocarbon topics in their high school curriculum, the test was employed as a pretest to gauge their initial levels of understanding and knowledge. To ensure the reliability of the intervention outcomes, a pretest administered at the onset of the study was also used as the post-test following the intervention period. To mitigate the potential for students to recall specific questions, alterations were made to the question order and options in the post-test assessment. This involved rearranging the sequence of questions compared to the pre-test assessment to prevent students from recognizing and recalling questions from memory. Additionally, changes were made to the options provided for each question to ensure that they were not identical or easily identifiable from the pre-test questions. These alterations aimed to minimize the influence of memory recall on students' responses and provide a more accurate assessment of their understanding and retention of the material.

Development and Application of a Semi-Structured Interview Protocol

In the qualitative analysis aspect of the research, it has been noted in literature that the case study method can serve as a viable approach for eliciting students' perspectives regarding the implemented instructional model. The case study methodology involves an in-depth examination of specific instances within the context of a defined problem or scenario (Gopalan et al., 2020). In the first week of the process, science teacher candidates were briefed about the model by providing an overview of the application's content and the teaching methodology of the course. It was mentioned that the experimental group would engage in internet-based learning and computer-assisted learning methods throughout the process. The teaching approach, application content, and implementation method were explained in detail to the experimental group, along with the technology and materials required for the application. The experimental group was informed that the courses would be taught using the FCM, and a brief introduction to the application's purpose was provided, followed by necessary explanations to motivate the science teacher candidates. During the qualitative data collection phase, a subset of 21 science teacher candidates from the experimental group (comprising 11 boys and 10 girls) was selected to provide insights into their interests and opinions regarding the application process and instructional model. This involved posing a single open-ended question to each participant. These questions cover a range of aspects related to the FCM, from its impact on learning outcomes and student engagement to its practical advantages and challenges. A semi-structured interview format was employed for qualitative data collection purposes. All textual materials were independently coded by two expert researchers. The reliability of the coding process was assessed using the agreement/disagreement and consensus method outlined by Miles and Huberman ([Agreement/Disagreement + Consensus])*100. To maintain participant anonymity, students within the experimental group were assigned code names A1 to A20. While quantitative data analysis methods remain prevalent in scientific research, there has been a notable surge in the utilization of qualitative data methods in recent years, propelled by ongoing advancements in contemporary education and training. This shift has prompted versatile developments in qualitative research methodologies. The analysis of the study was conducted using the content analysis method, one of the qualitative analysis techniques. The results were then interpreted in a suitable format, aligning with established practices in qualitative research (Turan & Göktaş, 2018).

Sixth week application process for the control group and experimental group

The control group in this study was assigned to Science Teaching II. During the fall semester, the General Chemistry IV course focusing on hydrocarbons was delivered to the control group in a traditional face-to-face classroom setting, following the conventional learning approach, for duration of 6 weeks. In the sixth week of the study, a pre-prepared post-test consisting of 30 questions was administered to assess the control group students' proficiency in topics such as alkanes, alkenes, and alkynes, which they had studied throughout the entire carbon chemistry process. The experimental group also received lectures in the instructional technologies material design (ITMD) laboratory using the FCM over a 6-week period during the fall semester. The ITMD workshop was designed to minimize distractions for optimal focus. Round tables were arranged in a U shape to encourage peer cooperation and interaction. A 6-week lesson plan (12 hours total) was developed, and students were informed of the schedule, consisting of two-hour sessions during the day. Video lessons on hydrocarbons were prepared in advance, and students were instructed to create an email address and a WhatsApp group for communication and sharing video links and correspondence. Worksheets were sent weekly for students to complete after watching the videos, promoting engagement and collaboration. A 30-question pre-test was administered to assess academic proficiency levels before the implementation of the ITMD classroom environment. Detailed explanations of both the control group and the experimental group's experiences during the designated period are provided in the supplementary file.

Data Analysis

The analysis of data in this study was conducted using both quantitative and qualitative approaches. Quantitative data obtained from the pre-test and post-test measures were analyzed using statistical techniques, while content analysis was used to analyze the qualitative data. In this analysis, themes, categories and codes were determined in the participants' opinions. For the quantitative analysis, descriptive statistics such as means, standard deviations, and percentages were calculated to summarize the data. Paired-samples t-tests were utilized to compare the pre-test and post-test scores within each group (experimental and control) (Wyman & Watson, 2020). Additionally, due to the sample size being less than 50, the Shapiro-Wilks test was employed to confirm the homogeneity of variances in the quantitative data. The results of the final assessment indicated that the p-value for both the control and experimental groups was less than a = 0.05, emonstrating a significant difference between the groups. Moreover, independent-samples t-tests were employed to compare the differences in post-test scores between the experimental and control groups. In the qualitative analysis, transcripts from the semi-structured interviews were first transcribed verbatim. Then, thematic analysis was performed to identify recurring themes, patterns, and categories related to students' opinions, attitudes, and experiences with the applied instructional model. The coding process involved multiple steps, including data familiarization, code generation, theme development, and review by multiple researchers to ensure reliability and validity (Cheung & Tai, 2023). The integration of quantitative and qualitative findings allowed for a comprehensive understanding of the impact of the instructional model on student academic performance and attitudes. The triangulation of data sources further enhanced the credibility and robustness of the study's conclusions. In this qualitative research study, data collection tools were presented to four experts in the field to enhance the validity and reliability of the research. The goal was to increase the credibility of the qualitative data by having these experts validate the obtained results. Additionally, during the data collection process using the interview method, an expert supervised the process, and their recommendations were incorporated throughout the research. Furthermore, to ensure the validity and reliability of the qualitative data, the interview form was provided to the participants again, validating their responses and reviewing the responds in the form (Yildirim & Simsek, 1999).

To determine the appropriate analysis method, the normality of the distributions was first tested. Therefore, the Shapiro-Wilk test was used to assess the normality of the distribution. Since the sample size is less than 50, it is appropriate to use the Shapiro-Wilk test to evaluate the data's suitability for a normal distribution (Razali & Wah, 2011). In Table 1, which presents the academic achievement pre-test results for the experimental and control groups, it was observed that the distribution of test scores exhibited normality ($p > .05$), as indicated by the normality test result. Furthermore, the Shapiro-Wilk normality test was conducted to assess whether the post-test academic achievement test scores of the experimental and control groups exhibited a homogeneous distribution. As presented in Table 2, it was determined that the post-test academic achievement scores for both the experimental and control groups ($p > .05$) exhibited a normal distribution.

Table 1

Normality Values of The Pre-Test and Last Test

Group	Shapiro-Wilk (Predictive analysis)		
	Statistics	Df	Sig
Experiment of pre-test	.945	20	.299
Control of Pre-test	.925	21	.125
Experiment of last test	.970	20	.758
Control of last test	.958	21	.508

Finding

A pre-test was administered to the students to assess their prior knowledge before the application. According to the results of the independent groups t-test conducted for the test, it was concluded that the experimental and control groups obtained similar scores on the pre-test. Additionally, the number of boys and girls in the groups was proportionally similar, and they had equal conditions at the initial stage because they were students in the same branch.

Table 2 displays the number of students (N) who participated in the pre-test for both the experimental and control groups, along with the average pre-test scores, standard deviation values, and average error values. As the distribution was found to be normal, it was decided to conduct an independent sample t-test. As shown in Table 3, the pre-test results of the experimental and control groups, which represent the initial stage of the application process, were obtained through analysis of the independent t-test results. Upon examination of Table 3, it is observed that the mean value of the pre-test academic success scores for the experimental group (X_{pe}) is at 7.05, and the mean value for the control group (X_{pc}) is at 7.61. The independent samples t-test analysis revealed that there was no significant difference in terms of academic achievement results between the experimental and control groups (t=.970, p=.339 > .05).

Table 2

The independent t-test was conducted to compare the academic achievement scores of the Experimental and Control groups before the research (pre-test)

Group	N	Average	Standard deviation	t	p
			Pre-test		
Experiment	20	7.05	1.82		
Control	21	7.61	1.93	,970	,399
			Last test		
Experiment	20	22.20	3.63		
Control	21	16.19	3.24	5,578	,000

Upon examining the values in Table 3, it was noted that there were differences in the academic achievement test arithmetic averages between the experimental and control groups. Specifically, the arithmetic average test score of the students in the X_{le} (22.20) was higher than that of the X_{lc} (16.19). The results of the independent samples t-test analysis indicated a significant difference in terms of the academic achievement test variable among students in the experimental and control groups (FCM) within the learning environment. Qualitative analysis was conducted using a research table and coding method to measure opinions and attitudes. The results of this analysis are presented in the following Table 3. The data obtained from the interview forms was qualitatively analyzed using the descriptive analysis method. Through content analysis, the evaluations written by students on the semi-structured interview forms were carefully examined, focusing on 15 common themes: visual learning, enjoyable environment, teacher-learner interaction, active participation, effective learning, permanent learning, concrete learning, and social learning. Codes were assigned to capture aspects related to learning, interest and attitude, motivation, readiness, instant feedback and correction, interaction with technology, reinforcement of lessons, and attentional engagement.

Table 3

The results of qualitative analysis

Code	Frequency (N)
Visual-Concrete learning	7
Academic success	9
Remarkable	6
Active participation	12
Readiness	11
Interest -Attitude	12
Permanent learning	13
Social Learning	7
Level of Motivation	10
Reinforcement of the Lesson	11
Interacting with Technology	8
Effective Learning	11
Instant Feedback Correction	6
Teacher Student Interaction	5
Entertaining Application Environment	7

Some examples of students' thoughts and attitudes regarding the relevant codes in the interview form are as follows. For instance, concerning the theme of visual concrete learning, the opinions and thoughts of students A4, A9, A10, A11, A13, A14, and A19 were observed in the semi-structured interview form (SIF) questions. The common opinion among the participants was, "*I find teaching the lesson in a more visual and concrete way to be the most effective and useful aspect of this application.*"

In our second example, the opinions and thoughts of students A1, A3, A4, A7, A8, A9, A10, A11, A13, A15, A16, A17, and A19 were observed in the SIF regarding the relevant code for permanent learning. The common opinion among the participants was, "*Teaching the course using this model made the information we learned more permanent.*"

As the third example of the study, the common opinion expressed by participants regarding the relevant codes A1, A2, A4, A5, A10, A13, A14, A15, A16, and A19 for the motivation level was analyzed in the SIF with the following expression. After conducting content analysis, it was determined in the SIF that the common opinion of the participants was, "I believe that the way the course was taught increased our motivation for the course."

In our last example, students A5, A8, A13, A14, A15, A16, A18, A20, and A21 expressed their opinions on the relevant code for academic success. The common opinion among these participants was identified in the SIF with the following statement: "*I noticed that my success in the course increased, and I became more.‘’*

Discussion and Conclusion

In this model, students engage with instructional content outside of class, often through videos or online materials, and then participate in interactive activities, discussions, and problem-solving exercises during class time (Butt, 2014; Tawfik & Lilly, 2015). The study investigated the impact of the FCM on student academic performance and attitudes in science education. The results showed that both the experimental and control groups had similar academic achievement scores, with a slight increase favoring the experimental group. While there was no significant difference between the groups, the FCM led to improved academic achievement for students. The literature review supported these findings, indicating that students adopting the FCM tended to have higher academic success. Similar sentiments were observed in student opinions, showing potential for the FCM to enhance learning outcomes and promote positive attitudes towards learning. Studies by Aydın (2016) and Demiralay (2014) also highlighted the positive impact of the FCM on academic achievement, stress reduction related to homework, and improved student attitudes towards learning. Aydın (2016) studied 44 students, with 24 in the experimental group and 20 in the control group. Results showed that the Flipped Classroom Model (FCM) positively impacted academic success and reduced homework-related stress. Similar findings were seen in Demiralay's (2014) study, where the FCM improved student attitudes and success. Studies by Çakır (2017) and Turan (2015) further supported these results. Çakır (2017) found a significant increase in academic success among 7th-grade science students using the FCM, with positive student opinions. Turan (2015) saw similar results in the pre-school department, with increased academic success and student motivation. Overall, these studies highlight the FCM's positive impact on academic success, student attitudes, and motivation, suggesting its potential to enhance learning outcomes and student satisfaction.

During interviews with students, it was noted that they perceived FCM learning environment as conducive to better learning outcomes. Students expressed that they comprehended subjects more effectively and felt more motivated in such an environment. The overall student opinions and results indicate that the FCM learning environment positively influences student success and fosters interest and enthusiasm towards the course (Bishop and Verleger, 2013). Analyzing the students' attitudes and opinions revealed a notable increase in positive attitudes among those in the experimental group where the FCM learning environment was implemented, particularly towards Science Education courses. Learners reported experiencing no difficulties throughout the lessons, attributing this to the engaging and enjoyable nature of the FCM (Demiralay, 2014; Turan, 2015). Consequently, it can be inferred that courses delivered in the FCM learning model significantly contribute to enhancing student attitudes towards Science courses. In alignment with these findings, it was further revealed that the efficiency of courses conducted in the FCM learning environment, coupled with increased student interest, active participation, course appeal, and success rates, was notably higher among the experimental group students. Moreover, the collaborative and interactive nature of the FCM, fostering individual and group cohesion, and promoting a sense of common responsibility, led to a higher level of course meaningfulness. In summary, the FCM learning environment plays a crucial role in improving student attitudes towards Science courses, enhancing learning outcomes, and fostering a collaborative and engaging learning atmosphere (Li et al., 2022).

In conclusion, the analysis results indicate that the experimental group exhibited statistically higher levels of academic success compared to the control group. Furthermore, the results from the semi-structured interview forms revealed a positive and significant difference in the students' interest, attitudes, and opinions towards the FCM, which serves as the application model for the course. These findings are consistent with numerous studies, including our own research, demonstrating an increase in students' academic achievements and their positive reception of the model. As a result, this study suggests that the FCM is effective in enhancing the academic success of university students and addresses a gap in the existing literature on the FCM. It is anticipated that these findings will contribute to the utilization of the FCM in the General Chemistry IV course within the Department of Science Teaching and facilitate its more effective implementation in the future.

Recommendations

Future research in the field of education can focus on several key areas to enhance teaching methodologies and improve learning outcomes. One area of interest could be examining the effects of the FCM in a larger sample group across different subjects within the same department. Additionally, research could investigate the impact of the FCM on student academic success in various departments within Education Faculties. Another potential area of study is exploring the usability of the FCM among university faculty members.

Limitations

The study was conducted with a limited sample size, which may affect the generalizability of the findings to a larger population. A larger and more diverse sample could provide a more comprehensive understanding of the effectiveness of the FCM across different student demographics. The study was conducted over a specific period of time, and the effects of the FCM were observed within that timeframe. Longer-term studies could provide insights into the sustainability and long-lasting impact of the FCM on student academic success and attitudes. The study was conducted within a specific academic department and course. Different contextual factors, such as variations in teaching styles, student backgrounds, or institutional policies, could influence the outcomes and applicability of the FCM in other settings. The study utilized semi-structured interview forms and quantitative analysis methods. While these tools provide valuable insights, using additional assessment tools or methodologies could offer a more comprehensive understanding of the FCM's impact on student outcomes and perceptions. External variables, such as students' prior knowledge, motivation levels, or extracurricular activities, could have influenced the outcomes observed in the study. Controlling for these variables or conducting additional analyses could enhance the validity of the findings. It is important to acknowledge these limitations as they provide opportunities for future research to build upon the current study and further explore the effectiveness and potential challenges associated with implementing the FCM in science education.

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Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of interest

None

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