Bartın University Journal of Faculty of Education
BUEFAD Volume 14, Issue 4

1214-1239
dergipark.org.tr/buefad
DOI: 10.14686/buefad.1457403

Implementing STEM-FLIP in A Science Course: A Case Study*

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Research Article
Received: 22.3.2024
Revised: 2.9.2025
Accepted: 10.10.2025

Abstract

This study aimed to investigate the applicability of the flipped learning model supported by STEM activities (STEM-FLIP) in science courses by using the case study design, one of the qualitative research methods. The holistic single case model was selected to assess the perspectives of both students and teacher researcher on the STEM-FLIP tasks in the 8th-grade modules on energy conversion and environmental science. The study group consisted of 20 eighth-grade students. Semi-structured interviews, student diaries, and field notes were used as the data collection tools. Inductive content analysis was used to analyze the data. In the interviews, students stated that watching videos and doing activities out of class helped them prepare for the class and discover their learning styles. They also stated that the videos enabled them to learn flexibly by increasing the opportunity to take notes and make repetitions. Most students felt that the STEM-FLIP activities increased active participation in class and provided meaningful learning. During the in-class studies, students indicated that the STEM-FLIP activities were meaningful, enjoyable, and helped them transfer knowledge to everyday life. Teacher field notes indicated that students developed creative ideas through group activities, produced solutions to problems they encountered, and enjoyed creating products together. In addition, STEM-FLIP increased student interest and motivation in science education, improved their collaboration and communication skills, and increased their use of technology. Some suggestions were made in light of the research findings.

Keywords: Case study, energy conversion and environmental science, science education, STEM-FLIP

Fen Bilimleri Dersinde STEM-FLIP Uygulamaları: Bir Durum Çalışması

Öz

Bu araştırmada fen bilimleri dersinde STEM etkinlikleri ile desteklenmiş ters yüz öğrenme modelinin (STEM-FLIP) uygulanabilirliğini incelemek amaçlanmıştır. Araştırmada nitel araştırma yöntemi desenlerinden durum çalışması kullanılmıştır. Hem öğrencilerin hem de araştırmacı öğretmenin, 8. sınıf enerji dönüşümleri ve çevre bilimi ünitesinde STEM-FLIP uygulamalarına ilişkin bakış açılarını değerlendirmek amacıyla bütüncül tek durum modeli tercih edilmiştir. Araştırmanın çalışma grubunu 20 sekizinci sınıf öğrencisi oluşturmaktadır. Veri toplama aracı olarak yarı yapılandırılmış görüşme, öğrenci günlükleri ve saha notları kullanılmıştır. Verilerin analizinde tümevarımsal içerik analizi kullanılmıştır. Yapılan görüşmelerde öğrenciler ders dışı uygulamalarda video izlemenin, etkinlikler yapmanın derse hazır gelmeyi ve öğrenme stillerini keşfetmelerini sağladığını belirtmişlerdir. Aynı zamanda videoların not tutma ve tekrar yapma imkânını arttırarak esnek bir öğrenme ortamı sunduğu ifade edilmiştir. Öğrencilerin büyük bir kısmı uygulamaların derslere aktif katılımı arttırdığı ve anlamlı öğrenmeyi gerçekleştirdiğine yönelik görüşlerini açıklamışlardır. Ders içi uygulamalarda ise öğrenciler STEM etkinliklerinin anlamlı öğrenmeyi, eğlenerek öğrenmeyi ve bilginin günlük hayata transfer edilmesini sağladığını ifade etmişlerdir. Öğretmenin saha notları incelendiğinde öğrencilerin grupça etkinlikler yaparak yaratıcı fikirler geliştirdikleri, karşılaştıkları problemlere yönelik çözümler ürettikleri ve birlikte ürün oluşturma mutluluğu yaşadıkları tespit edilmiştir. Aynı zamanda araştırmacı STEM-FLIP ile öğrencilerin fen dersine yönelik ilgi ve motivasyonlarının arttığını, iş birliği ve iletişim becerilerinin geliştiğini ve teknoloji kullanımının arttığını tespit etmiştir. Araştırma bulguları doğrultusunda önerilerde bulunulmuştur.

Anahtar Kelimeler: Durum çalışması, enerji dönüşümleri ve çevre bilimleri, fen eğitimi, STEM-FLIP

To cite this article in APA Style:

Kurtel, E., & Nacaroğlu, O. (2025). Implementing STEM-FLIP in a science course: A case study. *Bartın University Journal of Faculty of Education, 14*(4), 1214-1239. https://doi.org/10.14686/buefad.1457403

*This research was produced from the first author's master's thesis.

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INTRODUCTION

STEM (*S*cience-*T*echnology-*E*ngineering-*M*athematics) education is a teaching approach that emphasizes interdisciplinary practices by linking at least two STEM disciplines (Bybee, 2010). Gaining global importance (Wang et al., 2022), STEM offers many contributions to students (Takeuchi et al., 2020). STEM education enables students to participate in scientific study by including their interests and experiences (National Research Council [NRC], 2011), aiming to increase students' scientific literacy and international competitiveness (European Commission, 2016). Pimthong and Williams (2018) assert that STEM education is an important approach in preparing students for their professional career paths. Stehle and Peters-Burton (2019) emphasize that STEM education provides appropriate learning environments to develop students' 21st century skills. Some studies have also reported that STEM education positively contributes to academic achievement (Chang et al., 2024; Olivarez, 2012), motivation (Lynch et al., 2017; Shurygin et al., 2023), STEM literacy (Falloon et al., 2020; Tati et al., 2017) and attitude (Guzey et al., 2016; Toma & Greca, 2018). In addition, STEM education helps develop various student skills such as critical thinking (Hacıoğlu & Gülhan, 2021), metacognitive thinking (Anwari et al., 2015), and problem solving (Yuliati et al., 2018). However, it has not been effectively implemented in many countries due to weak associations between knowledge and the real world, as well as lack of support (Honey et al., 2014; Thomas & Watters, 2015). Consequently, there are issues (e.g. lack of materials, time problems, and lack of learning pedagogies) that must be addressed in STEM education (Fung, 2020; Mutambara & Bayaga, 2021).

In STEM education, teachers may experience difficulties related to the curriculum (Margot & Kettler, 2019) and designing STEM activities (Sungur Gül et al., 2023). The assessment of interdisciplinary learning in STEM disciplines is considered a challenging process (Gao et al., 2020). One of the major issues confronted in STEM education pertains to managing time effectively (Nadelson & Seifert, 2017). It is crucial to allow students adequate time to solve problems that are oriented around STEM (Portz, 2015). To address current challenges, integrating the Flipped Learning Model (FLM) into STEM education is recommended (e.g. Dodds, 2015; Kone, 2022; Misbach & Rilianti, 2022; Ramírez et al., 2014). The rationale is that STEM education activities require a lot of labor and time (Misbach & Rilianti, 2022). FLM, one of the blended learning approaches, integrates in-class and out-of-class learning environments and facilitates the practical application of theoretical knowledge (Bergmann & Sams, 2014; Kim et al., 2014). FLM enhances learning opportunities outside the classroom and enables high-level cognitive activities within classroom settings (Bishop & Verleger, 2013). Especially during the COVID-19 pandemic, the significance of FLM in learning environments increased. FLM facilitates the acquisition of recall and comprehension level outcomes outside the classroom, while high-level outcomes are obtained in the classroom (Davies et al., 2013). Thus, FLM offers a versatile learning platform (Bergmann & Sams, 2012), which enables students to utilize their learning time productively and achieve mastery-level learning (Lafee, 2013; Milman, 2012). FLM's incorporation of activities in which students actively participate allows for closer observation of student progress and learning levels by teachers (Bergmann & Sams, 2014; Talbert, 2012). Additionally, students can obtain feedback from their teachers or peers, both inside and outside the classroom (Rahman et al., 2020). Due to its numerous advantages, the implementation of FLM in STEM education is considered effective in addressing encountered obstacles (Karunia & Ridlo, 2022; Sartika, 2019; Wibawa & Kardipah, 2018). The research identifies FLM practices facilitated by STEM activities, collectively termed STEM-FLIP. Figure 1 illustrates the planning of STEM-FLIP activities within this framework.

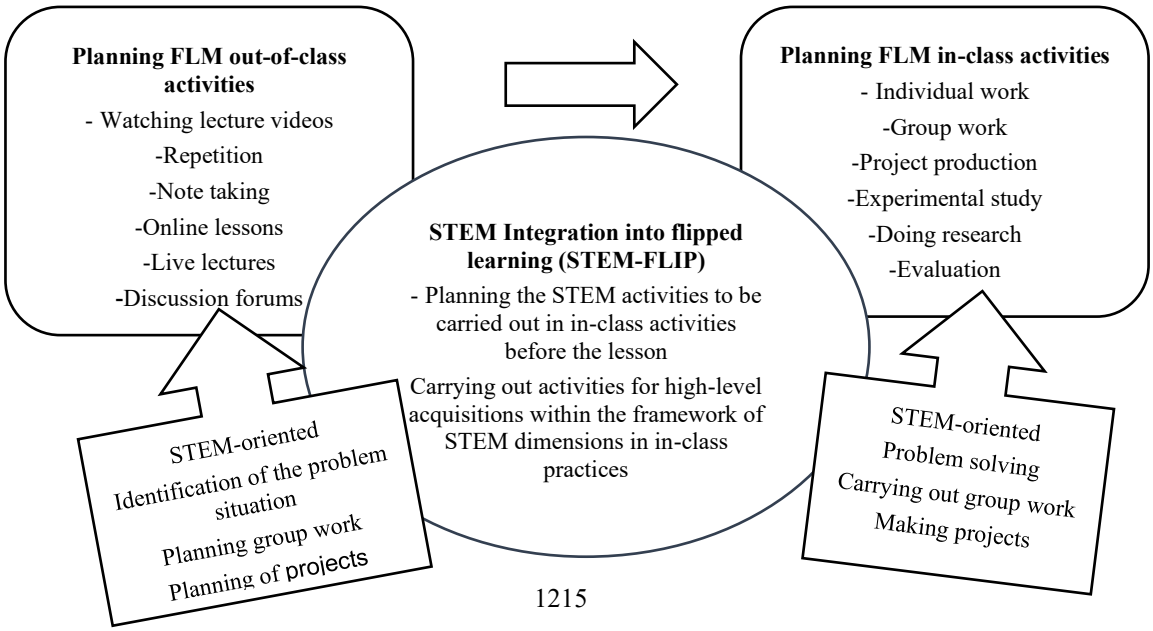


Figure 1. *STEM-FLIP implementation process*

As can be seen in Figure 1, STEM-FLIP practices can be summarized as planning STEM activities to be carried out in the classroom during out-of-class time, and carrying out activities that achieve high-level outcomes with STEM activities during in-class time. In this way, it is believed that the difficulties encountered in STEM education can be overcome (Fung, 2020) and students can be given the opportunity to apply the theoretical knowledge they have learned to real-life problems (Sitole, 2016). The related literature reports that STEM-FLIP activities make many contributions to students (Karunia & Ridlo, 2022). For example, STEM-FLIP practices have been found to contribute to the development of students' critical thinking, creative thinking, and problem-solving skills (Baharin et al., 2018; Sartika, 2019). Ramírez et al. (2014) found that FLM enables STEM students to learn the content better by providing learning flexibility and increasing their motivation. Wibawa and Kardipah (2018) concluded that FLM can improve students' performance in STEM education, and FLM and STEM can be two compatible models in terms of active participation and meaningful learning. Talley and Scherer (2013) stated that STEM-FLIP activities contribute to student achievement and meaningful learning. Ding and Zhu (2021) asserted that utilizing FLM in STEM education can provide distinctive prospects such as extensive participation, communication, collaboration, and time management. Fung (2020) affirmed that STEM education with FLM is more practical and presents more opportunities for students to engage in hands-on work. Karunia and Ridlo (2022) also found that STEM-FLIP activities enhance critical thinking abilities. Sartika (2019) further confirmed that FLM significantly contributes to students' meaningful learning. However, Fung (2020) and Sergis et al. (2017) recommended conducting more research on how FLM assists STEM education across diverse cultures and subjects.

Literature Review

FLM is a sub-model of the blended learning model developed by Staker and Horn (2012). In practical terms, it allows students to learn theoretical knowledge outside of school using online communication technology and apply that knowledge during in-class activities, as described by Bergmann and Sams (2012). Additionally, Wanner and Palmer (2015) suggest that FLM promotes active participation in high-level activities during lessons. In fact, this situation allows for the development of skills like analysis, synthesis, project work, problem-solving, communication, and cooperative learning (Bergmann & Sams, 2012; Roach, 2014). Consequently, FLM reverses Bloom's taxonomy (See Figure 2).

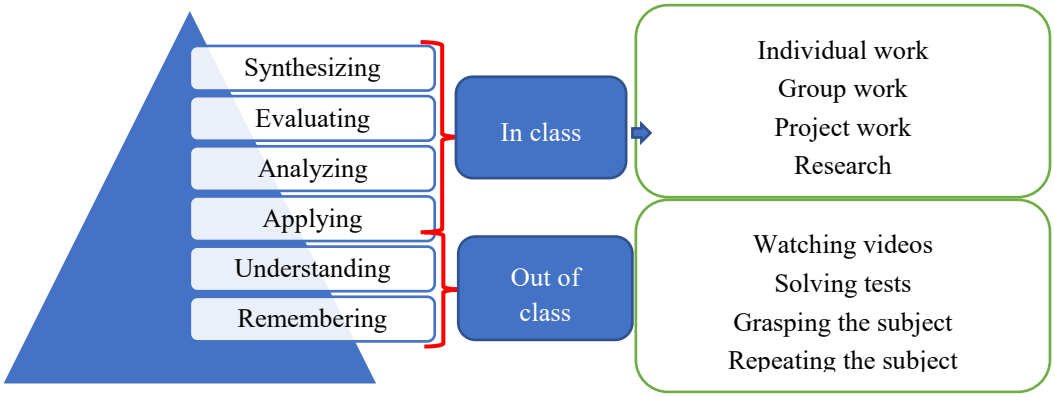


Figure 2. *Bloom's taxonomy in FLM (Hayırsever & Orhan, 2018; Nacaroğlu & Bektaş, 2023)*

As can be seen in Figure 2, FLM aims to provide students with learning outcomes at the recall and comprehension levels outside of class, while other higher-level steps are intended to be acquired during class (Divjak et al., 2022), which increases the time allocated to in-class activities and enables the development of higher-level learning in which students are active (Bergmann & Sams, 2014; Talbert, 2012). A review of the literature shows that many studies have been conducted on the effectiveness of FLM in science education (e.g., Doğan et al., 2023; Serrano Amarilla et al., 2022; Widodo, 2022). For example, Jdaitawi (2020) found that the use of FLM in science education has a positive effect on students' sense of learning. Zheng et al. (2020) concluded that FLM has a moderate effect size on academic performance and learning motivation. Nja et al. (2022) found that FLM had a positive effect on students' attitudes toward the course. These studies provide evidence for the benefits of using FLM in science education. Although the studies in the literature enable practitioners and students to adopt FLM, further in-depth research is needed (Colomo Magaña et al., 2020; Doğan et al., 2023).

The recent literature shows an increase in studies that combine STEM education and FLM (e.g., Aspridanel et al., 2022; Cheng, 2023; Fung, 2020). According to Erkan and Duran (2023), STEM-FLIP activities positively impact students' scientific creativity and STEM interests. Fung et al. (2022) concluded that FLM is an effective approach in STEM education and enhances students' 21st century skills. Jeong et al. (2020) noted that students can focus on STEM activities utilizing FLM and experience a positive effect on their learning performance. Kay and Dermott (2018) emphasized the potential suitability of using FLM in STEM-based activities due to its emphasis on active participation. On the flip side, STEM-FLIP activities encounter challenges including students' incapacity to concentrate on videos (Yeung, 2014; Yong et al., 2015), deficiencies in self-control (Foertsch et al., 2002), insufficient extracurricular implementations, incapability to offer instantaneous feedback (McCleery, 2015), failure to correctly plan activities during lessons (Wasserman et al., 2017), and an excessive workload for learners (Smith, 2013). However, a review of the literature suggests that the impact of STEM-FLM activities has not been adequately studied (Cheng, 2023).

Current Study

In the current study, the aim was to explore student and teacher views on STEM-FLIP practices in science courses in depth. Practitioner teachers, flexible learning environments, and learning cultures are emphasized as the key components of FLM (Flipped Learning Network [FLN], 2014). Therefore, examining the views of students and teachers is considered important to obtain detailed data on their implementation. Additionally, in the current research, activities were planned according to unit energy conversion and environmental sciences.

When the achievements in this unit are examined, students are expected to gain knowledge and skills regarding the concepts of energy transformation and matter cycles, understand environmental problems, and propose solutions to these problems (Ministry of National Education [MoNE], 2018). Since it is necessary to conduct interdisciplinary research-based and application-oriented in a sustainable environmental education (Christie et al., 2013; Kopnina, 2020), STEM-FLIP activities were planned within the scope of this unit. By integrating FLM into STEM education, it is aimed to include the strengths of both approaches in the learning process. Although the contributions of this model to students are emphasized in the literature, it is important to examine its effects on students in more depth. Ting et al. (2020) stated that students can participate in problem-based learning activities with the use of FLM in STEM education, and suggested that qualitative studies should be conducted to reveal its effect on students in more detail. Jung and Hong (2020) suggested that further research should be conducted to implement FLM in STEM classrooms.

As such, the answers to the following questions were sought:

- What are the students' views on teaching the 8th grade energy conversion and environmental sciences unit according to the STEM-FLIP model?
- What are the researcher observations on teaching the 8th grade energy conversion and environmental sciences unit according to the STEM-FLIP model?

METHOD

Research design

In this study, the case study design was used to examine the applicability of STEM-FLIP in the 8th-grade science course. Case study allows for an in-depth examination of one or more limited situations by using more than one data collection tool and creating a deep perspective with rich descriptions (Hancock & Algozzine, 2006; Creswell, 2007). In other words, case study is in-depth research using multiple data sources without intervening in a situation by focusing on how and why questions (Yin, 1984). There are different case study models in the literature. In this study, the holistic single case model, one of the case study models proposed by Yin (1984), was preferred. In the holistic single case model, a single case focuses on a single situation and the study is conducted by considering a single case such as an institution, program, practice, individual, or school (Yıldırım & Şimşek, 2021). For this investigation, a comprehensive single-case design was selected to assess the perspectives of both students and teacher researcher on the STEM-FLIP tasks in the 8th-grade modules on energy conversion and environmental science.

Study group

The study group consisted of 20 eighth-grade students. Semi-structured interviews were conducted with nine of these students. Maximum diversity was considered in selecting the students to be interviewed, and nine

students were included in the interview, three students each with low, medium, and high participation in the activities. The general characteristics of the students in the study group are described below. Students who were interviewed are indicated with an asterisk (*).

*S1: She is a student with moderate academic achievement. She is responsible.

*S2: A student with good academic performance. She is passive in class participation. She is reluctant to express what she knows.

S3: A student with good academic performance, but at a level that could be better.

S4: She is a boarding student who fulfills her responsibilities in the dormitory.

S5: She is a student with low academic success. At the same time, she cannot attend some classes because she is undergoing physical therapy.

*S6: He is a student with good academic performance. He does not have regular study habits.

S7: His academic performance is very poor. He is reluctant to take responsibility.

S8: He is a student with moderate academic performance. His participation in class is low.

S9: He is a student with low academic achievement. Does not like to take responsibility. He has good communication with his friends.

S10: She is a student with low academic achievement and low class participation.

S11: She is a student with low academic achievement, and has difficulty expressing himself in class.

S12: He is a student who likes to look at things from different perspectives, but does not like to study and does not do her homework regularly. He is not responsible.

S13: He is a student with low academic achievement and is not interested in class.

*S14: He is a student with low academic achievement. Although he is a student who does not do his homework, his participation in class is good and he approaches problems in a solution-oriented way.

S15: She is a student with poor academic performance, but she fulfills his homework and responsibilities.

*S16: Her academic achievement is moderate. She works hard in her classes but her attendance and is a student who is inadequate in expressing what she knows.

*S17: She is a student with moderate academic achievement. She fulfills his homework and responsibilities.

*S18: Her academic achievement is at an average level. Although she has the capacity to do better, she does not study regularly.

*S19: She is a student with good academic achievement. She has regular study habits, knows what he wants and works in line with her goals. She likes to study with her friends.

*S20: Her academic achievement is lower in numerical courses than in verbal courses. She cannot study efficiently. Her communication with her friends is strong.

Data Collection Tools

Semi-structured interviews, student diaries, and field notes were used as data collection tools.

Semi-structured Interview

Semi-structured interviews allow the comparison of information obtained by systematically collecting data from different individuals (Polat, 2022). In this study, the interview was preferred as a data collection tool to allow the participants to express themselves better, to be easily analyzed, and to conduct in-depth analysis on the topic if needed. A semi-structured interview form was prepared by the researcher to determine the students' views on STEM-FLIP (Appendix 1). To make the questions clear and understandable to the students, they were first submitted to expert opinion. In line with expert opinion, the interview questions were arranged to cover in-class and out-of-class activities. The necessary permissions were obtained prior to the interviews in accordance with ethical rules, and it was explained to the participants that the data obtained would not be used in any way outside the research. The researcher conducted semi-structured interviews with nine students identified after the six-week implementation. The interviews were conducted one-on-one in a place where the students felt comfortable (library and lab).

Student Diaries

Through diaries, researchers can closely monitor participants' learning processes and make arrangements to support their learning (Nunan, 2002). In this study, the researcher aimed to determine the difficulties

encountered by the students in the implementation, their level of participation in the activities, what they learned, and their feelings and thoughts about the implementation with the help of diaries. For this purpose, the researcher had the students keep out-of-class diaries for out-of-class STEM-FLIP activities and in-class diaries for in-class activities (Appendix 2 and Appendix 3). Within the scope of the research, all students were asked to keep diaries. In-class diaries were filled out by students at the end of the course. Out-of-class diaries were kept by students before coming to class. The teacher examined the diaries kept every week before the lesson started and talked to the students about their diaries.

Field Notes

Field notes are data collection tools in qualitative research in which the researcher expresses his/her observations, experiences, feelings, and thoughts by taking short notes during the implementation process. The notes taken by the researcher according to the situation of the students regarding in-class and out-of-class practices are clues. As a matter of fact, the internal and external validity of field research is high because it is conducted by the researcher in the research environment (Bhattacharjee, 2012). The researcher takes notes in the first way that comes to mind so as not to forget, and then reviews and re-evaluates these notes. The field notes kept by the researcher were handwritten to save time. Field notes helped the researcher to preserve and record his/her observations and findings during the research process. The field notes included observations about difficulties encountered during the research process, successes, and student behaviors. The field notes kept by the researcher were shared with the expert. Evaluations were made with an expert and if there was a problem, planning was made to prevent this problem from occurring again. The field notes helped to obtain accurate and detailed data (Appendix 4).

Data Collection Procedures

In this study, data were collected in the spring semester of the 2022-2023 academic year. Six-week lesson plans were prepared in line with the research purposes. Before preparing the lesson plans, the researcher conducted interviews with a science education specialist. This interview focused on topics such as lesson plans for STEM-FLIP implementation, activities to be carried out, and preparation of lesson videos needed for out-of-class activities. After planning the topics to be covered, draft lesson plans were prepared by the researcher taking into account the expert opinions. For each problem encountered during the implementation, the necessary changes were made, if needed, through interviews with the expert. The researcher met with the expert every week before and after the implementation of the lesson plans. The interviews focused on the problems encountered by the researcher and the issues related to his observations in situations such as accessing and watching videos, delivering worksheets to students, and conducting in-class STEM activities for the out-of-class FLM activities. In preparing the lesson plans, the REACT strategy of contextualized learning was taken into consideration. The Relating and Experiencing stages of the REACT strategy were applied in the out-of-class FLM activities. The course video and worksheet were delivered to students via the Education Information Network (EBA). Students were asked to fill out the worksheets and send them to their teachers via EBA. In addition, it was checked whether the students did out-of-class activities or not using a communication tool (WhatsApp). The aim of these practices is to ensure that students come to class prepared. The Applying, Cooperating, and Transferring stages were used in the in-class activities (Figure 3).

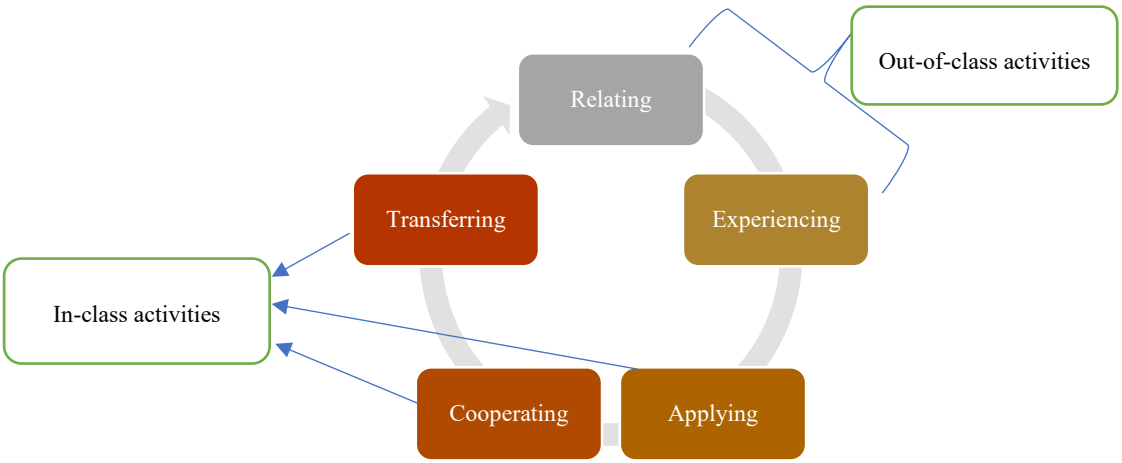
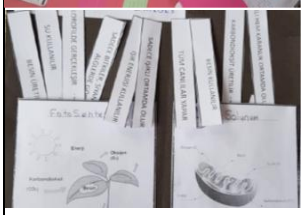


Figure 3. *Adaptation of the REACT strategy to STEM-FLIP activities*

The Relating stage aims to learn in the context of daily life (Crawford, 2001). The context is presented to students in the form of a scenario, picture, newspaper article, and students are expected to establish a correct relationship between their previous experiences and prior knowledge (Crawford, 2001). In the Experiencing stage, students focus on real-life problems (Asmahasanah et al., 2018). At this stage, it is important for students to access information on their own (Crawford, 2001). The Applying stage is the stage where students develop a deeper sense of understanding, during which they solve problems and carry out project activities related to the concepts they want to learn (Asmahasanah et al., 2018; Crawford, 2001). At this stage, it is important for students to understand the necessity of learning the new concept and to be willing to learn this concept. In the Cooperating stage, students share the information they have learned with each other and benefit from the experiences of their peers (Navarra, 2006). In the Transferring stage, students adapt the concepts they have learned to different situations (Crawford, 2001). The reason for choosing the REACT strategy in the current research is that it allows planning in-class and out-of-class practices within the framework of FLM. With the Relating and Experiencing stages, students are given the opportunity to identify a problem situation and experience it. High-level classroom activities can be planned within the framework of the implementing, cooperating and transferring stages. The practices carried out during the research within the framework of these steps are presented in Table 1.

Table 1. In-class and out-of-class activities during the data collection process

	Out-of-class activities	**In-class activities**	**Example**
Week 1	**Relating stage** ✓ Sending the lesson video ✓ Scenario (Bees) **Research question:** What can be done for bees to continue their existence in the ecosystem? Do research within the framework of this question. Plan your solution suggestions that will answer this problem until the lesson time. **Experiencing stage** ✓ Identifying living things in the environment ✓ Creation of food web and food chain	**Applying stage** ✓ Discussion of solution proposals related to the research question ✓ Making a design for solution proposals ✓ Making cost analysis related to the design **Cooperating stage** ✓ Presentation of design drawings ✓ Evaluation of ideas for design drawings and cost analysis ✓ Reviewing the prototypes **Transferring stage** ✓ Designing and presenting designs for solution proposals ✓ Researching different endangered living groups and proposing solutions	 
Week 2	**Relating stage** ✓ Sending the lesson video ✓ Scenario (LED technology for growing plants) **Research question:** What can be done to increase the rate of photosynthesis in plants? Do research to answer this question. Plan your solutions to this problem until the lesson time. **Experiencing stage** ✓ Determination of factors affecting photosynthesis, drawing graphs of these factors ✓ Making a leaf model describing photosynthesis	**Applying stage** ✓ Discussion of answers to the research question ✓ Deciding on solutions in line with the hypotheses developed **Cooperating stage** ✓ Groups test hypotheses and share results **Transferring stage** ✓ Creating different setups where hypotheses can be tested	 

Week 3	**Relating stage** ✓ Sending the lesson video ✓ Scenario (Respiratory event) **Research question:** What is the importance of respiration for living things? What kind of respiration do living things do? What is the importance of breathing exercises for a healthier life? Conduct research to answer these questions. Design a poster in line with the research you have done. **Experiencing stage** ✓ Investigating photosynthesis and oxygenated respiration ✓ Activity to create photosynthesis and respiration pockets	**Applying stage** ✓ Let's observe the changes in the balloon activity ✓ Predict-observe-explain activity **Cooperating stage** ✓ Brainstorming for the posters to be designed ✓ Drawing for poster design **Transferring stage** ✓ Design and presentation of posters ✓ Performing breathing exercises ✓ Sharing the knowledge learned with the immediate environment	  
Week 4	**Relating stage** • Sending the lesson video ✓ Scenario (Ecosystem and cycles) **Research question:** What are the factors that enable the plant to survive? Which other plant species can adapt to these conditions? Research the environments that provide the necessary conditions for living things to live for many years. Design your own aquarium based on your research. **Experiencing stage** ✓ Drawing of the water cycle ✓ Writing the story of the journey of water	**Applying stage** ✓ Aquarium design drawing ✓ Deciding on the design ✓ Making the design **Cooperating stage** ✓ Exchanging ideas about the positive and negative aspects of the aquarium ✓ Presenting suggestions for improving the design **Transferring stage** ✓ Designing a closed ecosystem by using jars	 
Week 5	**Relating stage** ✓ Sending the lesson video ✓ Scenario (saving water) **Research question:** What are the effects of global climate change and environmental problems on the Earth and human life? What are the problems that will be encountered as a result of not using resources economically? What can be done to increase the economic use of resources and reduce environmental problems? Do research to answer these questions. Plan your solutions to these problems until the lesson time. **Experiencing stage** ✓ Conducting research on environmental problems ✓ Creating a news column	**Applying stage** ✓ Discussion of solution proposals for the research questions ✓ Poster and project design **Cooperating stage** ✓ Presenting the designs ✓ Identifying the shortcomings of the designs **Transferring stage** ✓ Implementation of the ecological footprint test ✓ Reporting of test results	 

Week 6	**Relating stage** ✓ Sending the lesson video ✓ Scenario (recycling) **Research question:** Considering that resources can be depleted if not used sparingly, what can we do as citizens to contribute to recycling? Research materials that can be recycled. Design recycling products by examining the reusable items around you. **Experiencing stage** ✓ Writing slogans about recycling ✓ Making a list of household waste	**Applying stage** ✓ Exchanging ideas about the design of recycling products ✓ Making designs **Cooperating stage** ✓ Presentation of designs ✓ Identifying the deficiencies in the designs through group discussions **Transferring stage** ✓ Collection of unused items, toys and excess stationery ✓ Creation of a donation box for old items ✓ Organizing a campaign to deliver the goods to those in need	 

Data Analysis

Inductive content analysis was used to analyze the data obtained in the study. Content analysis is based on summarizing the data obtained through deduction or induction (Drisko & Maschi, 2016). Inductive content analysis involves the process of arriving at themes from the codes obtained from the research data (Elo & Kyngäs, 2008). In this regard, open coding, categorization, and summarization stages were used in the current study (Sütcü et al., 2022). First, the data obtained from semi-structured interviews and diaries were analyzed individually by the researchers. In this context, interviews with nine volunteer students and diaries of all students were included in the analysis. Meaning clusters were formed by coding similar statements made by students that supported each other. Then, categories were formed by examining the relationships between the codes and themes that fit the categories were determined. Similarly, codes were created by analyzing the field notes taken by the researcher. These codes were classified into specific categories and analyzed under the heading of weekly themes. The codes, categories and themes obtained in the analysis conducted by the researcher were finalized by taking the opinion of an expert. Analysis continued until a consensus was reached between the expert and the researcher. For example, student opinions regarding out-of-class activities were collected under four categories by the researcher. By obtaining expert opinion and conducting repeated interviews with the expert, the positive and negative aspects of out-of-class activities were grouped into two categories.

Validity and Reliability

In the present study, a number of strategies were employed to ensure validity and reliability. Long-term interaction, participant confirmation, direct quotation, and triangulation strategies were used to increase the internal validity (credibility) of the study (Creswell, 2003). As part of the long-term interaction, the researcher was in constant communication with students in classroom and out-of-class learning environments, made field observations, and collected in-depth data as a participant observer (Shenton, 2004). Triangulation involved the inclusion of corroborating or refuting sources in the qualitative research process through the use of interview, observation, and document data collection tools (Denzin & Lincoln, 2005). For participant confirmation, a voice recorder was used in the interview and the data collected was confirmed by the participants. In other words, during and after the data collection, the researcher tried to achieve harmony by discussing the data obtained by the researcher or the judgment made from these data with the participants participating in the research (Guba, 1981). The data collected in the findings section were presented as direct quotes. External validity, also known as transferability in qualitative research, highlights the capability of the study outcomes to be applied to comparable situations and contexts (Houser, 2015). To enhance the external validity of the study, the paper provides detailed information on the research model, study sample, data collection techniques, data analysis, and presentation of the findings. The researcher remained impartial throughout the study. Moreover, participant names were coded to ensure anonymity. The results section includes direct quotations from participants' perspectives. To enhance the trustworthiness of this study, internal and external reliability tests were undertaken (Lincoln & Guba, 2013). The interview-derived information was coded by a different researcher, and the coherence among the concepts was verified. To enhance internal reliability, no subjective evaluations were included while presenting the results and qualitative data were directly recorded. Purposeful questions were used during the data collection phase to address research inquiries. Additionally, a peaceful atmosphere was maintained during the interviews, allowing the

participants to freely express themselves. Interviews were recorded on voice recorders with participants' consent to prevent data loss. The consistency of the research was increased accordingly. In order to boost external reliability, the findings are presented in the discussion and conclusion section, supported by the relevant literature.

Research Ethics

Ethical approval has been received from the Sivas Cumhuriyet University Scientific Research and Publication Ethics Board with the decision date of 27.12.2022 and number of 245530.

FINDINGS

Student Views on STEM-FLIP

As part of the research, all students kept diaries of both in-class and out-of-class practices, and semi-structured interviews were conducted with nine students at the end. The data from the diaries and interviews were analyzed and the findings are presented under the themes of before and during class. Table 2 shows the results related to the "pre-lesson" theme.

Table 2. Student Opinions on Out-of-Class STEM-FLIP Practices

Category	Code
Positive aspects of out-of-class practices	Facilitating learning (S1, S2, S6, S14, S16, S17, S19, SS20) Coming to class prepared (S1, S2, S3, S6, S14, S16, S17, S19) Flexible time and ease of note-taking (S2, S3, S16, S19, S20) Increasing class participation (S14, S16, S19, S20) Reinforcing learning (S6, S14, S19) Fun (S6) Boosting self-confidence (S20)
Negative aspects of out-of-class practices	Access to video (S1, S14, S16, S17, S19, S20) Lack of materials (S1, S14, S16, S17) Getting feedback (S20)

When Table 2 is analyzed, it is seen that a significant portion of the students stated that watching the lesson videos and doing the activities before the lesson facilitated their learning. For example, S16 stated, "It helped me a lot. I learned about the subject before coming to the class. It made learning, easier and watching videos in this way was more effective." S19 stated, "...I answered the questions more easily because I had watched that video before. I had my own prior knowledge." Eight of the students stated that the out-of-class practices enabled them to come to the lesson prepared by doing detailed research. For example, S19 stated that "When a question was asked in the lesson, I remembered the topics because I had watched that video before and answered the questions more easily." In support of this, S19 stated in his diary: "I liked watching this subject of the science course from the lecture video because it helped me to have prior knowledge about the course. I felt like I was in the lesson; it helped me get information." Some of the students stated that the out-of-class practices increased their active participation in the lesson within the framework of coming prepared for the lesson. For example, S20 explained his opinion as follows: "Since I watched the lesson videos beforehand, I participate in the lesson better by using the information I learned." Five of the students stated that the out-of-class applications provided ease of note-taking by creating flexible time. For example, S2 said, "First, I watched the lesson videos you posted on EBA. Then I stopped the videos and took small notes of them. Then I got help from those notes while doing the activities. Thus, it made it easier for me to do the activity and learn," while S3 explained his opinion as "While listening to the lesson, we can stop the video and take notes.". In support of this, S3 stated in his diary, "I liked watching this subject of the science course on the lecture video because I could stop the video and take notes.". S19 expressed his opinion as follows: "Instead of listening to the lesson in a boring way at school, I can go home and listen to it when I am in a good mood during the time we want to listen to it. I can stop the videos and take notes."

Four of the students stated that watching lecture videos and doing activities before the lesson increased their active participation in the lesson. For example, S14 stated that "Since I watched the lesson videos beforehand, I was able to participate in the lesson by using the information I learned," while S16 stated that "I watched videos before coming to the lesson, and when I did such activities, I participated more actively in the lesson and expressed myself better." Three students stated that out-of-class practices reinforced learning. For example, S19 stated that "In the activities, I gained more knowledge, and the information I learned was reinforced.". In support of this, S19 stated the following in his diary: "I liked watching this subject of the science lesson from the lesson video; I liked

it very much because it reinforced my knowledge with examples." S6, who stated that watching the lesson videos and doing activities made the lesson fun, expressed her opinion as "The lesson became fun," expressed this in her diary by saying "I liked watching this subject of the science lesson from the lesson video because they are fun." In addition, S20 stated that watching the lesson videos and doing activities before the lesson increased her self-confidence: "Since I knew the subject before coming to the lesson, I felt confident, and my participation in the lesson increased a lot."

Looking at Table 1, it is clear that some students encountered several problems during the out-of-class practices. Six of the students stated that they had problems accessing the video. For instance, S14 said: "I sometimes had problems accessing the video." Four of the students mentioned having problems with lack of materials. For example, S1 pointed at "the limited opportunities in terms of the materials we need to use," while S14 said "Sometimes I had problems because I could not access the material." S20, who stated that he had problems getting feedback from his friends, explained it by saying "I had some difficulty communicating with my friend," and supported this opinion in his diary with "When I called my friend to ask something about the activity, I could not reach him." Table 3 shows the findings related to the theme during the lesson.

Table 3. Student Opinions on STEM-FLIP Activities during the Lesson

Category	Subcategory	Code
Learning style during the activities	Participation in individual work	Challenging (S1, S6)
		Effective (S16)
		Fun (S19)
	Participation in group work	Creative ideas (S1, S16, S17, S19)
		Division of labor and joint decision making (S2, S6, S16, S19)
		Ability to use time effectively (S2, S3, S19, S20)
Contribution of the activities	Contribution to learning	Facilitating learning (S1, S2, S3, S14, S16, S17, S19, S20)
		Increasing motivation (S3, S14,S16, S17, S19, S20)
	Contribution to problem solving and creative thinking	Ability to generate alternative solutions (S2, S3, S6, S16, S17, S19)
		Ability to generate new ideas (S1, S3, S6, S16, S17, S19)
		Developing problem-solving skills (S1, S14, S16)
	Contribution to technology use	Ability to conduct detailed research (S1, S2, S6, S14, S17, S16, S20)
		Enriching learning (S2, S16)

Focusing on Table 3, it can be seen that two students had difficulties with individual work during the lesson. For example, S6 said, "Sometimes I can't think of anything. I cannot find an idea, and I have a hard time." S16, on the other hand, stated that individual work was more effective: "I can do the activity better because I research and learn the subject beforehand." S19, who evaluated the activities during the lesson in terms of individual work, stated in his interview that he found it to be fun. While S19 explained his opinion as "It was fun to work individually; for example, when I was designing a recycling product, I did what I wanted directly because I planned it in my head," he supported this situation in his diary with the statement "Working individually in this week's recycling activity was better and more fun than some other studies." S16, on the other hand, stated that individual work was more effective and explained his opinion as follows: "I could do the activity better because I had researched and learned the subject beforehand."

Examining Table 3, four of the students stated that group work during the lesson enabled creative ideas to emerge. For example, S16 expressed his opinion as "Friends come with different ideas. That's why our project ends up better," and in his diary he supported this view by saying, "I realized the importance of working as a team while doing the project. We gave each other different ideas, and we got along well." Four of the students stated that participation in group work enabled division of labor and making joint decisions. For example, S2 said, "For example, individual work is also good, but when we are in groups, we both present our common ideas, make a common decision, and do the activity." Most of the students stated that the activities during the lesson facilitated learning. Regarding this, S3 explained his opinion as "the activities helped us learn the subject more easily." S16 explained this in his diary as "...doing projects and activities in the lesson helped me to keep the subject in my mind better."

Six of the students stated that the activities during the lesson enabled them to produce alternative solutions to problems. S2 expressed his opinion about this as follows: "For example, when we did a water-saving project,

there was a glitch. It started to leak when we were placing the pipes. Then we discussed how to fix this problem. We all offered our ideas and reached a common ground, and then we tried it together. Our project worked." Similarly, six students stated that the activities during the lesson contributed to generating new ideas. For example, S19 said, "When we were doing a recycling project, since everyone was an individual, everyone put forward their own ideas. Good ideas came out. We developed our creativity by doing something new to be used." Three of the students stated that the activities during the lesson improved their problem-solving skills. Regarding this, S1 said the following: "When I had a problem, I could produce a better solution to that problem." Seven of the students stated that the use of technology enabled them to conduct detailed research. For example, S20 said, "Technology helped us a lot in this process. We used technology both for watching the videos and for doing research." S16 stated: "when we encountered a problem, we solved the problem with the help of technology. It helped us come up with many ideas while doing the project."

Researcher Field Notes on STEM-FLIP

Field notes were kept by the researcher throughout the six-week implementation. The results of the first week are presented in Figure 4.

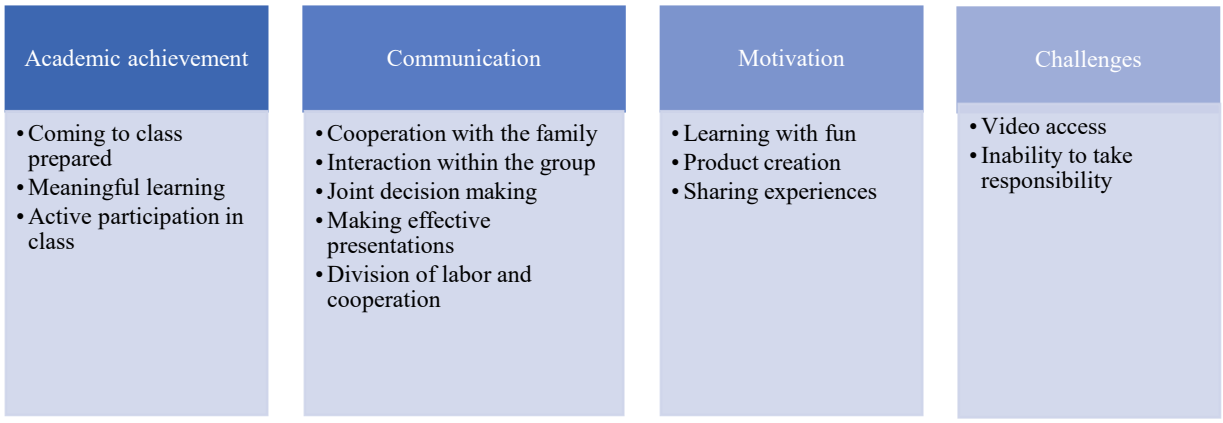


Figure 4. *Results from the Field Notes for the First Week*

When the implementation of the first week was analyzed in terms of academic achievement, there were codes indicating that the students came prepared for the lesson, realized meaningful learning, and actively participated in the lesson. A sample explanation from the field notes is the following: "After the question and answer activity during the lesson, the answers given by the students coded S1, S2, and S3 in the first group gave the impression that they learned the subject. From the feedback of these students, I realized that after watching the video and doing the activities, they came together to produce solutions for the research question and conducted detailed research." In the researcher's field notes for the first week, there were statements indicating that the students cooperated with their families, had good interactions within the group, were able to make joint decisions, and made effective presentations. The researcher noted this in the field notes as follows: "The student coded S18 exchanged ideas with his father because his father kept bees and explained how his father looked after the bees." However, when the first week was analyzed in terms of motivation, codes such as learning the lesson with fun, creating products, and sharing experiences were created. In the first week, some students had problems taking responsibility and accessing the video. The researcher wrote these problems in the field notes: "Students coded S13 and S14 did not do the activities they were supposed to do before the lesson on time and forgot to bring them to the lesson. S1, S14, S19, and S20 had problems accessing the video, but they solved this problem by communicating with their teacher and friends. S15 came to the lesson without watching the video because he could not access the video." The results obtained in the second week of the study are presented in Figure 5.

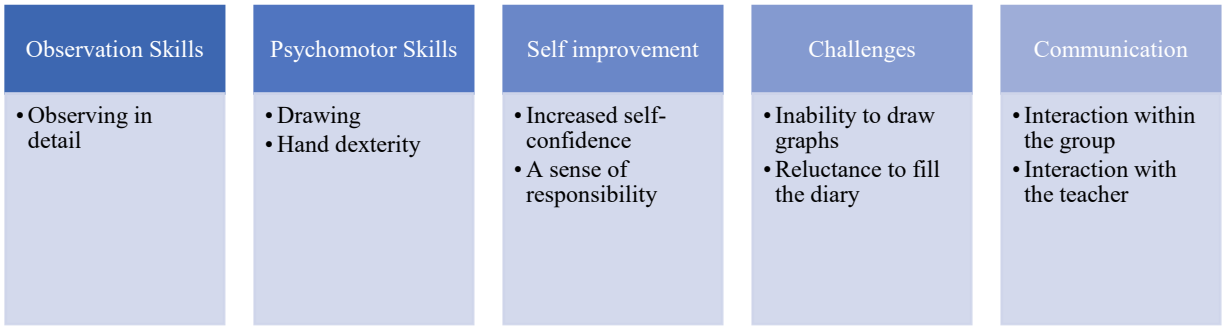


Figure 5. *Results from the Field Notes for the Second Week*

In the field notes of the second week, there are statements about which students made detailed observations. The researcher stated these statements in the field notes: "The students left the plants they had planted the week before in a suitable place in the laboratory and library to examine the factors affecting photosynthesis. Sometimes they came to me a few days apart, asked for the key, and said that they wanted to water and observe their plants. Then they brought them to the lesson where we were going to do the activity and made examinations and comparisons. The students coded S7, S8, and S9 were students with low motivation who did not actively participate in the lesson, but in this activity, they made observations with curiosity." In the field notes, codes for drawing and manual skill development were identified in terms of students' psychomotor skill development. In addition, in the field notes of the second week, there are statements that students' self-confidence increased in terms of their personal development and that they developed an awareness of taking responsibility. The field notes included statements that students were reluctant to draw graphs and fill in diaries. The researcher stated this with the following: "The students in the second group, coded S12 and S13, could not do the graph drawing activity out-of-class because they did not fully understand it. So, I briefly explained it in the lesson, and then they did it." The results obtained in the third week of the research are presented in Figure 6.

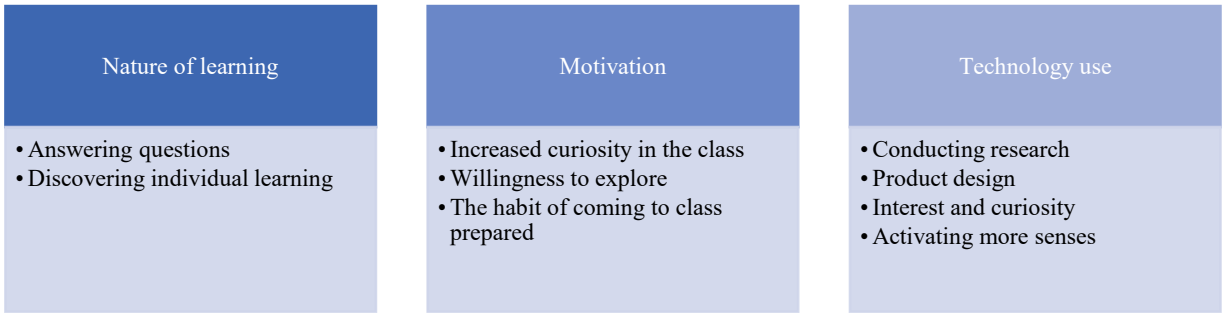


Figure 6. *Results from the Field Notes for the Third Week*

Examining the field notes of the third week, it is clear that the students improved their ability to answer questions directly and learn individually, and that their intrinsic motivation increased. For example, the teacher said, "The student coded as S1 in the first group watched the videos and did the out-of-class activities completely. I realized that most of the other students also completed detailed out-of-class research and were more curious and enthusiastic about doing in-class activities." The researcher, who stated that the use of technology enabled gains such as conducting research, designing products, arousing interest and curiosity, and activating more senses, expressed these views in his field notes as follows: "Especially S6 and S10 prepared a virtual board for the research question. Then they presented this board to the whole class. Thus, they enriched their activities with visuals and various studies." The results obtained in the fourth week of the research are presented in Figure 7.



Figure 7. *Results from the Field Notes for the Fourth Week*

In the implementation in the fourth week, the codes of working efficiently, active participation in the lesson, exploring individual learning were identified in terms of academic achievement; cooperation, taking responsibility, self-expression, entrepreneurship, communication in terms of social skills; and dislike of the activity in terms of problems. Sample field notes related to these codes are presented below.

The student coded S2 took notes by watching the videos. The answers he gave to the questions in the lesson and his participation in the activities created the impression that he came to the class after learning the subject. S1 enjoyed doing activities with his friends and guided them. Student coded S6 learned the subject well during out-of-class activities. S6 does not like to study much when she is on her own, but when given homework, she tries to fulfill her responsibilities diligently. S11 likes to do in- and out-of-class activities and participates more actively compared to the lessons before the implementation." The results obtained in the fifth week are presented in Figure 8.

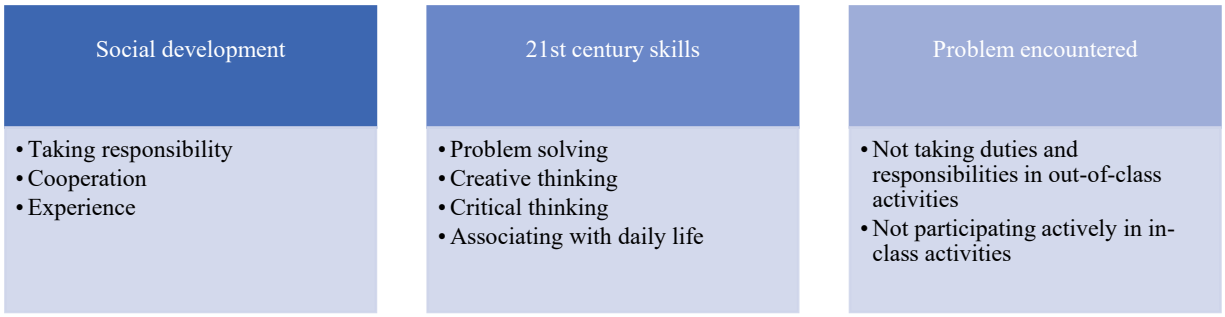


Figure 8. Results from the Field Notes for the Fifth Week

When the fifth-week practice was analyzed in terms of social development, there were codes related to cooperation, gaining experience, and taking responsibility. The field notes of the researcher stated that "S1, S2, and S3 in the first group came together after doing out-of-class activities and thought about the research question. S2 shared the research he had done and produced different ideas for his own designs. S3 talked to his grandfather about his designs and stated that they needed a water motor and got permission to bring it to the lesson. Since S3 did not know how to use the water motor before, he gained experience by learning how it works from his grandfather. S4 could not meet with his friends before the lesson because he was staying in a dormitory, but he worked in cooperation with his friends in the in-class activities." However, three students experienced problems such as not taking on duties and responsibilities in out-of-class activities and not actively participating in in-class activities. The results obtained in the sixth week of the study are presented in Figure 9.

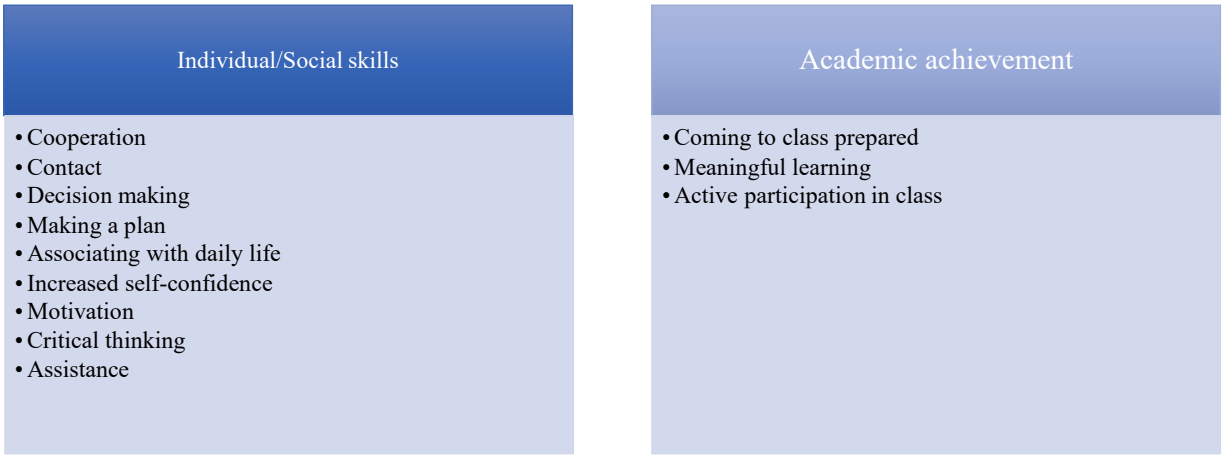


Figure 9. *Results from the Field Notes for the Sixth Week*

When the sixth week of implementation is analyzed in terms of personal and social skills, the codes for the development of cooperation, decision-making, communication, and planning skills are identified. In terms of personal development, the codes such as cooperation, productivity, association with daily life, increase in self-confidence, and motivation emerge. Coming prepared to class, increased retention, and active participation in class

are the codes signifying academic achievement. Some of the sample field notes regarding these codes are as follows:

"In this week's activity, it was planned for the students to design a recycling product individually instead of working in groups. The majority of the students worked in collaboration with some of their friends, as in the previous weeks' activities. They exchanged ideas and made suggestions to each other."

"S1 did detailed research on recycling before the lesson and was excited to design a product. Since S1 decided what to do in the in-class activity by planning in line with the research question, she brought the necessary materials with her. S1 enthusiastically stated that she would create more than one product if she had enough time."

"S2 designed a car with recycled materials. When the design was finished, he excitedly checked whether his car was working or not."

"Since S3 has advanced psychomotor skills, he enjoys designing products and also helps some of his friends."

"While S6 was designing, his injector broke, and his friends immediately made some suggestions to him, but S6 confidently said, 'OK, I can handle it; I have something in my head,' and produced his own solution to his own problem. Then he presented the finished design to his friends."

DISCUSSION & CONCLUSION

Discussion

This study aimed to examine the observations of teacher researcher and the views of students on STEM-FLIP practices. Practices were carried out within the framework of STEM-FLIP-oriented lesson plans for six weeks. In this process, students kept diaries about both in-class and out-of-class practices. At the end of the implementation, semi-structured interviews were conducted with nine students. A significant portion of the students stated that they could watch the videos whenever they wanted, pause and take notes, and develop their own learning styles, which facilitated learning. In addition, most participants reported that these practices allowed them to come to class prepared and increased their active participation in class. These findings are similar to some studies (Bishop & Verleger, 2013; Enfield, 2013; Frydenberg, 2012; Fulton, 2012). For example, Enfield (2013) emphasizes that the videos and content prepared before the lesson in FLM help students both to review the subject and discover their own learning style and pace. In addition, studies in the literature support the use of FLM in promoting student learning and participation in STEM education (Casselman et al., 2019; Nasir et al., 2020). The use of FLM in STEM education is considered important in terms of student engagement and acquisition of high-level skills (Eichler & Peeples, 2016). The literature also highlights the potential of FLM to increase student engagement and satisfaction compared to traditional classrooms (Sarker et al., 2023).

When surveyed about the negative aspects of the STEM-FLIP, most participants reported no issues or difficulties during the process. Nonetheless, one student encountered problems with obtaining instant feedback from his peers on out-of-class activities, leading to lessened efficiency in the in-class activities. Analyzing the problems encountered, the students revealed that they faced issues like limited video access and insufficient materials. The literature also indicates studies with comparable outcomes to those encountered in FLM. For instance, Aydın (2016) found that students had some issues since they came unprepared to the class without watching the videos. Thus, teachers play a vital role in this context. Enfield (2013) asserts that teachers are responsible for directing and guiding their students' learning process. Accordingly, the teacher's primary objective should be to establish a culture of learning. To this end, the teacher should engage in individual or group work with students to gain a thorough understanding of their interests and requirements (Miller, 2012). Prior to class, learners must discuss any issues they encounter with the instructor and receive instructions for both in-class and out-of-class activities (Verim, 2022).

The students were also asked about the contribution of in-class activities to their learning, and they indicated that these activities made the subject interesting and reinforced their understanding. In addition, participation in the activities facilitated learning by having fun and meaningful learning was realized. These opinions are also consistent with the researcher's field notes. For example, the researcher found that the students actively participated in the classroom activities and that the subject was learned thanks to the feedback they received in the question-and-answer activities. In addition, when the researcher examined the activities that the students carried out in the classroom, he noticed that they did detailed research on the subject and put the knowledge they acquired into practice. The related literature supports these findings (Birgin, 2022; Love et al., 2014). For example, Filiz

and Kurt (2015) found that teaching the subjects in FLM in out-of-class activities increases the in-class activity time, reinforces learning, and makes learning meaningful. The students stated that new ideas emerged with the activities carried out during the lesson, which improved their problem-solving and creative thinking skills by providing quick solutions to the problems encountered. Some studies support this finding (Kong, 2015; Moraros et al., 2015). Moraros et al. (2015) found that FLM provided pedagogical opportunities to implement constructivist and creative learning activities in the classroom.

The findings of the current study show that the majority of the students have positive opinions about STEM-FLIP activities in science courses. For example, they think that in-class and out-of-class activities reinforce the subject they have learned and increase the usability of the information in their daily life. At the same time, the pre-lesson videos and activities enabled individual learning, allowed students to express themselves more comfortably, and encouraged them to actively participate in the lesson. Stone (2012) found that in-class FLM activities enabled meaningful learning to take place by ensuring students' active participation. In the interviews, the students stated that it was fun to participate in the activities and that they learned the lesson in a fun way. These findings are supported by the related literature (Aksoy, 2020; Coşkun, 2020; Fulton, 2012; Kurt, 2017). For example, Turan and Göktaş (2018) found that FLM facilitated learning by making it enjoyable. Some of the students stated that the scenarios presented in the out-of-class activities captured their attention and made them more sensitive to their environment. They also indicated that these activities improved their problem-solving skills. The field notes support these findings as well, which indicate that the students developed products inspired by the environment in which they lived and that they sought solutions to problems by sharing information with their families. Demir (2020) found that FLM improved students' attitudes toward the environment and increased their environmental awareness. In addition, Hew et al. (2020) concluded that FLM improved peer-assisted learning and the process allowed for better problem solving.

The field notes indicate that the students faced a challenge of insufficient supplies that occasionally led to demotivation during in-class activities. This situation is also found in interviews and diaries. However, this problem was reduced in the subsequent weeks as the researcher implemented adjustments that involved less reliance on materials in the lesson plans and activity designs. A lack of materials and teacher anxiety about completing the curriculum are recognized as drawbacks to implementing STEM activities in the literature (Eroğlu & Bektaş, 2016; Çınar & Kereci, 2020). These issues faced by educators are mostly attributed to the notion of creating complex STEM materials. The researcher concluded that approaching STEM activities with a more specific focus during the planning phase, rather than viewing them as a new invention, will enhance their practicality. Stohlman et al. (2012) support this perspective by highlighting that STEM activities can be conducted using simple experiments or even just a board. In the current study, the stage for research questions and solution suggestions during the out-of-class activities of FLM empowered students to plan their STEM activities beforehand. Subsequently, students attempted to mitigate problems encountered during STEM activities by proactively preparing and accessing necessary materials within their means. The researcher reported that students developed the habit of arriving to class prepared and demonstrated increased interest and motivation towards the lesson. Students also included this situation in their interviews and diaries. These findings align with previous research indicating that FLM enhances motivation (Abeysekera & Dawson, 2015; Ramirez et al., 2014). Furthermore, the related literature highlights that STEM education enhances students' problem-solving skills and boosts motivation levels (Kılınç, 2014; Özdemir, 2015). For instance, Birgin (2022) implemented FLM and STEM together and reported that it resulted in an innovative and enjoyable lesson experience while simultaneously boosting students' interest in and enthusiasm towards the subject matter. In line with the students' opinions and the teacher's observations in the current study, it can be concluded that STEM-FLIP has positive effects on the development of 21st century skills such as critical thinking, creative thinking, in-depth understanding and problem solving, as well as on students' academic performance. Finally, this study provided a learning process that increased students' motivation, improved their cooperation and communication skills, and encouraged their use of technology.

Conclusions

This research aimed to examine the applicability of STEM-FLIP in science courses. As a matter of fact, it is stated that the effects of STEM-FLIP activities have not been sufficiently examined in the literature (Cheng, 2023) and more research is needed to apply FLM in STEM classes (Jung & Hong, 2020). In this context, six-week lesson plans were developed and data were collected using semi-structured interviews, student diaries and field notes. Students stated that watching videos and doing activities in extracurricular practices enabled them to come

to class prepared and discover their learning styles. Most students expressed their opinions that the applications increased active participation in lessons and enabled meaningful learning. In in-class activities, students stated that STEM activities enable meaningful learning, learning with fun, and transferring knowledge to daily life. When the teacher's field notes were examined, it was determined that the students developed creative ideas by doing group activities, produced solutions to the problems they encountered, and experienced the happiness of creating products together. At the same time, the researcher found that with STEM-FLIP, students' interest and motivation towards science lessons increased, their collaboration and communication skills improved, and their use of technology increased. The current study has several limitations. 20 students participated in the study and nine students were interviewed. Although the number is not important in qualitative research (Creswell, 2012), it is important to have more students participate in the study to obtain data from many different perspectives. In addition, the STEM-FLIP practices lasted for six weeks. Longer studies of STEM-FLIP practices can be conducted. The study used interviews, diaries, and field notes as data collection tools. More in-depth data can be obtained by using different data collection tools. It was concluded that FLM offers potential benefits in improving student learning outcomes and participation in STEM education. However, further research is needed to understand the conditions under which the use of FLM in STEM education is most effective and to address potential challenges related to its implementation (Fung, 2020; Sergis et al., 2017). Based on the findings, the following recommendations can be made:

- In the lessons where STEM-FLIP is used, students should first be given detailed information about the model, closely monitored throughout the implementation process, and measures should be taken for problems that may be encountered (e.g. Internet access, lack of technological tools, lack of materials, etc.).
- Teachers can continually review and improve STEM-FLIP by receiving feedback from students and other stakeholders. This feedback can reveal the impact of the model and changes in students' learning. In this context, it is recommended to carry out studies at different levels in order to provide the opportunity to examine the usefulness of the model in more detail.
- Teachers should be provided with professional development and training opportunities to implement STEM-FLIP effectively.

Statements of Publication Ethics

All ethical rules were followed throughout the research.

Researchers' Contribution Rate

Authors	Literature review	Method	Data Collection	Data Analysis	Results	Conclusion
Author 1's name	☒	☒	☒	☒	☒	☒
Author2's name	☒	☒	☐	☒	☒	☒

Conflict of Interest

We confirm that there are no conflicts of interest associated with this research.

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APPENDIX

Appendix 1

Semi-structured interview form

1. How did watching the lecture videos and doing the activities before coming to class affect your learning?

2. What are the problems you encountered in the out-of-class practices?

- Did you have problems accessing the video?

- Did you have problems doing the activities?

- Did you have problems in getting instant feedback (from your teacher, friends, family...) in order to complete your learning deficiencies in out-of-class activities?

3. What do you think are the positive aspects of out-of-class activities?

4. What do you think are the negative aspects of out-of-class activities?

5. What kind of activities did you do in the in-class practices?

6. What are the contributions of the activities in the in-class practices?

- Evaluate in terms of your learning

- Evaluate individual and group work in terms of participation.

- Evaluate in terms of its contribution to your problem solving skills.

- Evaluate in terms of putting forward creative ideas.

- Evaluate in terms of using technology.

7. What are your opinions about the use of the Flipped Learning model supported by STEM activities in science courses?

- Would you like the flipped learning model supported by STEM activities to be used in other units of the science course?

Appendix 2

Out-of-class Student Diary

1. I liked watching this topic of the science lesson from the lecture video because.....
2. I didn't like watching this topic of the science lesson from the lesson video because.....
3. I learned from the lesson videos.....
4. I liked the activities my teacher shared with me before the lesson because.....
5. 5. I did not like the activities my teacher shared with me before the lesson because.....
6. I learned... from the activities before the lesson.
7. My other feelings and thoughts about extracurricular practices ……

Appendix 3

In-class Student Diary

1. I liked ..... the activities we did today.

Because

2. I didn't like ..... the activities we did today.

Because

3. I learned from the activities we did today.

4. I had difficulty with the activities we did today.

5) My other feelings and thoughts about the in-class practices are:

.....

.....

Appendix 4

Researcher Field Notes

Date:
Subject:
My observations: