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COMMENTARY

Flipped Learning Model: An Effective Approach to Primary School STEM Education

Xiaoqiao Cheng

Nanjing Normal University, Nanjing 210024, Jiangsu, China

"Change is the End Result of All True Learning." –Leo Buscaglia

AS early as 1986, the US National Science Board published *Undergraduate Science, Mathematics, and Engineering Education*, which is regarded as the initiation of STEM education (NSB, 1986). In October 2005, the National Academy of Science, National Academy of Engineering, Institute of Medicine, and National Research Center jointly submitted to the Congress of the United States *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, a report that put forward relevant recommendations to promote STEM education (Bybee, 2010). In October 2007, the US National Science Board issued *A National Action Plan for Addressing the Critical Needs of the US Science, Technology, Engineering, and Mathematics Education System*, proposing to expand STEM education from colleges to primary and secondary schools (NSB, 2007). In 2009, former President of the United States, Barack Obama, emphasized the need for the nation to prioritize the development of STEM education. Since then, the US federal government has heavily invested in STEM education research across all levels, from kindergarten through higher education. Educational communities in other countries have also begun researching and implementing STEM education practices. Numerous studies and extensive practice have demonstrated the potential of STEM education in promoting students' cognitive development, enhancing their critical thinking, problem-solving, and creativity skills, as well as improving their emotional and spiritual well-being.

The traditional science education approach predominantly consists of lecture-style presentations. However, the limitations of this method have become increasingly evident in the 21st century. To effectively implement STEM education, new teaching models are required that can integrate new technologies to improve the efficiency of classroom teaching. In this context, the flipped learning model has emerged and garnered widespread attention in educational communities. This model blends the strengths of face-to-face instruction and distance learning, utilizing the advantages of both environments. In essence, flipped learning is a combination of in-person classroom education and learning activities that students perform outside of the classroom using various online tools. This approach enables students to customize their learning experience by adjusting the time, place, and pace of their learning to meet their individualized needs (Staker & Horn, 2012). By implementing the flipped learning model in STEM education, students' learning resources are greatly enhanced. They are given access to videos, slides, and texts related to the subject matter, allowing them to learn at their own pace in a personalized environment. As a result, more time can be devoted to active classroom activities, including discussions, leading to a considerable improvement in the efficiency of STEM teaching.

The majority of previous studies on the flipped learning model have focused on its application to foreign language and computer knowledge learning, with few examining its use in science classes. Moreover, the effects of STEM education assisted by the flipped learning model have not been adequately examined at the primary education level. *A Review on the Effects of STEM Activities Conducted with the Flipped Learning Model on Primary School Students' Scientific Creativity, Attitudes, and Perceptions Towards STEM* in this issue is an empirical study conducted by a Turkish researcher that investigates the effects of flipped learning-supported STEM activities on fourth-grade students' science education. The research findings indicate that STEM education supported by the flipped learning model has positive effects on primary school students' scientific creativity and perceptions about STEM. The flipped learning model also increases students' engagement in STEM activities, improves classroom efficiency, and reduces their anxiety towards science learning, making it more enjoyable (Erkan & Duran, 2023). This study provides valuable experience in implementing STEM education in primary schools.

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Correspondence to:
Xiaoqiao Cheng
PhD
Nanjing Normal University
Nanjing 210024
Jiangsu
China
E-mail: xqcheng2008@vip.163.com

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COMMENTARY

Mobile Technology-Powered Education in Developing Countries

Min Zhou

Suzhou University, Suzhou 215031, Jiangsu, China

"If Your Plans don't Include Mobile, Your Plans are not Finished." –Wendy Clark

MOBILE learning, which is supported by mobile applications and devices such as smartphones and tablets, has gained significant popularity due to the widespread adoption of mobile technology and continuous improvements in internet infrastructure. This trend is reflected in the growing use of mobile learning worldwide. Research has shown that smartphones play a crucial role in promoting student development, particularly in learning and research (Esechie et. al., 2022). Compared to traditional learning approaches, mobile technology-powered learning is more flexible and convenient, as it can be conducted at any time and in any places. Students can access learning resources via mobile devices, complete assignments and tests online, and more. Existing studies suggest that most students are receptive to mobile device-assisted learning, and student attitudes, strategies, and preferences are the main factors influencing their mobile learning experience (Tang et al., 2019).

In addition, mobile learning has the potential to significantly enhance educational equity by overcoming geographical and economic barriers, making high-quality education more accessible to a wider range of learners. By establishing a system that incorporates open digital learning platforms, shared top-notch learning resources, and mobile education powered by state-of-the-art communication technologies, a more balanced and equitable education can be achieved (Zheng, 2009).

A Mixed-Methods Study of Secondary Student and Teacher Attitudes to Mobile Education Apps in Lagos, Nigeria in this issue is an evaluation of the perceptions and attitudes of Nigerian students and teachers towards the use of mobile apps in classroom learning. Nigeria, being one of the most populous countries in Africa, has always prioritized educational development in its national agenda. However, the country faces numerous educational challenges, including gender differences, regional divides, and disparities between the wealthy and the impoverished in basic education due to unbalanced economic development and diverse languages and cultures (Xiong & Yue, 2011). In such a context, mobile learning technology can be an effective tool to bridge various educational gaps. By integrating mobile technology into classroom instruction, learning opportunities can be significantly expanded. It enables education to better cater to the personalized learning needs of students and provides them with authentic learning practices when traditional teaching methods fail (Shokirovch, 2022). This study employed a mixed-methods design that combined quantitative and qualitative research to identify barriers and motivators in the use of mobile apps for enhancing or augmenting learning in the classroom (Krochinak et al., 2023). The research findings provide valuable insights into promoting mobile technology-assisted instruction in Nigeria and other developing countries, with the goal of improving the quality of basic education and narrowing the educational gaps between regions.

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Correspondence to:
Min Zhou
PhD
Suzhou University
Suzhou 215031
Jiangsu
China
E-mail: 32403339@qq.com

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ORIGINAL ARTICLE

The Effect of Activities Performed in the Science Center on Students' Perceptions of Out-of-School Learning Environments¶

Metin Doldur,[1] Hulya Ertas Kilic[2]

1. *Gazipaşa Muzkent Imam Hatip Middle School, Antalya, Turkey*
2. *Aksaray University, Aksaray, Turkey*

***Abstract**: This study aimed to investigate the effects of the applications conducted in the science center within the scope of the science lesson "Solar System and Beyond" unit of the 7th-grade students in the secondary school, on the perceptions of the students about the out-of-school learning environments (OSLEs). In the quantitative part of the research, in which nested design, one of the mixed research designs, was used, the study group consisted of 42 students. Also, in the quantitative part of the study, a quasi-experimental design with the pre-test-post-test control group, which is one of the experimental research methods, was used. The Science course was conducted in the classroom with the students in the control group as the program predicted. In addition to the science lessons conducted in the classroom with the experimental group students, activities within the scope of the unit were carried out in the science center and the planetarium. Quantitative data were collected with the "Out-of-School Learning Environments Perception Scale (OSLEPS)". The follow-up test was applied to the experimental group of students three months later. In the qualitative part of the study, semi-structured interviews were conducted with eight students from the experimental and control groups. When the results obtained from the qualitative data are evaluated together with the quantitative data, it is seen that the practices in the science center and the perceptions of the experimental group students towards out-of-school learning environments differ positively compared to the control group students.*

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About the Authors: *Metin Doldur, Science teacher, Gazipaşa Muzkent Imam Hatip Middle School, Antalya, Turkey, E-mail: mtn.fen@gmail.com, ORCID: https://orcid.org/0000-0001-6745-3424*

Hulya Ertas Kilic, Assistant professor, Department of Math and Science Education, Faculty of Education, Aksaray University, Aksaray, Turkey. E-mail: ertashulya@aksaray.edu.tr, ORCID: https://orcid.org/0000-0001-9683-3186

Correspondence to: *Dr. Hulya Ertas Kilic at Aksaray University of Turkey.*

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¶: This study was produced from the master's thesis conducted under supervision of Assistant professor Hulya Ertas Kilic.

Introduction

WHEN it comes to learning environments, the first ones that come to mind are school and classroom environments. If evaluated separately, classroom environments can often be scanty in adapting to the changing world conditions and solving the problems encountered in daily life. There is a need for informal learning environments outside the school where students can be directly intertwined with daily life. These informal learning environments are of great importance in reinforcing the information learned at school and in learning new information. However, visits to these environments without focusing on the achievements in the curriculum and without planning will be no different from a trip (Sarıoğlan & Küçüközer, 2017). Salmi (1993) defined the approach of using informal learning environments for formal learning within the framework of a certain curriculum as out-of-school learning (OSL). In the context of OSL, it would be more meaningful to express informal learning environments as OSLEs. OSLEs are crucial in enabling students to be influenced by materials in real-life situations, learning by doing, and providing learning opportunities in various ways. OSLEs are becoming the most used option among learning activities that complement and support many gaps that formal education cannot fill in the realization of the objectives based on the curriculum (Balçın & Yavuz Topaloğlu, 2019).

Intended goals can be achieved efficiently when out-of-school activities are supported by complementary activities in the classroom. The activities carried out in OSLEs increase the way students understand the subject and help them to make connections in their daily lives (Ertas et al., 2011). Since the activities carried out are enjoyable and interesting, it can be stated that students have a longer recall period (Lakin, 2006). Sontay et al. (2016) stated that with the lessons held in OSLEs, the information became more permanent, and the lessons were more fun and effective. For individuals, school is a preparation for life, and it aims to transfer the learned information to life beyond the classroom walls. In this sense, activities to be carried out in OSLEs, where individuals can take an active part in learning information meaningfully and permanently, play a crucial role. Many OSLEs can be mentioned, however, science centers and planetariums are among the prominent OSLEs for the Science course. The instinct of learning and curiosity of people, and the desire to study form the basis of scientific development. People always want to learn new things, do research, and share their knowledge with other people verbally or written. Exhibitions in science centers appear as a way of conveying knowledge. These exhibition areas and interactive experiment sets stimulate people's desire to wonder and question. Science centers contribute to teachers' professional development and allow society to deal with science. In addition, students gain a positive attitude toward science by obtaining permanent and meaningful knowledge (Öztürk & Başbay, 2017). Science centers ensure students with opportunities to provide permanent information, develop research and inquiry skills, and gain critical thinking skills (Bozdoğan, 2007; Ertas Kilic & Sen, 2014; Erten et al., 2016; Yılmaz, 1996).

Students and teachers' perspectives towards OSLEs guide the realization of activities in OSLEs. It can be said that teachers stay away from visits to OSLEs for reasons such as time and student control, content training concerns, and security. Students, on the other hand, can see OSLEs only as areas where they have a good time (Bozdoğan, 2018; Duruk et al., 2018; Orion et al., 1997; Rennie & McClafferty, 1995). When the literature is examined, it is seen that the perspectives of students and teachers on OSL are mostly tried to be determined through qualitative research (Duruk et al., 2018; Ok & Aslan, 2020). Moreover, in the literature, there are mostly studies in which undergraduate-level students, preservice teachers, and teachers' views are investigated on OSL and OSLEs. In this context, studies with elementary school students and secondary school students are needed. In this study, it was aimed to investigate the perceptions and changes in the perceptions of 7th-grade secondary school students towards OSLEs within the framework of the science center and planetarium, which we consider as OSLEs.

Perception, which consists of signals in the nervous system that occur with the physical stimulation of the sense organs, is shaped together with memory, learning, and expectation. Accordingly, perception; is the process of transforming the stimuli received with the five sense organs (eye, ear, skin, nose, tongue) into meaningful stimuli that activate the organism by interacting in the dimensions of objective reality and subjective experience (Aydın, 2001). The perception of students who have never experienced OSLEs can only summarize their expectations. For this reason, it is thought that the activities in these environments are crucial in terms of shaping and permanence of the perception towards OSLEs. In the study, OSL activities were conducted in the science center and planetarium, based on the scope and achievements of the "Solar System and Beyond" unit in the program. It was aimed to determine the effect of OSL activities on students' perceptions of OSLEs. In addition, the permanence of the effect determined in perception was investigated by performing follow-up tests. In the research, it was studied with secondary school students studying in a village school, which can be described as a disadvantaged region for its farawayness from the city center. Quantitative data provide a more general understanding of the research problem, while qualitative data provide a more detailed comprehension of the problem. Bringing together and discussing the quantitative and qualitative findings allows the research results to be more comprehensive (Creswell & Plano Clark, 2015). For this reason, the mixed method was preferred in determining the perceptions of students toward OSLEs.

Method

Research Model

In this study, a mixed method was used. The reason for choosing the mixed method is to eliminate the deficiencies that arise when qualitative and quantitative research are applied on their own and to address the research conducted in multiple stages and data sources. The study was based on the "nested pattern" in the classification of Creswell and Plano Clark (2015), one of the mixed-method studies. The nested mixed design occurs when the data are collected in qualitative and quantitative research designs and are tried to give meaning. The main purpose here is to find a better solution to the study problem by integrating qualitative and quantitative data. In this study, quantitative and qualitative data collection tools were obtained simultaneously.

In the quantitative phase of mixed methods research; "pre-test-post-test control group design" and follow-up test, which are quasi-experimental designs used in experimental research. In the quantitative part of the study, it was aimed to determine the perceptions of students towards out-of-school environments with OSLEPS. During the implementation process, the lessons were carried out in the experimental group (EG), following the current curriculum in the classroom, as well as the practices were carried out in the science center and planetarium. Three months after the completion of the applications in the EG, the permanence of the change in the perceptions of the students was tried to be determined by the follow-up test. In the control group (CG), the lessons were carried out in the classroom following the current curriculum. In **Table 1**, the quantitative part of the research is indicated.

In the qualitative phase of the research, it was desired to investigate the pre-perceptions and post-perceptions of the EG students before and after experiencing the science center and planetarium with practices, towards OSLEs. Here, it was tried to shape the perceptions of the EG students with learning, memory, experience, and expectation. Although the CG students did not experience the science center and planetarium, interviews were conducted with them and their perceptions at the level of expectation were tried to be determined. In addition, considering the possibility of the CG students visiting different informal environments such as science centers with their families and listening to the experiences of their peers, it was decided that it would be appropriate to conduct pre-interview and post-interview with them as well.

Participants

The study group consists of 7th-grade students (42 students) studying secondary school. Of these students, 24 (14 boys, 10 girls) are in the EG, and 18

Table 1. Quantitative Pattern of the Research.

Groups	Pre-Tests	Application	Post-Tests	Follow-up Test
CG	OSLEPS	Courses conducted in the classroom according to the current curriculum	OSLEPS	-
EG	OSLEPS	Practices carried out in the science center together with the lessons carried out according to the current curriculum in the classroom	OSLEPS	Determining the permanence of the effects of the implemented practices on student perceptions

(10 boys, 8 girls) are in the CG. It was determined that none of the students in the CG visited the science center before the study, and only two students from the EG experienced the science center. In the research, convenience sampling method, which is easy to access and practical, was preferred (Neuman, 2008). It is a method that accelerates the research with appropriate sampling. In this sampling, while choosing a sample from the immediate environment and accessible to the researcher; it is mostly used when other sampling methods cannot be selected (Dawson & Trapp, 2001).

While creating the study group in the qualitative data collection process, criterion sampling, which the purposeful sampling method is used in qualitative research, was used. Criterion sampling is used when a situation is examined in detail by the researcher and wants to determine certain types of case studies (Neuman, 2008). Patton (1997) clarifies purposive sampling as a sampling method that allows a detailed study of events known to have rich information. None of the students selected for the interview had been to the science center before. Moreover, interviews were conducted with students in EG and CG with low, medium, and high achievement in science courses. For this purpose, interviews were conducted with four volunteer students from the EG before and after the trip and four volunteer students from the CG.

Data Collection Tools

Quantitative and qualitative data collection tools were used together in the research. OSLEPS was used as a quantitative data collection tool and a semi-structured interview form was prepared by the researcher as a qualitative data collection tool.

Out-of-School Learning Environments Perception Scale (OSLEPS)

OSLEPS which consists of 16 items, was applied to measure students' perceptions of out-of-school environments. Developed by Sen et al. (2021) the scale has four sub-dimensions: “Incentive for learning, learning benefits, integration (association with in-school learning), and involvement”. The Cronbach Alpha coefficient reported by the researchers for the developed scale is 0.80. In this study, the Cronbach Alpha coefficient of the scale applied to the students for the pretests was calculated as 0.80, and the coefficient for the posttests was calculated as 0.79.

Semi-Structured Interview Form

With the interview form created by the researcher, students’ perceptions and perspectives on OSL were tried to be determined. The form includes seven open-ended questions prepared by considering the OSLEPS sub-dimensions (incentive for learning, learning benefits, integration, and involvement) used in the quantitative research part. Distinctly from the questions about the dimensions in the scale, two questions asking students to define their OSLEs were also included in the interview form. To assess the relevance of the questions on the interview form, the opinions of three academicians who worked on OSL in the field of science, were sought. Afterward, a pilot study was conducted with three students. As a result of the feedback from the experts and the pilot application, necessary arrangements were made and the form was finalized. The questions were as follows:

- *What do science lessons outside of school mean to you?*
- *If science was to be taught outside of school, where would you like it to be done?*
- *What kind of benefits do you think being taught science outside of school will provide for you?*
- *Do you think that the science lesson taught outside of school will contribute to the science lesson you take at school?*
    - *Sub-question: If you think so, how can it contribute?*
- *Do you know what a science center is?*
- *What would you say if I asked you to relate the science lesson outside of school with the science lesson you took at school?*
- *How do you think you feel about learning science outside of school?*
    - *Sub-question: For example, how would you feel at the Science center?*
- *How do you feel about expressing your thoughts and participating in learning environments outside of school?”*

Implementation Process

The research was started after obtaining the approval of the ethics committee and permission to practice. The science course, which has 4-course hours per

Table 2. Applications Carried Out in the Science Center and Planetarium with the EG

Before the science center visit	Introductory presentation about the science center
At the science center	Reminder events
	Events held in the exhibition area
	Workshops
	Planetarium
	Free time activity
After the science center visit	In-class complementary activities

week, was carried out for a total of 16-course hours for 4 weeks in line with the "Science Education Program" that came into effect in 2018. In the Science Curriculum, the 7th-grade first unit "Solar System and Beyond" was taught in line with the plan. In the CG, the unit was carried out in the classroom environment in line with the lesson plan.

In addition to the lesson, which was carried out according to the current program in the classroom with the EG, practices were carried out in Konya Science Center. The applications related to the science center and planetarium carried out with the EG were arranged in accordance with the program outcomes. These practices can be grouped under three main headings: before the science center, at the science center and after the science center. The applications related to the science center and planetarium carried out with the EG are given in **Table 2**.

Before the science center visit, a presentation containing introductory information about the science center was shown to the students. In the prepared presentation, students were given information about the activities to be carried out.

Science center activities are grouped under five main headings. Reminder events: It is an event called "I Know the Planets" and was held in the "Our Universe Exhibition" gallery of the Science Center. This activity deals with the Planets topic in the 6th-grade "Solar System and Eclipses" unit. The primary purpose of the 20-minute event which is based on the principle of "learning from the known to the unknown", is to give reminders about the planets that the students learned in the 6th grade. In this way, it is thought to be a prelude to the main activities to be held in the science center. Below are the outcomes of the event:

- *"Compares the planets in the solar system with each other."*
- *"Ranks the planets in the solar system according to their distance from the sun."*

- *"Knows the general characteristics of the planets in the solar system."*

A reminder of the information they learned in the 6th-grade was presented to the students with the exhibition setup of our solar system in our universe exhibition gallery. Afterward, the following questions were asked to the students through the Solar System model in the exhibition setup:

- *Which star is closest to our earth?*
- *What are the planets in the Solar System?*
- *How are the planets in the Solar System arranged according to their distance from the sun?*
- *What is the name of the largest planet in the Solar System?*
- *What is the name of the smallest planet in the Solar System?*
- *Why don't Mercury and Venus have moons?*

During the activities held in the exhibition area, 9 exhibition setups were selected from the 21 exhibition setups in our Universe Exhibition Gallery in accordance with the subject acquisitions. These exhibition setups consist of black holes, stars' habitats, constellations, telescope models, observation satellites, light pollution, space rocket preparation, space station, and space shuttle setups. The black hole experiment setup is interactive, and the students have experienced it themselves. The other experimental setups are in the form of presentations, and the students were studied by applying the question-and-answer method to the experimental setups. The activities held in the exhibition area lasted an average of 60 minutes.

Within the scope of the workshops, three workshops were held: "I am designing a space shuttle", "I am discovering the telescope" and "I am observing the sun with a telescope". These studies lasted approximately 60 minutes. In the I am designing a space shuttle study, the EG consisting of 24 students was divided into six groups of four. Activity papers and necessary materials were distributed to each group, and they were asked to design a space shuttle. In the I am discovering the telescope workshop; the parts of the telescope were introduced to the students in detail by the expert in the science center. The students were divided into two groups and each group was asked to assemble the telescopes in pieces. Sun observation was made by going out to an open area with the students who prepared their telescopes.

In the last stage, the planetarium was shown. There are 7 screenings in the planetarium; Mystery of the Unseen World, Dynamic Earth, Astronaut, Life of Trees, Return to the Moon, Space and Its Rotation, and Flight of Butterflies. An expert working at the science center was interviewed about the screening. The "Space and Its Rotation" notation was adapted to the objectives of "Comparison of the solar system with other stars, constellations, sky representation, finding the pole star and its properties" in the curriculum. By making a start-stop where necessary, the question-and-answer technique was applied to the students within the demonstration. This activity lasted approximately 40 minutes. After the planetarium event, students were given free time to examine all the exhibition areas in the science center themselves. Free time lasted about 30 minutes. After the science center, complementary activities were carried out in the classroom for two lesson hours. In the complementary activities, the students worked in groups of four, concept maps, the fishbone method, and puzzles were used, and they were asked to write diary-style writings conveying their feelings and thoughts.

Analysis of Data

The SPSS-22.00 program was used in the analysis of the data collected in the quantitative part of the research. By using descriptive statistics, the characteristics of the student groups were determined and frequency values: mean, standard deviation, percentage, and frequency reached by the quantitative analysis, were examined. Normal distribution conditions were examined to decide whether to use parametric or non-parametric tests. While controlling the normality distribution for the groups, the Shapiro-Wilks test was used because the group size was less than 50 (Büyüköztürk et al., 2017). It was determined that the OSLEPS pretests, posttests of the CG and EG, and follow-up test scores of the EG showed normal distribution but were not homogeneously distributed. Although the test scores were normally distributed, the Mann-Whitney U test and Wilcoxon signed-rank test were used, which are non-parametric statistical analysis techniques because the groups were smaller than 30. (Büyüköztürk, 2017). Content analysis was used in the analysis of the data collected through interviews. The audio recordings taken during the interview were converted into written form and coded. These codes were gathered under categories and presented in tables. To ensure the credibility of the qualitative research, the data were coded and categorized by meeting with the researcher and a field trainer at regular intervals. The consistency between the codes was determined as 85%. In the excerpts, the names of the students belonging to the CG are in the form of CGPre for the preliminary interviews and CGPost for the post-interviews; EG student names are described as EGPre for the preliminary interviews and as EGPost for the post-interviews.

Findings

Findings Obtained as a Result of Quantitative Research

Table 3. Mann-Whitney U Test Results for Pre-test Scores of Groups.

Groups	n	Mean Rank	Sum of Ranks	U	p
CG	18	26.89	484.00	119.000	0.014
EG	24	17.46	419.00		

Table 4. Mann-Whitney U Test Results for Post-test Scores of Groups.

Groups	n	Mean Rank	Sum of Ranks	U	p
CG	18	22.33	402.00	201.000	0.73
EG	24	20.88	501.00		

Table 5. Wilcoxon Signed-Rank Test Results of EG OSLEPS Scores Before and After Experiment.

Post-test - Pre-test	n	Mean Rank	Sum of Ranks	z	p
Negative row	5	4.80	24.00	-3.603*	0.000
Positive row	19	14.53	276.00		
Equal	0	-	-		

**: Based on negative ranks.*

Table 6. Wilcoxon Signed-Row Test Results of EG Follow-Up Test and Post-Test OSLEPS Scores.

Follow-up test - Post-test	n	Mean Rank	Sum of Ranks	z	p
Negative row	5	10	120.00	-0.550*	0.583
Positive row	19	14.18	156.00		
Equal	0	-	-		

**: Based on negative ranks.*

The findings obtained from the Mann-Whitney U test statistical analysis of the pre-test scores of the control and EG students for unrelated samples are presented in **Table 3**.

When **Table 3** is interpreted, it is seen that the mean OSLEPS pre-test rank of the CG is 26.89, and the mean OSLEPS pre-test rank of the EG is 17.46. When the rank totals are examined, it is seen that the rank total of the CG is 484.00, and 419.00 for the EG. It is seen that there is a difference between the rank totals of the groups and this difference is statistically significant ($U = 119.000$; $p = 0.014$; $p < 0.05$). According to these data, there was a statistically significant difference in favor of the CG between the EG and the CG's OSLEPS pretests at the beginning of the study. It can be said that the study groups are not equivalent to each other according to their perception scores.

The findings obtained from the Mann-Whitney U test statistical analysis of the post-test scores of the control and EG students for unrelated samples are presented in **Table 4**.

When the results of the analysis given in **Table 4** are examined, it was determined that the OSLEPS post-test rank average of the CG was 22.33, and the OSLEPS post-test rank average of the EG was 20.88. When looking at the row totals, it is seen that while the CG is 402.00, the EG's row total is 501.00. This difference between the mean rank and total rank of the groups was not statistically significant ($U = 201.00$; $p = 0.703$; $p > 0.05$).

This result shows that at the end of the research, there is no statistically significant difference between the EG in which the applications were made in the science center and the CG, in which the teaching envisaged by the program was applied, in the OSLEPS post-tests.

Wilcoxon signed-rank test was used to determine the significance of the change in the OSLEPS post-test scores of the EG according to the OSLEPS pretest scores. These statistical analysis findings are presented in **Table 5**.

When the results of the analysis given in **Table 5** are examined, it can be said that the difference within the EG is significant in favor of the posttest according to the Wilcoxon signed ranks test result [$Z = -3.603$, $p < 0.05$]. In **Table 6** below, the results of the follow-up test applied to the EG after 3 months were evaluated with the post-test.

When the results of the analysis given in **Table 6** are examined, it can be said that the difference within the EG did not show a statistically significant difference according to the Wilcoxon signed rank test result [$Z = -0.550$, $p > 0.05$].

Findings obtained from the data collected by the OSLEPS post-test and OSLEPS follow-up test, in the follow-up test performed after 3 months, no significant difference was found in the scores of the students compared to the post-test data. When the follow-up test scores of the group were evaluated according to the OSLEPS post-test scores; It can be said that the perceptions of students towards OSLEs have been permanent in the intervening time.

Findings Obtained as a Result of Qualitative Research

Table 7. The Codes of the "Definition" Category.

Pre-Interview (CG)	Post-Interview (CG)	Pre-Interview (EG)	Post-Interview (EG)
Noiseless environments	Laboratories	Laboratories	Science centers
Home	Home	Classrooms	Science exhibition
Library	Library	Study room	Library
Green spaces	Forests	Forests	Forests
Courses	Schoolyard	Schoolyard	Planetariums
Mosque	Mosque	Cafes	Science gallery
Parks	Parks	Seaside	Museum of Mevlana
Gardens	Cafes	Open spaces	Zoo
	Neighbors		Museums
	Relatives		

The questions in the interview form were prepared by considering the OSLEPS sub-dimensions. The findings regarding the answers given by the students to the interview form were presented by quoting directly and creating categories and codes. As a result of the analysis of the pre-interview and post-interview data of the CG and the EG students, the categories of defining OSLEs, learning benefits, integration with science, and affective influence were obtained. The codes concerning the "definition" category of the CG and the EG students' perceptions of OSLEs are presented together in **Table 7**.

When the codes in **Table 7** are examined; it is seen that CG students generally give examples from their immediate environment while describing their OSLEs. We can state that the EG students approximately determined the OSLEs in the pre-interview application. They expressed out-of-school environments as classrooms, forests, study rooms, cafes, open spaces, seaside, and schoolyards. After completing the unit, it was determined that the answers they gave varied in the last interview held after the practices in the science center and in-class complementary activities. It is seen that science center activities are effective in defining OSLEs in students. Below are examples of statements from participants that were assessed under the definition category.

> *"Quiet environments, places where there is not much noise. It could be home; it could be mm libraries. I mean, other than at school, at home or elsewhere, in our neighbors, relatives or otherwise, I don't know." (CGPre1)*

> *"So, it can be open areas, a large environment, a place with greenery. So, it would be better to have soundless environments. I wish it was done where there is more science information. For example, when talking about oxygen, it can be in a wooded place." (CGPre2)*

> *"It could be in places like a mosque, well it could be in an open place, it could be in a park, it could be in other wooded shady places. I mean, I don't know, I don't think about it. It's also nice to teach in the classroom." (CGPost3)*

> *"It could be in the woods, so it depends. Then it could be in the green, it could be in the laboratory, outside of school. Well, it can be my room, my study desk, cafes, and courses." (CGPost4)*

> *"For example, I would like it to be done in the laboratory; the teacher would show us and explain. I would like it to be done on the ground, depending on the subject, for example, in laboratories if we are processing pure substances and mixtures." (EG-Pre2)*

> *"It refers to the places where we learn the lesson in places outside the school or classroom. It can be a library, a science center, a science gallery, a planetarium, or a garden. A place like a greenery, forest, or zoo would also be nice. We went to the science center, sir, it was very nice. It was as if we had everything about our lesson. We learned a lot there. I think it would be better if we had our science lesson there all the time." (EGPost1)*

> *"Not here (in the village), but for example, in Konya, in places such as the science center. It can be in greenery places, so I would like to study in the forest, in the zoo. These are better places." (EGPost3)*

> *"So they are more fun, more informative places. I learn in places such as zoos when it comes to learning outside of school. Places like Mevlana, eh Seksen Binde Devri Alem Park, science center, I can't think of anything else but the planetarium. Like a lot of parks, it could be Valley of Butterflies after that." (EG-Post4)*

The codes concerning the "learning benefits" category of the CG and the EG students' perceptions of OSLEs are presented in **Table 8**.

Table 8. The Codes of the "Learning Benefits" Category.

Pre-Interview (CG)	Post-Interview (CG)	Pre-Interview (EG)	Post-Interview (EG)
Repetition	Reinforcement	Reinforcement	Reinforcement
Acquiring new information	Acquiring new information	More information	Willingness to learn
Success (exam success)	Success (exam success)	Success (exam success)	Success (exam success)
Obtaining pre- information	Permanent learning	Obtaining pre-information	Permanent learning
Ease in learning	Ease in learning	Lesson preparation	Ease in learning
		Course success	Getting detailed information
		Visual representation	Research desire
			Acquiring new knowledge
			Competition
			Reality
			Curiosity
			Information sharing
			Class attendance
			Loving science
			Career choice

When the codes concerning the "learning benefits" category of OSLEs were examined from **Table 8**, the CG students estimated the benefits of being in an out-of-school environment. The benefits of the pre-interview meeting; while expressing repetition, high grade, and subject repetition; similarly in the post-interview, they expressed success, reinforcement, high grades, and easy learning. When the codes concerning the learning benefits category are examined, it is seen that the codes of the EG students differ after the science center applications. In the pre-interview, EG students expressed the benefits of OSLEs as course success, prior knowledge, visual expression, and information. In the post-interview, it can be stated that the answers given by the EG students vary as they experience OSLEs. When the codes and student answers were examined in the post-interview; It is seen that science center activities made with EG students change the dimension of benefit from their perceptions of OSLEs. The following are examples of expressions from participants that were assessed concerning this category:

> *"I would learn new information, then I would learn new topics, I would have pre-information. There would be many things that caught my attention, I would learn things that I did not know." (CGPre1)*

"I repeat the lesson better, I listen well, I remember the topics better, I will do better in the exam" (CGPost2)

"I think I will be more successful in my studies. Well, my grades would be better. My lessons can improve." (CGPost3)

"I don't know what use it would be." (EGPre4)

"My teacher, I did not understand the science lesson here (in the classroom), I was a little bored, but I understood more there, I understood better, and I gave the answers well. My interest in science lessons increased a little more. It contributed a little more to my exams; I did it by thinking about it, in the exams. What I saw there remained better in my mind." (EGPost4)

"When we went to the science center, we learned the subjects that we did not know in the lesson better visually. We reinforced it more. We learned what we did not learn in the lesson. We learned what happened in the sky, we learned what we were wondering. We see it in books, this is pollution, but when we went there, we saw space pollution as if we were in space. I learned better about space rockets and astronauts." (EGPost1)

"I learned a lot at the science center, learned some of the subjects I hadn't learned, and then I started to attend the class more. It felt real there as if I was in outer space. We saw the satellites, and my curiosity increased. I learned things I did not know, I learned new information there. My curiosity about science increased, and it increased my desire to research. We just thought that the sun was big, but thanks to the planetarium, we saw that there are bigger stars in the Milky Way galaxy. It can enable us to better answer the questions asked in knowledge competitions. We can participate more in the lesson with what we remember from the show we watched there. I realized that things other than stars and clouds are in the sky. There were a lot of stars, I thought there were very few. We learn from the book or the smart board in the classroom, but we see it live there. It's more descriptive there and we don't get bored because it's fun. Everyone is listening, there is no sound, we understand better." (EGPost2)

"We can learn what we do not understand in the lesson, and we can understand more by seeing and hearing. We learn the

Table 9. The Codes Concerning the "Integration with Science (Specifically for the Science Center)" Category.

Pre-Interview (CG)	Post-Interview (CG)	Pre-Interview (EG)	Post-Interview (EG)
Planets	Planets	Planets	Planets
Dinosaurs	Dinosaurs	Dinosaurs	Planetarium
Space	Space	Space	Space shuttle
Electronic devices	Robots	Robots	Robots
Plants	Plants	Stars	Test sets
Microscopes	Microscopes	Mock-up	Telescopes
	Telescopes		Space telescope
	Satellites		Satellites
	Stars		Constellations
			Black hole
			Space station
			Light pollution
			Astronauts
			Exhibitions

lessons we will cover later. We learned it at school, and when we went there, we reinforced it even more". (EGPost3)

"My curiosity increased; more questions began to come to my mind. My desire to learn has increased. I explain what I learned there in class if my friends don't know, I explain them too." (EGPost4)

The codes concerning the "integration with science (specifically for the science center)" category of the EG students' perceptions of OSLEs are presented in **Table 9**.

When the CG students' codes are examined here, it can be said that the answers given by the students before the unit differ slightly compared to the answers given after the unit is completed. This differentiation is in the form of the diversification of the concepts related to the subject of the unit. Examining the student codes in the category of integration with science from the pre-interviews, it is seen that the EG students can integrate in a limited way. Looking at the post-interview codes after the science center activities, it can be said that the students also benefited from the experiment sets in the science center. The following are direct quotations from participants:

"In it, there may be something about physics and chemistry in those subjects. Well, it could be mixtures, plants, dinosaur bones, machines, pictures, or tools, I don't know." (CGPre1)

"In my opinion, there are robots in the science center, so we watch a video showing how robots are made, then maybe we can make small robots." (CGPre4)

"I think of things related to science, cell, dinosaurs, where we have more interesting things to learn more about. It can be introductory things, everything, it can be exhibitions. What remains of the past may be fossils of dinosaurs." (CGPost2)

"There are microscopes in the science center, I think we can study everything there. We saw it in the class, we learned about the planets, the stars, and then the moons in the science class, they can be there too." (CGPost3)

"For example, I did not know the parts of the telescope, I learned there, then we saw things and learned about artificial satellites there. It made me more interested; it made me examine more subjects. I realized there was a lot more to science. Well, I learned things we didn't know about planets. They were built so that they could learn new information for us. We built a telescope in the science center, then we did a lot of activities and went to the planetarium. We learned things we didn't know." (EGPost1)

"It was a place where planets could be seen with the display there where the planets were visible, and when we looked up it seemed like the stars were raining down on us. It was as if we were out in space in a space shuttle. After that, it felt like I could touch the planets, it was beautiful. It was a place like a cinema, we leaned on the seats, but there they put the curtain on the ceiling, it felt like the stars were falling on us, we passed through the sun or something, it was very beautiful, I saw that there are things bigger than the sun, the stars. It was spinning like this, then the music started, we swayed like it was spinning." (EG-Post2)

"There is a space shuttle in the science center, there are constellations, there are planets, and after all, it's like a museum. There was a place related to our body, our lungs, it swelled when we got the air. Then there was a place like a corridor. A place where there is a universal waste. There was the drum thing about

Table 10. The Codes Concerning the "Affective Influence" Category.

Pre-Interview (CG)	Post-Interview (CG)	Pre-Interview (EG)	Post-Interview (EG)
Happiness	Happiness	Happiness	Happiness
Excitement	Excitement	Excitement	Excitement
Fun	Interest	Exploring	Interest
Like	Like		Exploring
			Curiosity
			Feeling comfortable

sound, there were robots. He even had hair like a woman's face. The arm of the robot was moving. There were robots; there was sound vibration ground, space, satellites, black holes, and so on. There were other planets than these." (EGPost4)

Table 10 shows the codes concerning the "affective influence" category of the CG and EG students' perceptions of OSLEs.

As a result of the analysis of the pre-interview and post-interview with the KG students, it is understood that there is no change in the codes related to the "affective effect" category, except for "interest". As a result of the pre-interview in the "affective influence" category for OSLEs codes of the EG students were determined as excitement, happiness, and exploring. In the post-interview, the codes are exploring, feeling comfortable, interest, curiosity, excitement, and happiness. The following are direct quotations from participants:

"It makes me like science more; I become a more knowledgeable person. Science can make me like a subject I already like even more." (CGPre1)

"My interest in science increases, anyway, I have a special place for the science lesson, and extraordinary things come to my mind in this lesson. Science increases the motivation of people; I like science more than social sciences courses." (CGPost2)

"I like to learn new information, it interests me." (CGPost4)

"I was very impressed; it seemed to me that science class was better than it was in school. It increased my desire to learn a

> *little more. I liked making more such discoveries, I focused on it. Interest in science increased the things I wanted to learn. My interest in science increased." (EGPost2)*

> *"It increased my interest in science even more. I began to wonder more about objects in the sky. It increased my desire to learn, and I started to study harder." (EGPost3)*

> *"It made me feel a sense of curiosity, it's nice to see new places and I would like to go again." (EGPost4)*

When we look at the qualitative findings of the pre-interview data, it is realized that the "involvement" dimension among the four dimensions in the OSLEPS could not be determined as a category for both the CG and the EG. The "integration with the school" sub-dimension in the scale was determined as the "integration with science (especially science center)" category in the context of the course. While the learning benefits dimension in the scale was determined as a category, the "incentive for learning" sub-dimension in the scale was determined as codes under the "learning benefits" and "affective influence" categories. The "definition" category, which is not in OSLEPS, was obtained with the question, which was added to the interview form by the researchers, what the science lesson outside of school means and if science was to be taught outside of school, where they would like the lesson to be held.

The OSL activities, in the science center and planetarium were effective in changing students' perceptions of OSLEs in a positive way. After analyzing the pre-interview and post-interview data, we determined the categories as definition, integration with science, learning benefits, and affective influence. It is seen that the dimensions of involvement and incentive for learning in the OSLEPS could not be obtained from the post-interview data of the CG. In the EG, on the other hand, it is seen that the diversity of the codes increased and the codes that could be included in the content of the dimension of involvement and incentive for learning (information sharing, participation in the lesson, learning desire, research desire, etc.) were added. These codes were evaluated under the category of learning benefits.

Discussion and Conclusion

In this study, it was aimed to investigate the effects of the applications conducted in the science center within the scope of the science lesson "Solar System and Beyond" unit of the 7th-grade students in the secondary school, on the perceptions of the students about the OSLEs. Perception is the primary form of human cognitive contact with the world around them. The study of perception has always been of unique importance to philosophy and science, as all conceptual knowledge is based on or derived from this basic form of awareness (Efron, 1969). Perception is shaped by expectation, memory, and learning. In this sense, when the pre-tests and pre-interview findings are evaluated together, it can be said that students' perceptions of OSLEs that are tried to be determined remain at the level of expectations. When the post-tests and the post-interview findings are evaluated together, it is concluded that the perceptions of the EG students towards OSLEs are shaped by memory and learning.

Quantitative findings of this study show that the CG and EG are not equal in terms of their perceptions of OSLEs according to the pre-test findings. The results from the quantitative data indicate that the expectations of the CG students are higher than the expectations of the EG students. However, the results from the qualitative study show the EG and CG students' perceptions are similar at the beginning. It can be said that choosing the mixed research method is more explanatory in this sense. The perceptions of the CG students, which were determined by the post-tests and post-interviews, remained at the level of expectation since they did not experience the science center and planetarium as an OSL environment. It is also seen that there is no statistically significant difference between the pre-test and post-test scores. Although the averages of the OSLEPS pre-test of CG were higher than the EG, there was no significant increase in the number of codes obtained with the pre-interviews and post-interviews in the qualitative findings and there was no change in scope. The small change observed in the post-interviews under the category of "integration with science", one of the categories determined by the qualitative study in the CG, can be attributed to the completion of the "Solar System and Beyond Unit" of the students. It is seen that some concepts (stars, satellites, and telescopes) in the unit have been added to the codes obtained here.

As a result of the research, when the perception scores of the EG students before and after the science center activities were examined, it was seen that their perceptions of OSLEs differed positively. Moreover, in the results obtained in the qualitative study of the EG students, it is seen that there is a change in the number of codes and the scope of the codes, especially under the "learning benefits" category. It can be stated that, it is important for students to experience these environments in shaping and developing perceptions toward OSLEs. When the follow-up test scores of the EG were evaluated according to the OSLEPS post-test scores; It can be said that students' perceptions of OSLEs are permanent. We can state that the practices in the science center and in-class complementary activities have a positive and permanent effect on students' perceptions. OSLEs are an important tool for supporting learning and gaining experience (Balkan Kıyıcı & Yavuz Topaloğlu, 2016).

The results obtained from the "defining OSLEs" category of the students show that the EG students define the OSLEs more scientifically than the CG students. When the codes obtained under the "learning benefits" category are examined, it is remarkable that the EG students change compared to the CG students. As a result of their experiences, the students realized the benefits and contributions of the activities carried out in the science center for them and were able to express the scope of these contributions in detail. It is apparent that the EG students can express this contribution and benefit from different perspectives, for example, they can talk about the benefit for "choosing a profession". Anderson et al. (2000), in their study with 11- and 12-year-old students, state that visiting an interactive science museum has an important place in structuring the knowledge gained in OSLEs. In their study, Ok and Aslan (2020) investigated the effect of workshops held in the science center on primary and secondary school students. The results obtained reveal that as the age gets older, the students realize the contribution of the activities to themselves more, while the younger students are more interested in the fun side of the activities. All students stated that they were comfortable, peaceful, and happy. It has been determined that the objectives are achieved more in the activities carried out with secondary school students.

When the codes under the category of integration with science and the expressions of the students are examined, the importance of the concepts emphasized in the science center and the planetarium activity they experience for this category emerges. The statement of one of the EG students is given below:

> *"We see in the books that pollution is like this, but when we went there, we saw the space pollution as if we were in space. I learned better about space rockets and astronauts. I felt like astronauts there, as if I was in outer space. The dome is three-dimensional like a cinema, but it rotates like a space shuttle." (EGPost3)*

Küçük and Yıldırım (2020) stated in their study that out-of-school teacher guidance improves students' understanding of science, technology and environment. Yılmaz (2018)'s research, it was used the planetarium trip as a complement to the education together with the activities implemented in the classroom; in the study, it is stated that the students' participation in the lesson by asking more questions in the lesson, their interest and curiosity about space increased and also positively affected the development of their concepts. The result of the research shows that the desire to participate in the course and the awareness of the professions increased among students. When science subjects are examined, some units describe nature and events in nature at every grade level. Moreover, for students to understand these subjects, they need to watch, feel, smell, hear, try by doing and experience, and be curious (Türkmen, 2010).

Under the affective effect category, the EG students who experienced the science center stated that they wanted to learn and explore more, they felt more comfortable in the science center, and they were excited and happy. Salmi (1993) states that the field of science education, from kindergarten to the highest research level, is broad and complex, consisting of informal effects not only on the formal education system but also on modern society, technology, and cultural education. It emphasizes that science centers also affect the emotional aspect of learning, especially motivation. Likewise, in the study of Kırgız (2018) in which science center activities were evaluated by students, he reached the following results: students found the science lesson more enjoyable, their desire to research the lesson increased, they liked studying the science lesson more, they found the lesson interesting, they enjoyed listening to the lesson more, and the students associated the lesson with daily life. Plakitsi (2013) states that students feeling that science is exciting in science centers, and they want to experience what they did not do at school.

Recommendations and Limitations

OSLEs are always seen as more interesting and different by students, as it is always about "going out of the routine". However, it is clear that the influence of experiences in shaping perception is very important. The students, who are aware of the benefits of these environments, will participate in activities more willingly and voluntarily. In this sense, it is obvious that students should study in these environments to experience OSLEs.

The economic situation of families can be a factor in the approach of students to OSLEs (Köse, 2007). Especially the students who study in village schools far from the city or district centers can experience these environments thanks to the schools and their teachers. Activities to be carried out by schools and their teachers will enable students to change their perspectives and perceptions positively. In this study, OSLEs are limited to the science center and planetarium. It can be investigated how students' different OSLEs will affect their perceptions. Also, it is limited to the subject of the "Solar System and Beyond" unit. Perceptions of students can be determined through OSL research on different subjects.

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ORIGINAL ARTICLE

The Effects of STEM Activities Conducted with the Flipped Learning Model on Primary School Students' Scientific Creativity, Attitudes and Perceptions towards STEM

Hayriye Erkan, Meltem Duran

Giresun University, Giresun, Turkey

Abstract*: The aim of this study is to determine the effects of STEM activities carried out with the flipped learning model within the scope of science class on the scientific creativity, perceptions about STEM, and attitudes towards STEM of 4th grade primary school students and to reveal students' opinions about the learning process. The sample of this study consisted of 57 fourth grade students attending a public primary school in a city center in the Eastern Black Sea region in the spring semester of the 2021-2022 academic year. Mixed method was used in the study. Quasi-experimental method with experimental and control groups was used in the quantitative dimension of the study, and case study was used in the qualitative dimension. In the study, data were collected using the "Scientific Creativity Scale", "STEM Attitude Scale", "STEM Perception Test" and a "semi-structured interview form" developed by the researcher. SPSS 21 package program was used to analyze the collected quantitative data and content analysis was used to analyze the qualitative data. The quantitative results of the study revealed that STEM activities conducted with the Flipped Learning Model had a positive effect on students' scientific creativity levels and STEM perceptions, but had no effect on their attitudes towards STEM. The qualitative results of the study revealed that students mostly found the activities useful, instructive and fun. In line with the results obtained from the study, the use of STEM activities supported by the Flipped Learning model is recommended at all levels of education.*

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About the Author: *Hayriye Erkan, Master Student, Faculty of Education, Department of Elementary Teacher Education, Institute of Social Sciences, Giresun University , Giresun , Türkiye. E-mail: hayriye.erkan61@gmail.com, ORCID: https://orcid.org/0000-0002-7325-017X*

Meltem Duran, Assistant Professor, PhD, Department of Early Childhood Education, Giresun University, Giresun, Türkiye. E-mail: meltemduran2@gmail.com, ORCID: https://orcid.org/0000-0003-0580-6997

Correspondence to: *Dr. Meltem Duran at Giresun University of Turkey.*

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Introduction

IT is not wrong to call the 21st century the age of technology, where it develops and changes rapidly and where accessing, disseminating and learning information has become more comfortable. This technological age we are in is witnessing races between countries in the shadow of advancing technological developments. Economic success, technological development and education policies can be given as examples of these races (Yıldırım and Selvi, 2017).

Many published reports emphasize that societies will need individuals who can keep pace with change, contribute to the needs of the age, think creatively, have the ability to innovate and have multiple disciplines (National Academy of Engineering [NAE] & National Research Council [NRC], 2009; NRC, 2012; Next Generations Science Standards [NGGS], 2013). The transformation from science education to STEM education started in the United States of America and continues in some European countries and the studies are increasing rapidly. STEM education has become an integral part of 21st century learning programs (Honey, Pearson & Schweingruber, 2014; NAE & NRC, 2009; NRC, 2014). As science and technology progress in the world, the value of STEM education will become more important (Holdren, Lander, & Varmus, 2010).

In Turkey, the Science Curriculum revised in 2013 emphasized the need for STEM integration in learning environments (Ministry of National Education [MoNE], 2013). MoNE also included the engineering discipline in the science curriculum (MoNE, 2017). STEM education aims to enable learning by doing, researching and questioning in the fields of Science, Technology, Engineering and Mathematics, as well as creating an original product. Therefore, by understanding not only how to learn but also how to use knowledge, students will contribute to scientific and technological developments in countries and thus to economic development (Gonzalez & Kuenzi, 2012; Yıldırım & Altun, 2015; Bybee, 2010; Brenner, 2009; National Research Council [NRC], 2011; Scott, 2009; West, 2012). In this way, with an interdisciplinary education approach, students can associate and use the concepts and skills of many disciplines in school with their own life problems, and at the same time, effective teaching can occur (Bybee, 2016). A proper STEM education in accordance with the rules of its implementation improves students' abilities such as understanding the working methods of tools and equipment and using technology effectively (Bybee, 2010).

We observe that certain problems arise during the implementation of the STEM education approach. The intensity of the existing curriculum during the implementation of STEM education (Akın, 2019; Köken, 2020), situations where the class size is too crowded (Köken, 2020), the time allocated for the implementation is not enough (Ozan, 2019; Şen, 2019; Tomaç, 2019; Yazıcı, 2019), communication-related problems between student groups during teamwork (Doğan, Savran-Gencer, & Bilen, 2017; Şen, 2019; Yazıcı, 2019) can be given as examples of these problems. The problems mentioned and the difficulties caused by these problems indicate that STEM education cannot be implemented efficiently enough in learning environments. In this case, in order to implement STEM education effectively, there is a need for new teaching environments that will increase the effectiveness of face-to-face education in learning environments with the support of technology. Within the scope of these goals, one of the models discussed and studied to be developed is the flipped learning model.

The flipped learning model, which emerged by blending the strengths of face-to-face and distance learning, is an approach that utilizes the advantages of both learning environments (Ünsal, 2018). In other words, it is the combination of face-to-face education in the classroom with the learning activity that the student carries out outside the classroom with various online tools, where he/she can adjust the time, place and pace according to his/her needs (Staker & Horn 2012). That is; the student benefits from the advantages of both technology-supported learning environments and face-to-face instruction. When foreign studies on the flipped instruction model are investigated, we see that the concept is defined as "inverted classroom" (Bates & Galloway, 2012; Gannod, Burge, & Helmick, 2008; Lage et al., 2000; Morin, Kecshemety, Harper, & Clingan, 2013; Strayer, 2012, Talbert, 2012) or "flipped classroom" (Bergmann & Sams, 2012; Bishop & Verleger, 2013; Butt, 2014, Enfield, 2013; Hertz, 2012; Milman, 2012).

The concept of flipped learning is considered as a model where learning is performed by students at home with their own means, and homework practices, which are traditionally given by the teacher to be done at home, are done in the classroom environment (Bergmann & Sams, 2012). In the flipped learning approach, which can be briefly defined as a lesson at home and homework at school, resources are provided to the learner so that learning can take place in an individual environment. These resources are various multimedia tools such as videos, slide shows, texts related to the subject. Thus, in the time saved from direct teaching in the classroom, a more effective learning can be provided to the student in the classroom environment. In this context, it is a fact that the process of learning the preliminary theoretical knowledge required for STEM education will be realized in the out-of-school learning environment, and time will be saved in teaching by having only STEM applications in the classroom. McLean et. al. (2016), in their work, students reported that with the flipped approach they developed independent learning strategies, spent more time on the task, and engaged in deep and active learning.

Flipped learning is considered to be a useful model because it allows students to experience their learning. In flipped learning, students can access the topics required for the course at any time according to their learning time. In this way, students have the opportunity to re-access and learn the lessons they cannot reach or watch with the necessary materials (video, presentation, online tool, etc.). Likewise, the teacher can determine the individual needs of the students with the tools used by technology and respond appropriately in the classroom environment (Hertz, 2012). Thus, in STEM education, in and out of the classroom, the research dimension and the elimination of prior knowledge deficiencies are provided by flipped learning.

According to Bergmann and Sams (2012), flipped learning is not only about the use of online tools, but also about interactive activities during the lesson. Today, STEM education, which is applied in educational environments where the student is at the center and technology is used effectively, can be considered as an example of educational models that cause educational systems to change, just like flipped learning. In the same way, the flipped learning model and STEM education can be said to overlap in terms of targeting high-level learning skills, using technology in the process, giving great importance to the use of technology, and activating the student in the process (Söndür, 2020). Considering these issues, we believe that the STEM activities carried out with the Flipped Learning Model in the content of this study will support the development of students.

At the same time, the effects of the flipped learning model on achievement, motivation, self-efficacy, self-directed learning, cognitive load, computer thinking, risk taking and retention were examined and the model was examined in terms of student views (Arshad & Imran, 2013; Berret, 2012; Boyraz, 2014; Demirlay & Karataş, 2014; Johnson & Renner, 2012; Sezer, 2015; Sever, 2014; Yesterbasky, 2015).

While there are scientific studies on the Flipped Learning model (Şerefli, 2020; Yu, 2022; Ünlü, 2022) and STEM activities (Park & Ko, 2012; Kyere, 2017) separately in the literature, there are few studies investigating the effect of the Flipped Learning model and STEM activity applications together (Söndür, 2020; Coşkun, 2021; Birgin, 2022; Ramírez, Hinojosa & Rodríguez, 2014). When the studies are examined, we see that the studies on the flipped classroom model are mostly on foreign languages and computers, and there are very few studies on its use in science classs. In addition, there were no studies on scientific creativity in the studies using the flipped classroom model. Likewise, in the studies on the flipped classroom model and STEM education approach, there was no study on primary school 4th grade students. Considering these issues, we believe that this study will contribute to the literature in this respect.

In addition, there are very few studies in the literature measuring the effects of the Flipped Learning model on scientific creativity (Harjono, et. al. 2022; Ariani, et. al. 2022). The studies conducted on the flipped learning model mostly investigated the effect of the flipped learning model on academic achievement (Güven-Demir, 2018; Ök, 2019; Koçak, 2019; Şerefli, 2020; Tekin, 2020; Demir, 2020; Ünlütürk, 2022).This study aims to examine the effect of STEM activities carried out with the Flipped Learning Model on the learning products of Primary School 4th grade students. The fact that there is no such study in terms of the content study group and the method tools used within the scope of the study increases the importance of this study in terms of contributing to the literature. Clark (2013) and Coufal (2014) found it wrong to use the flipped learning model only in the educational life of university students and to conduct research only at this level. The most important factor that reveals the originality of this study is that the study was conducted with students at the primary school level (4th grade) and is an experimental study, aiming to find solutions to the current educational problems and problems in the process of more effective implementation of STEM education.

Study Questions

The aim of this study is to determine the effects of STEM activities carried out with the flipped learning model within the scope of science class on the scientific creativity, attitudes towards STEM and perceptions about STEM of 4th grade primary school students and to reveal the students' opinions about the learning process. The questions of the research are as follows:

i. Is there a significant difference between the mean pre-test and post-test scores of the students in the experimental group on the Scientific Creativity Scale?
ii. Is there a significant difference between the mean pre-test and post-test scores of the students in the control group on the Scientific Creativity Scale?
iii. Is there a significant difference between the mean post-test scores of the students in the experimental group and the students in the control group on the Scientific Creativity Scale?
iv. Is there a significant difference between the STEM Attitude Scale pre-test-post-test mean scores of the students in the experimental group?
v. Is there a significant difference between the STEM Attitude Scale pre-test-post-test mean scores of the students in the control group?
vi. Is there a significant difference between the mean STEM Attitude post-test scores of the students in the experimental group and the students in the control group?
vii. Is there a significant difference between the mean STEM Perception pre-test and post-test scores of the students in the experimental group?
viii. Is there a significant difference between the STEM Perception pre-test-post-test mean scores of the students in the control group?

ix. Is there a significant difference between the mean STEM Perception post-test scores of the students in the experimental group and the students in the control group?
x. What are the opinions of the students in the experimental group about the STEM activities carried out with the Flipped Learning Model before the implementation?
xi. What are the opinions of the students in the experimental group about the Flipped Learning Model and the STEM activities carried out after the implementation?

The Aim of the Study

The aim of this study is to determine the effects of STEM activities carried out with the flipped learning model within the scope of the 4th grade science class on the scientific creativity, perceptions about STEM and attitudes towards STEM of 4th grade elementary school students and to reveal student views on the learning process.

Materials and Methods

The Model of the Study

This study utilized a mixed method. Qualitative and quantitative data were collected together within the scope of the aims and sub-objectives of the study. The mixed design is based on the belief that using quantitative or qualitative analysis results alone from the statistical data obtained by the researcher is not sufficient to reflect the problems of the research, while combining statistical trends (quantitative data) with stories and personal experiences (qualitative data) is necessary to better understand the research problem (Creswell & Sözbilir, 2017). In the quantitative dimension of the study, the quasi-experimental method with experimental and control groups was used, and in the qualitative dimension, the case study method was used.

Population and Sample

The sample of this study consisted of 57 fourth grade students attending a public primary school in a city center in the Eastern Black Sea region in the spring semester of the 2021-2022 academic year. The sample was selected by convenience sampling method. Two 4th graders were selected as experimental and control groups. In this context, the frequency values of the sample are given in **Table 1**.

Table 1. Frequency Values Of The Students In The Experimental and Control Groups.

Groups	Gender	f	%
Experimental	Male	17	61
	Female	11	39
	Total	28	100
Control	Male	13	45
	Female	16	55
	Total	29	100
Total	Male	30	53
	Female	27	47
	Total	57	100

Data Collection Tools

In this study, quantitative data were collected with the Scientific Creativity Scale, STEM Perception Scale, STEM Attitude Scale and qualitative data were collected with a semi-structured interview form developed by the researcher.

Quantitative Data Collection Tools

- *Scientific Creativity Scale*

In this study, the Scientific Creativity Scale, which was developed by Hu and Adey (2002) and adapted into Turkish by Deniş-Çeliker and Balım (2012) as a quantitative data collection tool to determine the scientific creativity levels of the students, was applied to the experimental and control groups as pre-test and post-test. The Cronbach Alpha reliability coefficient of the measurement tool, which consists of seven open-ended questions, is 0.86.

Reliability calculations of the scale were made by the researcher in terms of internal consistency. For the scoring of the Scientific Creativity Scale, the researcher who adapted the scale was contacted and permission was obtained. Afterwards, the scoring of the scale was carried out in accordance with the determined stages. Total scores were calculated for seven items of the Scientific Creativity Scale. The Cronbach alpha internal consistency coefficient of the scale was found to be 0.82. A positive and high item-total correlation indicates that the items exemplify similar characteristics and the internal consistency of the test is high (Büyüköztürk, 2008).

- *STEM Perception Test*

This study used the STEM Perception Test adapted into Turkish by Gülhan (2016) to determine students' perception levels towards STEM. This test is of the type of "Osgood type emotional meaning scale" (in other words, semantic differences test) and was developed to measure what a situation means to an individual. This test also has a scale type that is simple in terms of ease of application to all age groups and economical in terms of time (Tavşancıl, 2014). The STEM Perception Test consists of 5 sections with sub-headings as science-technology-engineering-mathematics-career. In the test, for each sub-heading and section (science-technology-engineering-mathematics-career), there are 5 adjectives with opposite meanings and 5 more adjectives that are differentiated in terms of opposition. There are 7 different possibilities between the two opposites. These options are listed in a graded format. The students are asked to choose the adjective with the closest meaning to their current emotional state and check the box symbolizing closeness to the chosen adjective.

Reliability calculations of the scale were made by the researcher in terms of internal consistency. The Cronbach α reliability coefficient calculated for the reliability of the scores obtained with the STEM Perception Scale used in the study was α = 0.92.

- *STEM Attitude Test*

The study aims to determine students' attitudes towards STEM in terms of different variables, and the data related to this issue were obtained using the STEM Attitude Scale developed by Faber, Wiebe, Corn, Townsend, and Collins (2013) and adapted into Turkish by Özyurt, Kayiran, & Başaran (2018). The scale is a 5-point Likert-type scale consisting of 37 items and four subscales: math, science, engineering, and 21st century skills; and the construct validity of the rating scale was tested using confirmatory factor analysis by the researchers who adapted it into Turkish.

The reliability calculations of the scale were also made by the researcher in terms of internal consistency. The Cronbach α reliability coefficient calculated for the reliability of the scores obtained from the STEM Attitude Scale used in the research was found to be α=0.95.

Qualitative Data Collection Tools

Semi-Structured Interview Form

In the study, a semi-structured interview form was used as a qualitative data collection tool. For this method, which was preferred in order to obtain more comparative results, the researcher conducted the necessary research based on the information in the literature and prepared semi-structured interview questions to be applied as a pre-test consisting of 10 questions and post-test semi-structured interview questions consisting of 12 questions within the scope of the research scales. In the preparation process of the interview questions prepared by the researcher, attention was paid to criteria such as the question structures being simple and clear, not directing the respondent to different dimensions, being in a dimension to cover the criteria whose effect is measured within the scope of the research, and being at a level that students at the 4th grade level can understand (Bogdan & Biklen, 1992; cited in Yılmaz & Altınkurt, 2011). In order to check the extent to which the prepared semi-structured interview form would help the purpose of the study, its simplicity and applicability, an expert in the field and a classroom teacher were consulted in line with these issues. In line with the feedback received, the interview form was finalized and validity was ensured.

Implementation Process of the Study

The necessary permissions were obtained from the Ministry of National Education in order to carry out the activity implementations in the school where the research would be conducted and the studies were started to be carried out in the school mentioned for the implementation.

The study was conducted in a primary school in a provincial center in the Eastern Black Sea Region in the spring semester of the 2021-2022 academic year. In the first week of the study, experimental (f:25) and control (f:29) groups were determined and pre-tests were administered to both groups. The study groups (experimental and control groups) were administered the Scientific Creativity Scale, Attitude towards STEM Scale and Perception towards STEM Scale as pre-test and post-test. At the same time, focus group interviews were conducted with 8 students selected from the experimental group students before and after the application.

Before starting the implementation in the experimental group, the groups were formed by the classroom teacher to be heterogeneous. In the experimental group of 28 students, 2 were mainstreaming students.1 student could not attend the lessons regularly due to various health reasons. For this reason, 25 students actively participated in the application in the experimental group. In line with the opinions of the classroom teacher, the class was divided into 4 different heterogeneous groups, 3 groups consisting of 6 students and 1 group consisting of 7 students.

In the applications, science discipline was centered and integrated with other STEM disciplines, including at least one other discipline (mathematics, social sciences, Turkish, etc.).

Experimental Group Implementation Process

The study covered a 5-week period and before this process, students were given brief information about the flipped teaching model and STEM education approach and the implementation process was mentioned. At the same time, a meeting was held with the parents of the students in the experimental group in the presence of the class teacher and the activity implementation process was mentioned. In particular, the importance of the support that the parents will give to the students for the out-of-class applications of the flipped teaching model was mentioned. The main purpose here is to provide students and parents with general information about the flipped teaching model and STEM education before the study.

STEM activities were implemented in the experimental group for 5 weeks, 3-4 hours a week. Five different STEM activities prepared by the researcher were applied to the students for a total of 18 hours. The activities were prepared by the researcher taking into account the achievements specified in the 4th grade education curriculum of the Ministry of National Education.

In the out-of-class activities of the flipped learning model, students used EBA. In addition to lectures, animations and activities, students also watched presentations, documents and videos prepared by the researcher and previously uploaded to EBA (STEM technology dimension). Whether the students did the out-of-class activities was checked both from EBA data and from the students at the beginning of the lesson (5 minutes) with a question-answer activity. Thus, it was tried to prevent situations such as whether out-of-class applications were done or not. In addition, the first 5-10 minutes of the application lessons in the experimental group were spent in a mini question-answer round to check the readiness of the students and to go over the parts they could not fully understand. The students imagined their designs in line with the STEM activity problems given to them, and noted the problems that might occur in the design and their ideas on how the problems could be solved (STEM engineering dimension). Students calculated the dimensions of their imagined designs and how much of which material they would use (STEM mathematics dimension). The activities were planned based on the science class outcomes. As a subject, students were encouraged to make predictions and inferences about science concepts and to associate these concepts with daily life (STEM science dimension).

Control Group Implementation Process

In the control group, teaching was carried out by the classroom teacher within the scope of the Science class curriculum, using the textbooks of the Ministry of National Education and the smart board as teaching materials. In the control group classes, the researcher attended the lessons as an observer. Lecture, question and answer, brainstorming, demonstration, etc. were generally used as teaching methods in the learning environment, while the activities in the textbook were also utilized. In addition, class discussions were held in order to better teach the subject in the classroom environment and the evaluation questions in the textbooks were answered. The researcher observed that the control group did not include flipped teaching and STEM activities.

Collection of the Data

"STEM Attitude Scale", "STEM Perception Scale" and "Scientific Creativity Scale" were applied to the control and experimental groups as pre-test before the teaching process of the related units started. At the end of the teaching process, the "STEM Attitude Scale", "STEM Perception Scale" and "Scientific Creativity Scale" were reapplied to the experimental and control groups as a post-test.

In order to obtain more detailed data about the learning processes designed within the scope of the study and to understand the experiences of the students, qualitative data were collected through semi-structured interview forms and focus group interviews before and after the implementation. Face-to-face interviews were conducted with the students. The interviews lasted 25-30 minutes. Open-ended interview questions were asked to the children by the researcher and the answers were recorded by voice recording. The researcher told the participants about the importance of their answers in terms of the validity and reliability of the study and asked them to show the necessary sensitivity. No guidance was given during the interview. Afterwards, the audio recordings were transcribed and analyzed by the researcher.

STEM Activities Preparation Process

Before determining the STEM activities, a literature review was conducted to investigate which subjects were studied in the 4th grade science class. Within the framework of the 4th grade science education program, 5 weeks were planned for 5 activities. These activities consisted of the following contents:

Activity 1*: "sound insulated house design". This activity was created with the "sound pollution" content of the "Lighting and Sound Technologies" unit. However, the activity that requires reducing sound pollution was prepared to cover science, engineering and mathematics disciplines.*

Activity 2*: "economical irrigation system". This activity was organized taking into account the issue of economical use of resources. Within the scope of designing an irrigation system, it is aimed for students to blend science, mathematics, engineering, and technology disciplines.*

***Activity 3**: "I recycle my water design". This activity was organized to emphasize the importance of recycling the resources necessary for life. In this context, it was aimed for students to design creative recycling materials with household waste.*

***Activity 4**: "lighting tool design". This activity was organized to emphasize the importance of recycling the resources necessary for life. In this context, it was aimed for students to design creative recycling materials with household waste.*

***Activity 5**: "designing appropriate lighting". This activity was designed for students to set up a working electrical circuit and learn that the switches and cables in the school are circuit elements.*

For each of the prepared and selected activities, an activity sheet was prepared to support the learning environment based on the STEM education approach. The activity sheets included sections such as the approach to the emergence of the problem, the outcome-oriented problem, the rules determined within the scope of the problem scenario, the selection of the materials and the reasons for the selection, and drawing the sketches of the design. In the experimental groups, theoretical information was presented to the students with the help of instructional technologies and EBA contents outside the classroom environment within the framework of the flipped learning model. Video teaching materials were determined by taking into account the achievements of the relevant units within the framework of the current curriculum. The prepared activities, activity sheets and out-of-class teaching materials were examined by the class teacher of the experimental group, a science teacher and an expert in the field of science education and reorganized in line with the suggestions. Before the application, the students in the experimental groups were determined to have the internet, tools and equipment necessary for them to access out-of-class teaching materials and EBA content. In addition, it was also checked by the classroom teacher whether the students regularly watched the EBA content.

Analysis of the Data

Analysis of the Quantitative Data:

In the study, t-test for Dependent Samples, t-test for Independent Samples, Wilcoxon signed-rank test, Mann-Whitney U test, Shapiro-Wilk test were used to analyze the data. In examinations using the entire study group, the Kolmogorov-Smirnov test was used when the number of individuals was greater than 30. In examining whether the scale/test scores showed a significant difference according to the group (experimental-control group) of the students, Independent Samples t-test from parametric tests and Mann-

Whitney U test from nonparametric tests were used (Büyüköztürk, Çokluk, & Köklü, 2014). Statistical Package for Social Sciences (SPSS), version 21.0 computer package program for Windows was used for statistical analysis of the research data.

Analysis of the Qualitative Data

Regarding the tenth question of the study, the opinions of the students in the experimental group about the activity set applications developed within the scope of the Flipped Learning Model and STEM before and after the application process were analyzed through content analysis. The reliability of the qualitative data was analyzed by the researcher and then the opinion of an expert who has a PhD in statistics was taken.

Codes and themes were created by the researcher. These codes and themes were checked by an expert in the field of statistics and an expert in the field of science to ensure inter-rater reliability. The data obtained were explained statistically in tables using frequency (f). Due to the ethics of the research, the students were given codes as S1, S2, S3....

RESULTS

Quantitative Results:

Findings Related to the Effect of STEM Activity Set on Students' Scientific Creativity Levels

Regarding the first question in the study, it was examined whether there was a significant difference between the pre-test and post-test mean scores of the students in the experimental group in the Scientific Creativity Scale. For the analysis of the data, the parametric test assumptions were checked first. In order for the scores of the control group obtained from the Scientific Creativity Scale to be suitable for parametric testing techniques, they must first meet the assumption of normal distribution. The results of the Shapiro-Wilk normality test for the distribution of the pre-test and post-test scores of the students in the experimental group from the Scientific Creativity Scale are given in **Table 2**.

According to the results of the Shapiro-Wilk Test, it is seen that the score distributions for both the pre-test and post-test do not differ from the normal distribution since the p significance level of the statistical values of the total scores obtained from the scale is greater than 0.05. Accordingly, it was decided that parametric tests could be used for the total scores of the Scientific Creativity Scale (Field, 2009). Accordingly, the t-test for Depend-

Table 2. Shapiro-Wilk Test Results Regarding the Normality of the Score Distributions Obtained from the Scientific Creativity Scale of the Students in the Experimental Group.

		Shapiro-Wilk Test		
		Statistics	SD	p
Pre-test	Scientific Creativity	0.979	25	0.866
Post-Test	Scientific Creativity	0.926	25	0.071

Table 3. Dependent Samples t Test Results for the Comparison of the Mean Scores of the Experimental Group Students' Scientific Creativity Scale Pre-Test and Post-Test Scores.

Group	n	Mean	Ss	Mean Difference	t	SD	p
Pre-test	25	39.08	12.52	-10.60	-4.471	24	0.000
Post-Test	25	49.68	12.86				

Table 4. Shapiro-Wilk Test Results Regarding the Normality of the Score Distributions Obtained from the Scientific Creativity Scale of the Students in the Control Group.

		Shapiro-Wilk Test		
		Statistics	SD	p
Pre-test	Scientific Creativity	0.972	29	0.625
Post-Test	Scientific Creativity	0.971	29	0.594

Table 5. Dependent Samples t Test Results for the Comparison of the Pre-Test and Post-Test Scores of the Scientific Creativity Scale of the Students in the Control Group.

Group	n	Mean	Ss	Mean Difference	t	SD	p
Pre-test	29	35.52	19.21	0.17	0.055	28	0.956
Post-Test	29	35.34	17.78				

ent Samples was used to examine whether there was a significant difference between the mean scores of the students in the experimental group in the pre-test and post-test of the Scientific Creativity Scale. The results obtained are given in **Table 3**.

When **Table 3** is examined, it is seen that there is a significant difference between the total scores of the students in the experimental group from the Scientific Creativity Scale pre-test and the total scores from the post-test ($t = -4,471$, $p < 0.05$). When the results are examined, it is seen that the difference is in favor of the post-tests. Accordingly, the mean of the post-test scores of the Scientific Creativity Scale (mean = 49.68) is significantly higher than the mean of the pre-test scores (mean = 39.08).

Regarding the second question of the study, it was examined whether there was a significant difference between the pre-test and post-test mean scores of the students in the control group on the Scientific Creativity Scale. For the analysis of the data, the parametric test assumptions were checked first. In order for the scores obtained from the Scientific Creativity Scale to be suitable for parametric testing techniques, they must first meet the assumption of normal distribution. The results of the Shapiro-Wilk normality test for the distribution of the pre-test and post-test scores of the students in the control group from the Scientific Creativity Scale are given in **Table 4**.

According to the results of the Shapiro-Wilk Test, the p significance level of the statistical values related to the total scores of the control group obtained from the scale is greater than 0.05, which indicates that the score distributions for both the pre-test and post-test are normally distributed. Accordingly, the t-test for Dependent Samples was used to examine whether there was a significant difference between the pre-test and post-test mean scores of the students in the control group. The results obtained are given in **Table 5**.

When **Table 5** is examined, it is seen that there is no significant difference between the total scores of the students in the control group from the Scientific Creativity Scale pre-test and the total scores from the post-test ($t = 0.055$, $p > 0.05$). Accordingly, it was determined that the mean of the post-test scores of the Scientific Creativity Scale (mean = 35.34) was lower than the mean of the pre-test scores (mean = 35.52), but this difference was not significant.

Regarding the third question in the study, it was examined whether there was a significant difference between the mean post-test scores of the students in the experimental group and the mean post-test scores of the students in the control group in the Scientific Creativity Scale. For the analysis of the data, the parametric test assumptions were checked first. In order for the post-test scores obtained from the Scientific Creativity Scale to be suitable for parametric test techniques, they must first meet the assumption of normal distribution. The results of the Kolmogorov-Smirnov normality test

Table 6. Kolmogorov-Smirnov Test Results Regarding the Normality of the Score Distributions of the Students in the Study Group Obtained from the Scientific Creativity Scale.

		Kolmogorov-Smirnov Test		
		Statistics	**SD**	**p**
Post-Test	Scientific Creativity	0.052	54	0.200

Table 7. Independent Samples t Test Results for the Comparison of the Posttest Mean Scores of the Scientific Creativity Scale of the Students in the Experimental and Control Groups.

Group	n	Mean	Ss	Mean Difference	t	SD	p
Experimental	25	49.68	12.86	14.34	3.344	52	0.002
Control	29	35.34	17.78				

Table 8. Shapiro-Wilk Test Results Regarding the Normality of the Score Distributions Obtained from the STEM Attitude Scale of the Students in the Experimental Group.

		Shapiro-Wilk Test		
		Statistics	**SD**	**p**
Pre-test	Mathematics	0.966	25	0.547
	Science	0.937	25	0.125
	Engineering and Technology	0.946	25	0.202
	21st Century Skills	0.949	25	0.242
	Total	0.957	25	0.365
Post-Test	Mathematics	0.964	25	0.492
	Science	0.896	25	0.015
	Engineering and Technology	0.840	25	0.001
	21st Century Skills	0.901	25	0.020
	Total	0.903	25	0.021

for the distribution of the post-test scores of all students in the study group are given in **Table 6**.

According to the results of the Kolmogorov-Smirnov Test, since the p significance level of the statistical values related to the total scores is greater than 0.05, it is seen that the score distributions related to the post-test are suitable for normal distribution. In this direction, t-test for Independent

Samples was used to examine whether there was a significant difference between the mean scores of the post-test of the Scientific Creativity Scale of the experimental group and the mean scores of the post-test of the control Scientific Creativity Scale. The results obtained are given in **Table 7**.

When **Table 7** is examined, it is seen that there is a significant difference between the total scores of the students in the experimental group from the Scientific Creativity Scale post-test and the total scores of the students in the control group from the post-test ($t = 3.344$, $p < 0.05$). Accordingly, it was determined that the mean of the post-test scores of the students in the experimental group (mean = 49.68) was higher than the mean of the post-test scores of the control group (mean = 35.34) and this difference was significantly differentiated in favor of the experimental group. According to this result, when the post-test scores obtained as a result of the process applied to the experimental group are examined and compared with the post-test scores of the control group, it can be said that the process has a positive effect on the students' Scientific Creativity levels.

Findings Regarding the Effect of STEM Activity Set on Students' Attitude Levels towards STEM

Regarding the fourth question in the study, it was examined whether there was a significant difference between the STEM Attitude Scale pre-test and post-test mean scores of the students in the experimental group. For the analysis of the data, firstly, the parametric test assumptions were checked. In order for the scores obtained from the STEM Attitude Scale to be suitable for parametric testing techniques, they must first meet the assumption of normal distribution. The results of the Shapiro-Wilk normality test for the distribution of the pre-test and post-test scores of the students in the experimental group are given in **Table 8**.

When **Table 8** is examined, according to the results of the Shapiro-Wilk Test, it is seen that the score distributions for both the pre-test and post-test differ from the normal distribution since the p significance level of the statistical values for all sub-dimensions and total scores is not greater than 0.05. In this direction, Wilcoxon signed-rank test was used to examine whether there was a significant difference between the STEM Attitude Scale pre-test and post-test mean scores of the students in the experimental group. The results obtained are given in **Table 9**.

When **Table 9** is examined, it is seen that there is a significant difference between the total scores of the students in the experimental group from the STEM Attitude Scale pre-test and the total scores from the post-test ($z = -2.195$, $p < 0.05$). When the results are examined, it is seen that the difference is in favor of positive ranks, that is, post-tests. Accordingly, the mean of STEM Attitude Scale post-test scores (mean = 144.24) is significantly

Table 9. Wilcoxon Signed-Ranks Test Results for Comparison of STEM Attitude Scale Pre-Test and Post-Test Scores of Students in the Experimental Group.

	Post-Test-Pre-test	n	Rank Average	Rank Total	z	p
Mathematics	Negative	14	130.21	1850.00	-0.606	0.544
	Positive	11	120.73	1400.00		
	Equal	0				
	Total	25				
Science	Negative	6	120.75	760.50	-10.065	0.287
	Positive	14	90.54	1330.50		
	Equal	5				
	Total	25				
Engineering and Technology	Negative	6	120.08	720.50	-20.215	0.027
	Positive	18	120.64	2270.50		
	Equal	1				
	Total	25				
21st Century Skills	Negative	5	150.30	760.50	-10.872	0.061
	Positive	18	110.08	1990.50		
	Equal	2				
	Total	25				
Total	Negative	8	100.13	810.00	-20.195	0.028
	Positive	17	140.35	2440.00		
	Equal	0				
	Total	25				

Table 10. Shapiro-Wilk Test Results Regarding the Normality of the Score Distributions Obtained from the STEM Attitude Scale of the Students in the Control Group.

		Shapiro-Wilk Test		
		Statistics	SD	p
Pre-test	Mathematics	0.898	29	0.009
	Science	0.962	29	0.368
	Engineering and Technology	0.960	29	0.332
	21st Century Skills	0.946	29	0.148
	Total	0.981	29	0.858
Post-Test	Mathematics	0.948	29	0.161
	Science	0.957	29	0.283
	Engineering and Technology	0.964	29	0.419
	21st Century Skills	0.900	29	0.010
	Total	0.974	29	0.658

Table 11. Wilcoxon Signed-Ranks Test Results for Comparison of STEM Attitude Scale Pre-Test and Post-Test Scores of Students in the Control Group.

	Post-Test-Pre-test	n	Rank Average	Rank Total	z	p
Mathematics	Negative	11	140.91	1640.00	-0.602	0.547
	Positive	16	130.38	2140.00		
	Equal	2				
	Total	29				
Science	Negative	9	80.28	740.50	-30.096	0.002
	Positive	20	180.03	3600.50		
	Equal	0				
	Total	29				
Engineering and Technology	Negative	12	90.29	1110.50	-10.629	0.103
	Positive	14	170.11	2390.50		
	Equal	3				
	Total	29				
21st Century Skills	Negative	10	130.65	1360.50	-10.517	0.129
	Positive	18	140.97	2690.50		
	Equal	1				
	Total	29				
Total	Negative	10	120.55	1250.50	-10.990	0.057
	Positive	19	160.29	3090.50		
	Equal	0				
	Total	29				

higher than the mean of pre-test scores (mean = 135.80). Similarly, there is a significant difference between the pre-test and post-test scores of the students in the experimental group regarding the Engineering and Technology sub-dimension of the STEM Attitude Scale ($z = -2.215$, $p < 0.05$). When the results are examined, it is seen that the difference is again in favor of positive ranks, that is, post-tests. Accordingly, the mean of the post-test scores (mean = 35.60) for the Engineering and Technology sub-dimension of the STEM Attitude Scale is significantly higher than the mean of the pre-test scores (mean = 31.44). Finally, there is no significant difference between the pre-test and post-test scores of the STEM Attitude Scale Science, Mathematics and 21st Century Skills sub-dimensions ($p > 0.05$).

Regarding the fifth question of the study, it was examined whether there was a significant difference between the STEM Attitude Scale pre-test and post-test mean scores of the students in the control group. For the analysis of the data, firstly, parametric test assumptions were checked. In order for the scores obtained from the STEM Attitude Scale to be suitable for parametric testing techniques, they must first meet the assumption of normal distribution. The results of the Shapiro-Wilk normality test for the distribution of the pre-test and post-test scores of the students in the control group from the STEM Attitude Scale are presented in **Table 10**.

According to the results of the Shapiro-Wilk Test, it is seen that the score distributions for both the pre-test and post-test differ from the normal distribution since the p significance level of the statistical values for all sub-dimensions and total scores is not greater than 0.05. In this direction, Wilcoxon signed-rank test was used to examine whether there was a significant difference between the STEM Attitude Scale pre-test and post-test mean scores of the students in the control group. The results obtained are given in **Table 11**.

When **Table 11** is examined, it is seen that there is no significant difference between the total scores of the students in the control group from the STEM Attitude Scale pre-test and the scores related to all sub-dimensions except the Science sub-dimension and the post-test scores ($p > 0.05$). There is a significant difference between the pre-test and post-test scores related to the Science sub-dimension of the STEM Attitude Scale ($z = -3.096$, $p < 0.05$). When the results are examined, it is seen that the difference is in favor of positive ranks, that is, post-tests. Accordingly, the mean of the post-test scores (mean = 34.93) for the Science sub-dimension of the STEM Attitude Scale is significantly higher than the mean of the pre-test scores (mean = 30.72).

Regarding the sixth question in the study, it was examined whether there was a significant difference between the STEM Attitude Scale post-test mean scores of the students in the experimental group and the STEM Attitude Scale post-test mean scores of the students in the control group. For the analysis of the data, the parametric test assumptions were first checked. In order for the post-test scores obtained from the STEM Attitude Scale to be suitable for parametric testing techniques, they must first meet the assumption of normal distribution. The results of the Kolmogorov-Smirnov normality test for the distribution of the post-test scores of all students in the study group are given in **Table 12**.

When **Table 12** is examined, according to the results of the Kolmogorov-Smirnov Test, it is seen that the post-test score distributions differ from the normal distribution since the p significance level of the statistical values for all sub-dimensions and total scores is less than 0.05. In this direction, Mann-Whitney U test was used to examine whether there was a significant difference between the STEM Attitude Scale post-test mean scores of the students in the experimental group and the STEM Attitude Scale post-test mean scores of the students in the control group. The results obtained are given in **Table 13**.

Table 12. Kolmogorov-Smirnov Test Results Regarding the Normality of the Score Distributions Obtained from the STEM Attitude Scale of the Students in the Study Group.

		Kolmogorov-Smirnov Test		
		Statistics	SD	p
Post-Test	Mathematics	0.130	54	0.023
	Science	0.120	54	0.049
	Engineering and Technology	0.134	54	0.017
	21st Century Skills	0.128	54	0.027
	Total	0.093	54	0.020

Table 13. Mann-Whitney U Test Results for Comparison of STEM Attitude Scale Posttest Scores of Students in Experimental and Control Groups.

	Group	n	Rank Average	Rank Total	z	p
Mathematics	Experiment	25	230.82	5950.50	-10.598	0.110
	Control	29	300.67	8890.50		
	Total	54				
Science	Experiment	25	280.06	7010.50	-0.244	0.807
	Control	29	270.02	7830.50		
	Total	54				
Engineering and Technology	Experiment	25	310.12	7780.00	-10.574	0.116
	Control	29	240.38	7070.00		
	Total	54				
21st Century Skills	Experiment	25	290.92	7480.00	-10.053	0.292
	Control	29	250.41	7370.00		
	Total	54				
Total	Experiment	25	280.50	7120.50	-0.434	0.664
	Control	29	260.64	7720.50		
	Total	54				

When **Table 13** was examined, it was determined that there was no significant difference between the STEM Attitude Scale post-test mean scores of the students in the experimental group and the STEM Attitude Scale post-test mean scores of the students in the control group ($p > 0.05$).

Table 14. Shapiro-Wilk Test Results Regarding the Normality of the Score Distributions Obtained from the STEM Perception Test of the Students in the Experimental Group.

		Shapiro-Wilk Test		
		Statistics	SD	p
Pre-test	Science	0.818	25	0.000
	Math	0.867	25	0.004
	Engineering	0.898	25	0.017
	Technology	0.861	25	0.003
	Career	0.849	25	0.002
	Total	0.902	25	0.021
Post-test	Science	0.614	25	0.000
	Math	0.847	25	0.002
	Engineering	0.770	25	0.000
	Technology	0.757	25	0.000
	Career	0.844	25	0.001
	Total	0.851	25	0.002

Table 15. Wilcoxon Signed-Ranks Test Results for Comparison of STEM Perception Test Pre-Test and Post-Test Scores of Students in the Experimental Group.

	Post-Test-Pre-test	n	Rank Average	Rank Total	z	p
Science	Negative Sequence	8	70.38	590.00	-10.725	0.085
	Positive Sequence	12	120.58	1510.00		
	Equal	5				
	Total	25				
Mathematics	Negative Sequence	7	110.29	790.00	-0.973	0.330
	Positive Sequence	13	100.08	1310.00		
	Equal	5				
	Total	25				
Engineering	Negative Sequence	6	60.83	410.00	-20.175	0.030
	Positive Sequence	13	110.46	1490.00		
	Equal	6				
	Total	25				
Technology	Negative Sequence	7	100.50	730.50	-0.285	0.776
	Positive Sequence	9	60.94	620.50		
	Equal	9				
	Total	25				
Career	Negative Sequence	5	100.20	510.00	-10.507	0.132
	Positive Sequence	13	90.23	1200.00		
	Equal	7				
	Total	25				
Total	Negative Sequence	6	110.25	670.50	-10.917	0.055
	Positive Sequence	16	110.59	1850.50		
	Equal	3				
	Total	25				

Findings Regarding the Effect of STEM Activities on Students' Perception Levels Related to STEM

Regarding the seventh question in the study, it was examined whether there was a significant difference between the STEM Perception Test pre-test and post-test mean scores of the students in the experimental group. For the analysis of the data, firstly, the parametric test assumptions were checked. In order for the scores obtained from the STEM Perception Test to be suitable for parametric testing techniques, they must first meet the assumption of normal distribution. The results of the Shapiro-Wilk normality test regarding the distribution of the pre-test and post-test scores of the students in the experimental group are given in **Table 14**.

According to the results of the Shapiro-Wilk Test, it is seen that the score distributions for both the pre-test and post-test differ from the normal distribution since the p significance level of the statistical values for all sub-dimensions and total scores is less than 0.05. In this direction, Wilcoxon signed-rank test was used to examine whether there was a significant difference between the STEM Perception Test pre-test and post-test mean scores of the students in the experimental group. The results obtained are given in **Table 15**.

When **Table 15** is examined, it is seen that there is no significant difference between the total scores of the students in the experimental group from the STEM Perception Test pre-test and the total scores from the post-test ($z = -1.917$, $p > 0.05$). Similarly, there is no significant difference between the pre-test and post-test scores of the students in the experimental group regarding the STEM Perception Test Science, Mathematics, Technology and Career sub-dimensions ($p > 0.05$). Finally, there is a significant difference between the pre-test and post-test scores of the students in the experimental group regarding the Engineering sub-dimension of the STEM Perception Test ($z = -2.175$, $p < 0.05$). When the results are examined, it is seen that the difference is in favor of positive ranks, that is, post-tests. The mean of the post-test scores (mean = 31.04) for the Engineering sub-dimension of the STEM Perception Test is significantly higher than the mean of the pre-test scores (mean = 27.40).

Regarding the eighth question of the study, it was examined whether there was a significant difference between the STEM Perception Test pre-test and post-test mean scores of the students in the control group. For the analysis of the data, the parametric test assumptions were first checked. In order for the scores obtained from the STEM Perception Test to be suitable for parametric test techniques, they must first meet the assumption of normal distribution. The results of the Shapiro-Wilk normality test for the distribution of the pre-test and post-test scores of the students in the control group from the STEM Perception Test are given in **Table 16**.

Table 16. Shapiro-Wilk Test Results Regarding the Normality of the Score Distributions Obtained from the STEM Perception Test of the Students in the Control Group.

		Shapiro-Wilk Test		
		Statistics	SD	p
Pre-test	Science	0.897	29	0.008
	Math	0.919	29	0.028
	Engineering	0.960	29	0.325
	Technology	0.886	29	0.005
	Career	0.867	29	0.002
	Total	0.911	29	0.018
Post-test	Science	0.614	29	0.013
	Math	0.847	29	0.001
	Engineering	0.770	29	0.101
	Technology	0.757	29	0.007
	Career	0.844	29	0.004
	Total	0.851	29	0.174

Table 17. Wilcoxon Signed-Ranks Test Results for Comparison of STEM Perception Test Pre-Test and Post-Test Scores of Students in the Control Group.

	Post-Test-Pre-test	n	Rank Average	Rank Total	z	p
Science	Negative	13	140.96	1940.50	-0.863	0.388
	Positive	12	100.88	1300.50		
	Equal	4				
	Total	29				
Math	Negative	10	110.35	1130.50	-0.423	0.672
	Positive	12	110.63	1390.50		
	Equal	7				
	Total	29				
Engineering	Negative	12	130.67	1640.00	-00.601	0.548
	Positive	15	140.27	2140.00		
	Equal	2				
	Total	29				
Technology	Negative	13	140.54	1890.00	-0.344	0.731
	Positive	13	120.46	1620.00		
	Equal	3				
	Total	29				
Career	Negative	12	130.08	1570.00	-0.770	0.441
	Positive	15	140.73	2210.00		
	Equal	2				
	Total	29				
Total	Negative	15	130.37	2000.50	-0.057	0.955
	Positive	13	150.81	2050.50		
	Equal	1				
	Total	29				

When **Table 16** is examined, according to the results of the Shapiro-Wilk Test, it is seen that the score distributions for both the pre-test and post-test differ from the normal distribution since the p significance level of the statistical values for almost all sub-dimensions and total scores related to the STEM Perception Test is less than 0.05. In this direction, Wilcoxon signed-rank test was used to examine whether there was a significant difference between the STEM Perception Test pre-test and post-test mean scores of the students in the control group. The results obtained are given in **Table 17**.

When **Table 1**7 is examined, it is seen that there is no significant difference between the total scores and sub-dimension scores of the students in the control group from the STEM Perception Test pre-test and the total scores and sub-dimension scores from the post-test ($p > 0.05$).

Regarding the ninth question in the study, it was examined whether there was a significant difference between the STEM Perception Test post-test mean scores of the students in the experimental group and the STEM Perception Test post-test mean scores of the students in the control group. For the analysis of the data, the parametric test assumptions were checked first. In order for the post-test scores obtained from the STEM Perception Test to be suitable for parametric test techniques, they must first meet the assumption of normal distribution. The results of the Kolmogorov-Smirnov normality test for the distribution of the post-test scores of all students in the study group are given in **Table 18**.

When **Table 18** is examined, according to the results of the Kolmogorov-Smirnov Test, it is seen that the post-test score distributions differ from the normal distribution since the p significance level of the statistical values for all sub-dimensions and total scores is less than 0.05. In this direction, Mann-Whitney U test was used to examine whether there was a significant difference between the STEM Perception Test post-test mean scores of the students in the experimental group and the STEM Perception Test post-test mean scores of the students in the control group. The results obtained are given in **Table 19**.

When **Table 19** is examined, it is seen that there is a significant difference between the STEM Perception Test post-test total mean scores of the students in the experimental group and the STEM Perception Test post-test total mean scores of the students in the control group ($z = -1.822$, $p < 0.05$). Considering the rank averages, it was found that the STEM Perception Test post-test total mean score of the students in the experimental group (31.70) was significantly higher than the mean score of the students in the control group (23.88). Similarly, it was revealed that there was a significant difference between the STEM Perception Test Science sub-dimension post-test mean scores of the students in the experimental group and the STEM Perception Test Science sub-dimension post-test mean scores of the students in the control group ($z = -2.585$, $p < 0.05$). Considering the rank averages, it was

Table 18. Kolmogorov-Smirnov Test Results Regarding the Normality of the Score Distributions Obtained from the STEM Perception Test of the Students in the Study Group.

		Kolmogorov-Smirnov Test		
		Statistics	SD	p
Post- test	Science	0.815	54	0.000
	Math	0.853	54	0.000
	Engineering	0.884	54	0.000
	Technology	0.850	54	0.000
	Career	0.867	54	0.000
	Total	0.922	54	0.002

Table 19. Mann-Whitney U Test Results for Comparison of STEM Perception Test Post-Test Score Means of Students in Experimental and Control Groups.

	Group	n	Rank average	Rank total	z	p
Science	Experiment	25	330.42	8350.50	-20.585	0.010
	Control	29	220.40	6490.50		
	Total	54				
Math	Experiment	25	270.02	6750.50	-0.211	0.833
	Control	29	270.91	8090.50		
	Total	54				
Engineering	Experiment	25	350.64	8910.00	-30.563	0.000
	Control	29	200.48	5940.00		
	Total	54				
Technology	Experiment	25	300.78	7690.50	-10.441	0.149
	Control	29	240.67	7150.50		
	Total	54				
Career	Experiment	25	270.94	6890.50	-0.193	0.847
	Control	29	270.12	7860.50		
	Total	54				
Total	Experiment	25	310.70	7920.50	-10.822	0.048
	Control	29	230.88	6920.50		
	Total	54				

found that the STEM Perception Test Science sub-dimension post-test mean score of the students in the experimental group (33.42) was significantly higher than the mean score of the students in the control group (22.40). It was also determined that there was a significant difference between the

STEM Perception Test Engineering subdimension post-test mean scores of the students in the experimental group and the STEM Perception Test Engineering subdimension post-test mean scores of the students in the control group ($z = -3.563$, $p < 0.05$). Considering the rank averages, it was found that the STEM Perception Test Engineering sub-dimension post-test mean score of the students in the experimental group (35.64) was significantly higher than the mean score of the students in the control group (20.48). Finally, it was concluded that there was no significant difference between the post-test mean scores of the students in the experimental group on the STEM Perception Test Mathematics, Technology and Career sub-dimensions and the STEM Perception Test post-test mean scores of the students in the control group ($p > 0.05$).

Qualitative Results

Findings Related to Student Opinions on Conducting of STEM Activities in the Classroom and Learning Environments outside the Classroom

- Findings Regarding Student Opinions before Conducting STEM Activities

Table 20 shows that the most common answer under the theme "teaching methods" was "conducting experiments (f:7)". Other answers were "with the help of visuals-slides" (f:4), "using the textbook" (f:3), "using the interactive board" (f:2) and "making a presentation" (f:1).

Table 21 shows that the most common answer under the theme "teaching method" was "teaching by experimentation (f:5)". Other answers were "games" (f:4), "using laboratory" (f:4), "question and answer method" (f:3), "brainstorming (f:2)" and "discussion method" (f:2).

Table 22 shows that under the theme "suggestion", the most common answer was "homework should be in the form of research (f:5)". Other answers were: "it is fun" (f:2), "it should be more difficult" (f:3), "it provides repetition" (f:1), "it provides learning the subject (f:2)".

Table 23 shows that under the theme of "making preparations", the most common response was "making preparations from the textbook (f:6)". Other answers were: "preparing with the help of the internet (f:2)", "preparing with the help of family" (f:3) and "preparing by reading past subjects" (f:1). In addition, under the theme of "not preparing", there was the answer "I do not prepare (f:1)".

Table 20. Findings Related to the Question "How Do You Conduct the Science Class? Explain in Detail."

Theme	Code	Participant	f	Opinions
Teaching methods	Conducting experiments	S1,S2,S3,S4, S5,S6,S8	7	S1: We teach our lessons with the help of slide shows. However, we do experiments and projects using the smart board.
	With the help of visuals-slides	S3,S4,S5,S8	4	S4: We usually teach the lesson from the book. Occasionally we do experiments.
	Using the textbook	S2,S6,S7	3	
	Using the interactive board	S1,S3	2	
	making a Presentation	S1	1	

Table 21. Findings Related to the Question "How Would You Like the Science Class to Be Taught? Explain in Detail."

Theme	Code	Participant	f	Opinions
Teaching method	Teaching by experimentation	S1,S2,S4,S5,S6	5	S2: I would like to do experiments, activities, and learn by playing games. She did it on filtration and we had a lot of fun.
	Games	S2,S3,S4,S5	4	S8: I would like to do activities in the laboratory. I would like my teacher to make us think, such as question and answer, brainstorming methods.
	Using laboratory	S1,S4,S6,S7	4	
	Question and answer method	S3,S4,S6	3	
	Brainstorming	S6,S8	2	
	Discussion method	S4,S8	2	

Table 22. Findings Related to the Question "What are Your Opinions about the Homework Given by the Teacher in the Science Class? Explain in Detail."

Theme	Code	Participant	f	Opinions
Suggestion	Homework should be in the form of research	S4,S5,S6, S7,S8	5	S2: Our teacher always gives homework. I think it is useful, it helps us learn the subject better.
	It should be more difficult	S4,S6,S7	3	S5: Homework is generally good. However, I do not like writing-based homework, my hand hurts a lot. However, I like homework based on research based on our own learning.
Beneficial	It is fun	S3,S5	2	
	It provides repetition	S1	1	
	It provides learning the subject	S1,S2	2	

Table 23. Findings Related to the Question "Can You Give Information about Your Preparation Process before Coming to the Science Class? Explain in Detail."

Theme	Code	Participant	f	Opinions
Making Preparations	Making preparations from the textbook	S1,S3,S4,S6, S7,S8	6	S4: I get help from my family to prepare for the science class before coming to class. Since our teacher recommends a single source book, I try to prepare by examining the subject from there.
	Preparing with the help of the internet	S4,S5	2	S6: I read the subject from the book before coming to class.
	Preparing with the help of family	S1,S4,S8	3	
	Preparing by reading Past subjects	S2	1	
Not Preparing	I do not prepare	S5	1	

Table 24. Findings Related to the Question "What are the Resources You Use in Terms of Accessing Information in Out-of-Class Applications for the Science Class? Explain in Detail."

Theme	Code	Participant	f	Opinions
Resources	İnternet	S1, S2, S3, S4, S5, S6, S7, S8	7	S1: I check on the internet. S7: First I look in the book, then I ask my family. If it is something they do not know, I check on the internet.
	Family	S2,S3, S4, S5, S7, S8	6	
	Book	S2, S4, S6,S7	4	
	Teacher	S8	1	

Table 25. Findings Related to the Question "Do You Have Any Knowledge about the Units 'Lighting and Sound Technologies, Human and Environment, Simple Electrical Circuits' in Science? If Yes, What Do You Know? Explain in Detail."

Theme	Code	Participant	f	Opinions
I have knowledge	Natural and artificial envi-ronment	S1,S3,S6	3	S3: There are natural and artificial environments. I don't know about other units. S6: I do not know these units. I only know light pollution about lighting technologies. There are natural artificial elements. I don't have any other information.
	Light pollution	S6	1	
I don't know	I have no idea	S1,S2,S3,S4, S5,S6,S7,S8	8	

Table 26. Findings Related to the Question "Do You Know about STEM Activities, Have You Done STEM Activities in Science Class? What Did You Do? Explain in Detail."

Theme	Code	Participant	f	Opinions
I don't know	I have no idea	S1,S2,S3,S4,S5, S6,S7,S8	8	S3: I don't know, no
Negative	No	S1,S2,S3,S4,S5, S6,S7,S8	8	

Table 27. Findings Related to the Question "What Are Your Thoughts about the Science Class You Are Studying? Explain in Detail."

Theme	Code	Participant	f	Opinions
Positive	Fun	S1,S2,S5,S6	4	S1: This is also fun. There we only used to learn from the book. Our teacher explains the lesson to us, but STEM activities are more fun and I like them more.
	Preferring a different environment - laboratories	S4,S2,S8	3	S8: It would be even better if we used a laboratory.
Suggestion	Doing different activities in different places and with different materials		1	

Table 28. Findings Related to the Question "What Are Your Thoughts about the STEM Activities You Did during the Science Class? Explain in Detail."

Theme	Code	Participant	f	Opinions
Positive	Fun	S1,S2,S3,S4,S6	5	S1: It was fun, I liked it a lot, I think it was useful.
	Liking Useful Instructive	S1,S2,S4,S5, ,S6,S7 S8 S1,S4,S5 S4,S5	8 3 2	S2: It was good, it was fun, but I would have liked everyone in the group to participate in the process. Some of our friends did not participate in the activities in the group, but other than that, I liked it a lot, we had a lot of fun.
Suggestion	Group participation should be improved To continue	S2,S3 S8	2 1	

Table 24 shows that the most common answer under the "resources" theme was "internet" (f:7). Other answers were: "family" (f:6), "book" (f:4) and "teacher" (f:1).

Table 25 shows that under the theme "I have knowledge", students mostly gave the answer "natural and artificial environment" (f:4). Other answers were: "Light pollution " (f:1). In addition, the answers under the theme "I don't know" was "I have no idea" (f:8).

Table 26 shows that all of the students answered "no" (f:8) under the theme "negative" and "I have no idea" under the theme "no idea" (f:8).

Findings Regarding Student Opinions after Conducting STEM Activities

Table 27 shows that the most common answer under the "positive" theme was "fun" (f:4). Under the "suggestion" theme, they gave the answer "preferring a different environment" (f:3), "doing different activities" and "doing different activities in different places and with different materials" (f:1).

Table 28 shows that the most common answer under the theme "positive" was "Liking" (f:8), "fun" (f:5). Other answers were "group participation should be improved" (f:2), "useful" (f:2) and "instructive" (f:2).

Table 29 shows that under the theme "positive", the participants mostly answered as "participation in the lessons increased" (f:3). Other answers were "my self-confidence increased" (f:3) and "my creativity increased" (f:2). Under the "Negative" theme, there was the answer "it was not useful" (f:1). Also, under the theme "undecided" theme one student was found to be "undecided".

Table 30 shows that under the theme "positive", the most common answer was "it was useful" (f:8). Other answers were "it helped me learn better (f:3)" and "it helped us design" (f:2).

Table 31 shows that under the theme of "activities", the most common answer was "irrigation by saving" (f:3). The other answers were "Sound insulated house design activity" (f:2), "electricity activity" (f:2), " water treatment design" (f:1) and "All activities " (f:2).

When **Table 32** is analyzed, under the "no" theme, students answered "I did not have any difficulty" (f:5). The answers under the theme "(yes) I had difficulty with activities" were "sound pollution" (f:1), "water treatment" (f:1) and "electricity" (f:1).

Table 33 shows that under the theme of "courses", the most common answer given by the students was "Science" (f:6). Other answers were "Mathematics" (f:5), "Turkish" (f:4), "Engineering" (f:3), "Social" (f:2) and "Informatics" (f:1).

Table 34 shows that under the "positive" theme, the most common answer given by the students was "must continue" (f:8) and they also gave the answers "fun" (f:4), "better learning" (f:4), "useful" (f:2) and "increases creativity" (f:2).

Table 35 shows that under the "environment" theme, the most common answers given by the students were "more spacious" (f:3) and "quiet" (f:3), and the least common answers were "in the laboratory" (f:1). In the

Table 29. Findings Related to the Question "Did the STEM Activities Carried out during the Teaching of Science Class Have an Effect on Your and Your Friends' Participation in the Lesson? How?"

Theme	Code	Participant	f	Opinions
Positive	Participation in the lessons increased	S2,S3,S6	3	S5: It contributed a lot, I always come up with design ideas in other lessons. Even at home, I don't let my mother throw garbage anymore, I check the materials to see what I can do.
	My self-confidence increased	S2,S3,S7	3	S7: I feel confident now. I feel that my ideas are valued.
	Design ideas - my creativity increased	S4,S5	2	
Negative	It was not useful	S1	2	
Undecided	I am not sure	S8	1	

Table 30. Findings Related to the Question "Do You Think That the STEM Activities You Did during the Teaching of Science Class Helped You Learn the Subject Better? Explain Your Answer in Detail with the Reasons."

Theme	Code	Participant	f	Opinions
Positive	It was useful - effective	S1,S2,S3,S4, S5,S6,S7,S8	8	S2: I think it was very effective, I understood the topics very well because we came to the lesson knowing the unit. You made us think by asking a lot of questions in the lesson and it was very useful. It was also reinforced with the designs.
	It helped me learn better	S1,S2,S8	3	S8: I think it was useful. Coming to the lesson as having studied and your activities, STEM activities, those designs were very nice. It helped me understand better.
	It helped us design	S1,S2	2	
	In creative thinking	S3	1	

Table 31. Findings Related to the Question "Did You Like the STEM Activities You Did in Science Class? Which Activities Did You Like and Why?"

Theme	Code	Participant	f	Opinions
Activities	İrrigation by saving	S2,S3,S5	3	S3: Yes. I liked the irrigationby saving the most because we won first place in that design by designing the saving system used by my grandfather. It made me very happy to design something I saw at home.
	Sound insulated house design activity	S4	1	S8: Yes. I cannot distinguish, I liked them all very much.
	Electricity activity	S1,S2	2	
	Water treatment design	S6	1	
	All activities	S7,S8	2	

Table 32. Findings Related to the Question "Were There any Parts of STEM Activities That You Had Difficulty with? If Yes, Which Part? Why Do You Think You Had Difficulty in This Part? Explain."

Theme	Code	Participant	f	Opinions
Negative	I did not have any difficulty	*S1,S2,S3,S6,S8*	*5*	*S3: We did not have any difficulty, it would have been more comfortable if my friends had participated in the process.* *S4: I had a little difficulty with electricity, but then we understood it and made our design.*
Activities they are challenged with	Sound pollution	*S5*	*1*	
	Water treatment	*S7*	*1*	
	Electricity	*S4*	*1*	

Table 33. Findings Related to the Question "Which Other Courses Did You Associate the Science Class with While Making Your Materials/Designs during the Science Class? Why?"

Theme	Code	Participant	f	Opinions
Courses	Science	S1,S2,S4,S6, S7,S8	6	S6: Mathematics, Science, Engineering. Turkish. S7: Science, Mathematics, Social Studies. Because we thought and designed from life
	Mathematics	S1,S5,S6,S7,S8	5	
	Turkish	S3,S5,S6,S8	4	
	Engineering	S5,S6,S8	3	
	Social	S3,S4	2	
	Informatics	S2	1	

Table 34. Findings Related to the Question "Would You Like the STEM Activities You Did in the Science Class to be Continued in the Future? Why?"

Theme	Code	Participant	f	Opinions
Positive	Must continue Fun	S1,S2,S3,S4,S5, S6,S7,S8 S2,S6, S7,S8	8 4	S1: I would like to because I learned a lot and it improved my other lessons, for example, I think my math, Turkish and social lessons also improved. S4: I feel more knowledgeable and creative.
	Better learning	S1,S2,S3,S4	4	
	Useful	S2,S3	2	
	Increases creativity	S3,S4	2	

Table 35. Findings Related to the Question "What Would You Like to See Different in the STEM Activities Carried out during the Science Class?"

Theme	Code	Participant	f	Opinions
Environment	More spacious	S2,S5	3	S1: If the in-group discussion time was longer. It would have been better if we had done individual design instead of group activity. S4: The noises outside distracted me. I wish it was in a quieter environment.
	Quiet	S3,S4,S5	3	
	Laboratory	S3	1	
	Must do activities in all classes	S5	1	
Group	Using your own materials	S7,S8	2	
	Discussion time	S1	1	
Design	Individual design	S1,S2	2	

Table 36. Findings Related to the Question "Considering the STEM Activities We Did in the Science Class, Did You Feel Yourself as an Engineer of the Future? Do You Think about Being an Engineer in the Future?"

Theme	Code	Participant	f	Opinions
Positive	I felt like an engineer	S1,S2,S3,S4,S5, S6,S7,S8	8	S2: Yes, I did, I even felt myself as a scientist. S3: Yes, I did, I would like to be a computer engineer.
	The scientist	S2,S8	2	
	I don't want to be an engineer	S1,S5,S7,S8	4	
Profession	Computer engineer	S3	1	
	Design engineer	S4	1	
	Scientist	S4	1	
	Civil engineer	S6	1	

Table 37. Findings Related to the Question "What Are Your Thoughts about the Out-of-Class Lecture Videos You Made in the Science Class, Were These Videos Useful for You to Learn the Subject, Did You Have Any Difficulties in the Process? Explain in Detail?"

Theme	Code	Participant	f	Opinions
Positive	It was instructive	S1,S2,S4,S5, S6,S8	6	S4: This method is very clever. The idea of learning at home and coming back is very nice, I loved the videos, it was very instructive. Sometimes the connection was lost, I had no other difficulties. S3: There was no school, it was as if we were learning by ourselves, it was very fun, we were waiting with excitement, it was very useful to see what to watch. I watched it easily and had no difficulties. S5: I did not have any difficulty. I liked the videos very much, I think they were instructive.
Negative	It was fun connection problem	S3,S5 S4,S7	2 2	

Table 38. Findings Related to the Question "Do You Have Any Suggestions about the Process in General?"

Theme	Code	Participant	f	Opinions
Satisfaction	It is fun	S1	1	S1: I think it was very fun, it was very good, I liked it very much.
	They want to do it individually	S5	1	S5: I think we should have done these activities and designs individually, I did not like that we were a group.
	Change of groups in the process	S6	1	
	Inter-school competition	Ö4	1	
	Liking	S1,S3,S4,S8	4	

second theme, "group", the answers given by the students were Using Your Own Materials (f:1) and discussion time (f:1). Under the design theme, it was determined that they gave the answer "individual design" (f:1).

Table 36 shows that under the theme of "Positive", students mostly gave the answers" I felt like an engineer" (f:8), " I do not want to be an engineer" (f:4) and "scientist" (f:2). It is seen that answers were given as computer engineer (f: 1), design engineer (f: 1), scientist (f: 1), and civil engineer (f: 1) under the theme of "profession".

Table 37 shows that under the theme "positive", all of the students answered were "it was instructive" (f:6) and "it was fun" (f:2). Under the "negative" theme, the "connection problem" (f:2) was answered.

Table 38 shows that under the theme of "Satisfaction", students mostly gave the answer "it is fun" (f:1), they also gave the answers "they want to do it individually" (f:1), " Change of groups in the process " (f:1), "inter-school competition" (f:1) and "Liking" (f:4).

Discussion

Results and Discussion on Scientific Creativity

In terms of the results related to scientific creativity, the study showed that the application based on the STEM education approach supported by the Flipped Learning model increased the scientific creativity level of 4th grade students. Based on this result, STEM activities supported by the Flipped Learning model support the creativity of 4th grade students. In this context, we can say that students' spending more time with STEM activities, thinking about the problem, making discussions, drawing their designs and being free in the realization process, rather than theoretical knowledge in the classroom learning processes, increased the creativity dimension. It can be said that the flipped learning model provides the necessary time spent at school for creativity to develop. In addition, as stated by Şerefli (2020) and Demir (2020), the fact that the application based on the Flipped Learning model is an application that children easily adapt to may have led to this positive result. The fact that the STEM approach is an integrated approach that includes different disciplines such as science, technology, engineering and mathematics (Yakman, 2008), current issues and daily life (Park & Ko, 2012) may have increased students' scientific creativity. It has been stated that creativity is like a muscle and can be developed and strengthened through appropriate exercises (Yatt & McCade, 2011). STEM trainings may have served as appropriate exercises for creativity. Flipped Learning model may also be effective in increasing creativity by increasing student motivation, communication and interaction (Yu, 2022; Ünlü, 2022), enabling students to learn actively, providing high participation, and increasing interest (Kyere, 2017).

Looking at other studies that support this result we see that; Korucuk (2021) conducted a study to examine the effect of flipped learning practices on university students' creative thinking tendencies, communication skills, motivation and academic achievement and found that flipped learning practices had a positive effect on university students' creative thinking tendencies., Al-Zahrani (2015), in his research conducted with the students of the Faculty of Education, determined that the creativity levels of the students who attended the class designed with the Flipped Learning model were higher than those of the control group, Tsai et al. (2020) examined the effects of the flipped learning model on students' learning performance, motivation, student-teacher interaction and creativity and found that the flipped learning model increased students' creativity, Moghadam and Razavi (2022) conducted an experimental study with 3rd grade middle school students and found that students' creativity increased when the flipped learning method was used. In a parallel result, Rodríguez et. al. (2019) reported that students perceived that they developed creative and critical thinking skills and social awareness during the flipped classroom intervention and that after the flipped classroom intervention, students developed different creative skills such as identifying and analyzing problems, generating original ideas, exploring different options, incorporating different perspectives into complex situations, producing sound arguments, and communicating complex arguments while emphasizing main ideas. Nida (2019), on the other hand, found that the Flipped Classroom model was more effective than the direct learning model in increasing students' Mathematical Creative Thinking Skills. As a different study, Wannapiroon & Petsangsri (2020) in their study, which aimed to investigate and develop the STEAMification model in a flipped classroom learning environment to develop creative thinking and creative innovation, they concluded that the creativity of students working through

STEAMification was higher than students working with the normal model. Harjono et al. (2022), as a result of their studies, the experiments in which they aimed to identify those involving creative thinking with the video-supported blended flipped classroom model on students' work and energy materials, they determined that the video-supported blended flipped classroom model can develop creative thinking. Likewise, Farajallah & Al -Najjar (2022) as a result of their study, which aimed to reveal the effect of flipped classroom practice on the development of creative thinking skills and attitudes towards self-directed learning in mathematics in tenth grade students, it was concluded that there was a statistically significant difference between the post-test mean scores of the students in the experimental group and the control group in favor of the experimental group. The results of other studies (Hsia, et. al. 2021; Widyaningrum, 2020) in different fields investigating the effect of flipped learning on creativity have also revealed that it has a positive effect on creativity.

Looking at the studies on STEM education supported by the flipped learning model, these studies generally examined the effects of the flipped model supported by the flipped learning model and STEM applications on academic achievement, self-directed learning with technology, and interest in STEM professions (Söndür, 2020). Another study analyzed the effects of STEM activities implemented with the flipped model on pre-service teachers' self-efficacy beliefs and STEM education orientation (Coşkun, 2020).

The results of some studies showing that STEM activities are effective on creativity are in parallel with this result. Cho and Lee (2013) found that the creative personality, creative problem solving and learning levels of the experimental group students who received STEM programs increased in a study conducted with middle school students. Mayasari et al. (2016) found that STEM applications affect creativity; Gülhan (2016) found that STEM activities had partial effects on scientific creativity in a study conducted with 5th grade middle school students. Konca-Şentürk (2017), in a study conducted with 7th grade middle school students, found that the levels of creative thinking and the levels of flexibility and rationality sub-dimensions of creativity of the experimental group students who received STEM program were higher than those of the control group. Çiftçi (2018) conducted a study with 7th grade middle school students and found that STEM activities increased students' scientific creativity. Genek (2018) investigated the effects of STEM education on scientific creativity in a study with primary school students and found that the scientific creativity level of 4th grade students who started STEM education earlier was higher than that of 2nd and 3rd grade students. Kurtuluş (2019) found that STEM-based lego activities significantly increased students' scientific creativity levels in his research with 6th grade middle school students; Sarıçam (2019) conducted a study with 6th grade middle school students and showed that students' scientific creativity levels increased after STEM education; Baltabıyık (2019) showed that STEM applications had a positive effect on students' scientific creativity in her research with middle school 7th grade students; Asal (2020) showed that the scientific creativity levels of the experimental group students who took engineering design-based science classs with primary school 4th grade students were significantly higher than those of the control group; in the study conducted by Atabaş (2020) with primary school 4th grade students, it was shown that the scientific creativity levels of the students in the experimental group who received STEM education increased significantly; Öz çelik (2021) showed that STEM applications positively affected creative thinking, working collaboratively, communicating, problem solving, and self-regulation in a study conducted with middle school 7th grade students.

Results and Discussion on STEM Attitude

In terms of the results related to attitudes towards STEM, the study showed that the application based on the STEM education approach supported by the Flipped Learning model did not affect the attitudes of 4th grade students towards STEM. The fact that the STEM attitude level of the students increased in both the experimental and control groups can be considered that this increase occurred due to other uncontrollable factors other than the application. Students' experiences in their lives outside of school could be another factor. On the other hand, it can be explained by the fact that attitude change is resistant and the implementation process is not long enough for attitude change. Similar to the results of this study; Rehmat (2015) found that STEM attitude levels were not affected in his research with 4th grade primary school students; Kong and Huo (2014) and Yıldırım (2016) found that STEM activities did not affect the level of attitude towards STEM field; Kurtuluş (2019) conducted a study with 6th grade middle school students and found that there was no difference between the control and experimental groups in any of the STEM attitude sub-dimension levels after STEM activities. The result of this study on the effect of the application based on the STEM education approach supported by the Flipped Learning model on students' attitudes towards STEM is in line with the results of other studies (Rehmat, 2015; Kong & Huo, 2014; Yıldırım, 2016; Kurtuluş, 2019) which concluded that the application based on the STEM education approach did not affect their attitudes towards STEM.

On the other hand, while this study shows that the application based on the STEM education approach supported by the Flipped Learning model does not affect students' attitudes towards STEM, unlike this result; Tseng et. al. (2013) found that STEM activities had positive effects on engineering, science and technology from STEM attitude sub-dimensions; Güzey, Harwell, and Moore (2014) found that the STEM attitude levels of students in schools where STEM activities were implemented were higher than those in schools where STEM activities were not implemented; and in the study conducted by Gülhan (2016) with 5th grade middle school students, it was found that the STEM attitude level of the experimental group increased in science, engineering, technology and total attitude levels, but not in mathematics and 21st century skills. In line with this, it was revealed that the total attitude scores of the experimental group STEM attitude post-test levels of science, engineering and technology were higher than those of the control group. On the other hand, Yavuz (2019) examined the effects of STEM activities on STEM professions, perceptions, and attitudes of primary school 4th grade students and found that STEM activities increased interest in STEM professions, positively affected STEM attitudes and perceptions, and STEM attitude total levels increased after the application; Bircan (2019) conducted a study with 4th grade primary school students and found that STEM education positively affected students' attitudes towards STEM fields (science, technology, engineering and mathematics); Şirin (2020) conducted a study with middle school 7th grade students and found that STEM activities increased STEM attitude level; Özçelik (2021) found that STEM practices positively affected STEM attitudes in a study conducted with middle school 7th grade students.

Results and Discussion on STEM Perception

The results of the study revealed that the application based on the STEM education approach supported by the Flipped Learning model positively affected 4th grade students' science and engineering STEM perception levels, but not their mathematics, technology and career STEM perception levels. Based on these results, we can say that the application based on the STEM education approach supported by the Flipped Learning model partially affected the STEM perception levels of 4th grade students. We can conclude that the effect of the application was especially evident on engineering perception and that this application increased students' perception of engineering. It is also possible to say that the students' practices such as planning, preparation, thinking about design, drawing and creating the design during the application were effective in the prominence of engineering perception. As for the science perception, the fact that the students practiced only the content-oriented practices in the classroom, other than the science content, can be considered as factors that increase the perception, as it made them participate more willingly and interested in the lesson in this process.

When the studies on STEM perception in the literature are examined, it is seen that STEM activities increase STEM perception positively in line with the results of this study (Knezek et al., 2013; Alıcı, 2018; Kuvaç, 2018; Yavuz, 2019; Öner, 2019; Öztürk-İrtem, 2021). In parallel with the findings of this study, Knezek et al. (2013) found that students' STEM perception, mathematics and career sub-dimension levels increased significantly in the trainings where STEM activities were applied. In the study conducted by Alıcı (2018) with 5th grade middle school students, it was determined that students' perceptions towards STEM professions and interest in engineering profession increased after the application. Yavuz (2019), in a study conducted with 4th grade primary school students, showed that STEM activities positively affected STEM perceptions. Öner (2019) investigated how the attitudes and perceptions of middle school 5th, 6th and 7th grade students towards STEM fields differed according to demographic variables and showed that the perception levels of female students and upper grades were higher. In another study examining the perception of scientists, engineers, STEM perception and attitudes towards technology of 5th, 6th and 7th grade students, Öztürk-İrtem (2021) found that the level of STEM perception and perception levels of science, mathematics, technology and career sub-dimension did not differ according to gender, but the level of engineer perception was higher in female students. According to grade level, STEM perception level and mathematics and career sub-dimension levels were found to differ in favor of lower grades. As a different case study, Kuvaç (2018) found that the level of science, mathematics, engineering and technology sub-dimensions and perception levels increased significantly after STEM activities, except for the career sub-dimension, and it was also found that STEM trainings contributed to the perceptions of engineers and engineering. The result of this study on the effect of the application based on the STEM education approach supported by the Flipped Learning model on students' perceptions of STEM is in line with the results of other studies (Knezek et al., 2013; Alıcı, 2018; Kuvaç, 2018; Yavuz, 2019; Öner, 2019; Öztürk-İrtem, 2021) that concluded that applications based on STEM education approach affect perceptions towards STEM.

In a few studies, contrary to this result, it was found that STEM activities did not affect STEM perception or affected it negatively. In the study conducted by Gülhan (2016) with 5th grade middle school students, even though it was found that engineering, technology, career and perception levels increased significantly in the experimental group, no significant difference was found in terms of STEM perception levels in the post-test comparisons of the control and experimental groups. In his study, Mills (2013) showed that the STEM field's career perception level of middle school students who were applied STEM activities decreased.

Qualitative Findings and Discussion

The qualitative findings of this study, which were obtained before the application based on the STEM education approach supported by the Flipped

Learning model, showed that the students mostly taught the Science class by conducting experiments, using visuals, slides and using the textbook, and for this reason, the students stated that they wanted to teach the Science class by conducting experiments and in a fun way. The study revealed that the students stated that they mostly prepared from the textbook before coming to the Science class, and the majority of them benefited from the internet, family and textbook for the classroom applications of the Science class. The study also found that the majority of the students were partially aware of the titles of the units of the Science class, had no previous knowledge about STEM and had not practiced STEM. In the preliminary interview results, it was determined that they did not have any knowledge about STEM education and that an application was made in the Science class.

The qualitative findings of this study, which were obtained after the implementation of the application based on the STEM education approach supported by the Flipped Learning model, indicated that all of the students found the STEM activities carried out during the implementation process fun, that they enjoyed them and that they did not have difficulty in performing the activities. On the other hand, in the quantitative results, it was concluded that the implementation did not affect the students' attitudes towards STEM. This result can be interpreted that the implementation period was not sufficient to show a significant increase in the quantitative results.

Students mostly thought that the activities carried out during the implementation process were beneficial in terms of participating in the lesson and understanding the lesson better. As a result of a similar study, they explained how student engagement increased with the use of the flipped approach (McCallum et al., 2015). The students also associated the Science class with Science, Mathematics and Turkish courses the most. Students suggested that STEM activities should be continued because they are fun and provide better learning, and that STEM activities should be carried out in a wider environment and with higher participation. While half of the students stated that they felt like future engineers during STEM activities, the other half stated that they did not want to be engineers. With this result, the increase in their perception of engineering may not be seen as a factor in their choice of engineering as a profession. Likewise, Rodr ǵuez et. al. (2019), they concluded that the students were very satisfied with the flipped teaching model and recommended its regular implementation in the curriculum.

In terms of the qualitative results of this research, when the relevant literature on STEM activities is examined, there are studies that are similar to the findings of this research in terms of students finding the lessons with STEM activities more fun and satisfying (Kavak, 2019; Rehmat, 2015), thinking that learning is more permanent in lessons with STEM activities (Sarıçam, 2019), finding STEM activities more useful by students (Bircan, 2019; Yavuz, 2019), and students having positive opinions about STEM activities (Koçak, 2019).

In terms of the qualitative results of this research, there are studies that are in parallel with the findings of this study in terms of students' positive opinions about the use of the flipped classroom model (Aydın, 2016; Ünlü, 2022), the flipped classroom model increases students' participation in classroom activities (Güven-Demir, 2018), the flipped classroom model reduces anxiety levels towards science (Ünlütürk, 2022), and the flipped classroom model makes the lesson more fun (Ökmen, 2020; Şerefli, 2020), students' positive approach to learning (Long et al., 2016) and ease of access to resources (Talley & Scherer, 2013). In addition, they are in line with previous research showing that the flipped classroom approach to science education not only stimulates interest in the subject matter but also provides deeper knowledge, making it a more effective strategy than traditional learning (Stockwell, Stockwell, Cennamo, & Jiang, 2015). In contrast to this result, other studies have cited the perception of increased student workload as the reason for negative perceptions of a flipped approach (Khanova, Roth, Rodgers & McLaughlin, 2015; Hotle & Garrow, 2016). As a result of the study, students stated that they liked the out-of-class videos very much and that they were instructive and helped them to learn the content. Likewise another study (Ramírez, et.al. 2014) examining the advantages and disadvantages of reverse face-to-face education shows that the main advantages for students (according to their perceptions) are; flexibility to learn from videos, better comprehension of content, advantage to the class due to previous knowledge and motivation to learn, while among the disadvantages; technical problems, internet, software, etc. problems.

Suggestions

Based on the findings of the study, the following suggestions can be made for practitioners and researchers:

General Suggestions

- Since the findings of this study show that the STEM approach supported by the Flipped Learning model increased students' scientific creativity and STEM perception levels, the STEM education approach supported by the Flipped Learning model should be made widespread in schools. In addition, STEM activities supported by the Flipped Learning model should be used at all levels of education. STEM activities should be started at an early age.
- Since the Flipped Learning model requires students to have some tools and equipment, planning the applications according to the students' pos-

session of the necessary equipment can eliminate the inequality between students. Therefore, attention can be paid to this issue when implementing the Flipped Learning model.

- Teachers who are the implementers of the Flipped Learning model and STEM activities can be informed about these issues. For this purpose, the importance and necessity of these educational approaches can be explained to teachers and training programs can be created in this field both in university education and in vocational training in order to gain knowledge and experience.
- Teachers' ability to implement the Flipped Learning model and STEM activities efficiently depends on their ability to allocate additional time for planning and preparation. For this reason, teachers should be provided with this extra time when planning lessons and curricula.

Suggestions for Future Studies

- In this study, the effects of STEM approach supported by the Flipped Learning model on scientific creativity, STEM attitude and STEM perception were examined. Future research can examine the effects of these practices on other dependent variables.
- The sample of this study was selected from primary school 4th grade students. Future research can investigate the effects of applications based on the STEM education approach supported by the Flipped Learning model at other levels.
- In this study, the effects of demographic variables were ignored. Future studies should also examine the effects of demographic variables. In particular, it may be useful to investigate the moderating effects of demographic variables.

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ORIGINAL ARTICLE

Evaluation on College Students' Anxiety and Social Media Usage during Shanghai Closure

Qian Wei[1,2]

1. *Shanghai Zhongqiao Vocational and Technical University, Shanghai, China*
2. *Chapman University, California, USA*

Abstract*: As COVID-19 mutates, the highly infectious omicron mutants (BA. 5.2., BF. 7) tension shrouded China. Given the internet information explosion and youth social media addiction, observing the mental impact on college students during the 2022 Shanghai closure is worthwhile. A pilot survey study was conducted to explore the anxiety levels of college students during the closure. The sample size was limited to 101 second-year college students. In addition to demographics, the survey involved the Self-Rating Anxiety Scale, self-perceived COVID-19 anxiety, frequency of COVID-19 information reception, number of social media accounts, and number of electronic devices. Though 68.4% of students equipped with two electronic devices (N = 95) exceeded the students with only one electronic device, a Chi-square test showed that students with only one electronic device had the highest anxiety index (mean = 50). Further, the Kruskal-Wallis test indicated that the number of electronic devices affected the students' anxiety level (p = 0.027) while social media membership did not (p = 0.565). As a result, it was suggested that social media usage and pandemic information inputs among college students were significant concerns that required special attention from the government, schools, teachers, and families.*

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***About the Author**: Qian Wei, PhD Candidate, Shanghai Zhongqiao Vocational and Technical University, Shanghai, China; or Chapman University, California, USA. E-mail: qwei@chapman.edu, ORCID: https://orcid.org/0000-0002-1274-650X*

***Correspondence to**: Qian Wei at Shanghai Zhongqiao Vocational and Technical University of China or Chapman University of the USA.*

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Introduction

CORONAVIRUSES pose a mental health threat to the population worldwide (Grover et al., 2020; Marques de Miranda et al., 2020). A systematic review led by Marques de Miranda et al. (2020) is an excellent manifest of this development. Through the analysis of 51 articles retrieved from four databases (PubMed, Scopus, SciELO, and Google Scholars), anxiety, depression, and post-traumatic symptoms were widespread (Marques de Miranda et al., 2020). The researchers found that individuals of different ages reacted differently to the epidemic and that certain age-groups were more susceptible to COVID-19, promoting age as a significant factor to be examined throughout the pandemic. Moreover, Liu and colleagues (2020) conducted a cross-sectional study of mental health in different age groups with Chinese university students and elementary school students during this time. In February and March 2020, Liu et al. (2020) tested 198 college students and 209 elementary school students in Sichuan Province in China, respectively, using the Somatic Self-Rating Scale (SSS). In addition to the somatic assessments of the subjects, the SSS also included assessments of anxiety, depression, and mixed anxiety-depression symptoms. The results showed that more college students (63.6%) experienced more somatic symptoms concerning COVID-19-related concerns than the dependent child group. The COVID-19 concerns included "daily life necessities, the efficacy of prevention, and control measures" (p. 3), among which "daily life necessities" was their most significant concern. Liu et al. (2020, p.3) linked these three concerns to students' anxiety and levels of depression. Thus, it can be seen that in the post-epidemic era, college students, as independent individuals, are more likely to receive negative information than children – a significant threat to college students' mental health.

At the same time, Chang et al. (2020) administered a web-based questionnaire to 3,881 college students using the Cognitive Behavior Scale, Generalized Anxiety Inventory, and Depressive Symptom Scale to explore the factors affecting college students' anxiety during the pandemic. The results showed that 69.47% of college students had high COVID-19 awareness, 26.6% were troubled by anxiety, and 21.16% of respondents had depressive tendencies. Although the risk of mild anxiety is lower in the group with higher age and higher awareness of COVID-19, improving students' protection awareness by receiving online information is still risky. Moreover, college students who received more than half of the total amount of negative messages out of all received information about the outbreak were more likely to experience mild anxiety and depression (Chang et al., 2020). Therefore, the authors highly recommend that the social media accounts authorized by universities or colleges should promote health education to guide young people in a positive way. Thus, evaluating and supervising the channels sending negative information is necessary. As for college students, screen time cannot be ignored.

Screen time has long been a threat to young people’s physical and mental health worldwide. In Canada, longer screen time is associated with anxiety and depression among young people (Maras et al., 2015). In Iceland, longer screen time and shorter physical activity pose a significant threat to young people’s mental health (Hrafnkelsdottir et al., 2018). While in China, the same theme has been studied. According to Feng et al. (2014), a study of first-year students at Wuhan University showed lower levels of anxiety and depression among students with high levels of physical activity and low screen time. Nevertheless, Wu et al. (2015) emphasized that low physical activities and long screen time could induce mental health risks and poorer quality sleep among Chinese college students, since poor sleep is a precursor to anxiety, which in turn is a precursor to mental health problems. Therefore, physical activities and screen time are essential factors to consider.

However, throughout the pandemic, college students’ lifestyles changed to include less physical activity and a long-sedentary-screen-time lifestyle (Qin et al., 2020; Xiang et al., 2020). A pilot study was conducted during the Shanghai closure when students had almost negligible access to physical activity due to long-term home or dormitory confinement (Zhang et al., 2021). In this case, to seek the latest COVID-19 information (Zhang et al., 2021), the likelihood of students using electronic devices was significantly increased, along with the increasing possibility of receiving negative COVID-19-relevant information.

More recently, Shanghai has been infected by Omicron since March 2022, with the daily growth of infected people exceeding 2,000 cases per two consecutive days (Shanghai Coronal Virus Report, 2022). The coronavirus spread resulted in the Shanghai closure (The General Policy of "Dynamic Clearing," 2022) and an increased risk of mental problems (i.e., anxiety, panic, and PTSD). The ongoing COVID-19-related information advocated in the media has posed a significant threat to human mental health (Hamza Shuja et al., 2020; Marques de Miranda et al., 2020; Vindegaard & Benros, 2020). Then, the correlation between social media usage and college students mental health during pandemic closure is worth exploring.

College Students Pandemic Anxiety and Self-Rating Anxiety Scale

According to Chang et al. (2021), the youth’s mental health is more susceptible to the external environment. Moreover, the topic of the mental health of people in the epidemic era, or post-epidemic era, has been a massive concern for scholars around the globe since the first wave of global closure in 2019

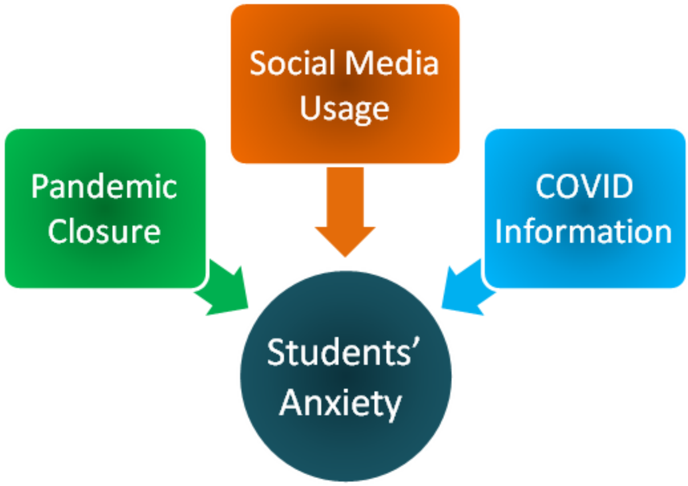

Figure 1. Source of Students' Pandemic Anxiety.

(Deng, 2021). In addition, studies on the 2019 Wuhan closure could serve as a practical guide for this study. Considering the research on college students' pandemic mental health could be a sustaining concern even in the post-epidemic era. If so, how can we spotlight people's anxiety? The **Figure 1** can be a manifest that the overusing of social media where flooded the COVID-19 information during the pandemic closure is a threat to students' anxiety level.

In China, the Self-Rating Anxiety Scale (SAS) was widely used, and the articles on "college students" and "anxiety" with the SAS ranked at the top on CNKI (Zhou, 2012). As the founder of assessing anxiety disorders, Zung (1971) provided both psychopathologists and psychological researchers with assessment tools: the Anxiety Status Inventory (ASI) and the Self-rating Anxiety Scale (SAS). Two scales can be used as measurement tools, but the former is for physician observation, and the latter is for the patient's self-assessment. Zung (1971) created the Self-Rating Anxiety Scale (SAS) by retrieving examples of anxiety symptoms from patient interviews and pairing them with the Observer Anxiety Inventory (ASI) to develop 20 congruent diagnostic criteria with a correlation of 0.74 between the two scales. According to Zung (1971), SAS uses a four-point Likert scale with twenty items ranging from: 1 = none or a little of the time, 2 = some of the time, 3 = a good part of the time, 4 = most or all of the time. Twenty items in the survey scored 1 to 4, while items 5, 9, 13, 17, and 19 were exceptions, with a reversed score of 4 to 1. Moreover, a rough pooled score of these twenty items would be multiplied by 1.25 to get a standard score ranging from 25 to 100, and the mild anxiety level fell in the range of 50-59, the moderate anxiety was 60-69, while 70 or even higher signaled a severe anxiety status (Zung, 1971).

While in 1986, the National Scale Collaborative Group in China discovered that five of the scale's items were difficult for the public to understand, which had an impact on the scale's accuracy. As a result, the Collaborative Group adjusted the scale into positive components and conducted initial tests. In this way, the reliability with Cronbach alpha of 0.931 and validity of the Chinese revision of Self-rating Anxiety Scale (SAS-CR) were achieved, and the well-translated Chinese SAS was authorized to be applied in larger populations in China (Tao & Gao, 1994). Hereinafter, the SAS-CR will be used in this pilot study.

Literature on Pandemic Anxiety

The above scale was applied by Duan et al. (2022) in their latest survey among 1,457 college students in Wuhan, implying that 62.91% of college students were deeply affected by anxiety and depression after the epidemic. Plus, a systematic review of 86 core articles presented by Deng et al. (2021) showed that 34% of college students suffered from depression and 32% from anxiety, significantly different from the pre-epidemic period.

Accordingly, problematic social media use was surveyed among 3,123 college students in Shanghai, showing that it could significantly influence their anxiety levels during the pandemic (Jiang, 2021). Though social media studies during the Wuhan closure displayed that social media could be both an accompaniment and a threat, its abuse may lead to mental issues such as depression (Zhong et al., 2021). Consequently, literature conducted after closure from May to August 2020 showed that weekly social media use surged from 17.2 to 21.4 hours compared with before COVID-19, and nearly 40% of respondents increased their social media use by more than 3.5 hours per week. Plus, 26.4% of the respondents suffered from anxiety (Luo et al., 2021). Therefore, the social media usage research on college students' stress was far-reaching for those experiencing the pandemic closure.

The same attention has been paid to global research. Vindegaard and Benros (2020) analyzed 43 studies related to the pandemic from 2002 to 2003 and revealed that people suffered higher levels of anxiety and depression than before. Much worse, after extracting and investigating 51 COVID-19 articles from four databases, Marques de Miranda et al. (2020) concluded that children and teenagers greatly suffered from anxiety, depression, and post-traumatic symptoms, and schools' role was underestimated. Likewise, when exploring the factors that influenced the post-pandemic students' stress and mental health in 63 countries via ANCOVA and Chi-square tests, Varma et al. (2021) found that the younger the participants were, the more vulner-

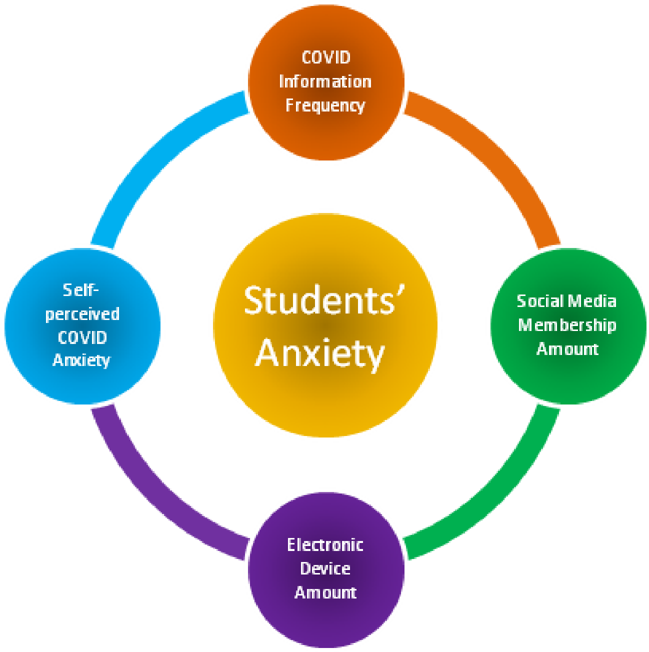

Figure 2. Factors Involved in Students' Anxiety.

able they were, and the more support they needed after. Therefore, students' anxiety during and after the pandemic is a big concern.

Still, comparison anxieties study before and after closure could be more persuasive. To investigate how SNS usage changed among college students during the pandemic, Tuck and Thompson (2021) studied 176 college students during online teaching in the United States. The questionnaire was issued twice with a one-month time interval to track their changes. With an increasing daily time-spending on social media, the students' enjoyment decreased, and their negative emotions augmented. More than that, their stress was due to their addiction to SNS and the degree they received pandemic-related content. Meanwhile, based on quantitative research among 209 students at a university in Turkey, Balaban Sali and Simsek (2014) found that social media membership was positively correlated with internet addiction and mental well-being.

Toward that end, according to the **Figure 2**, this article aimed to explore whether the COVID-19-related information on social media affected college students' emotions and generated their COVID-19-related anxiety during the closure. Hence, this pilot was designed to test the interrelationship between the students' self-perceived COVID-19 anxiety, COVID-19 information frequency, and amount of social media membership with students' anxiety. Hypothetically, students with more electronic devices and more social media membership may tend to get more COVID-19 information and be more stressed.

Therefore, the Null Hypotheses will be:

$H_0$1: The distribution of electronic devices is the same across different anxiety groups.

$H_0$2: The distribution of social media accounts is the same across different anxiety groups.

Methods

This research was piloted among second-year college students at a private vocational and technical university in Shanghai. The random sampling of 101 sophomores who majored in English were enrolled. The online questionnaire was made (https://www.wjx.cn/vj/Oj7sAwm.aspx) and distributed via the "Survey Star" system, a famous web-based software platform for data collection in China. After scanning the questionnaire's Quick Response (QR) code on their mobile phones, participants could access the questionnaire anywhere. And the data was collected from May 15, 2020, to May 25, 2022, during which the omicron concern was still pending. Moreover, the collected anonymous data was highly confidential and adequately documented. After releasing the online questionnaire, 95 (94.1%) students responded, consisting of 74 (77.9%) females and 21 (22.1%) males, who have been experiencing pandemic closure for almost two months in Shanghai. Thus, one of the significances of this pilot study is that it can be extended to foreign language students in similar universities or other comprehensive universities in China.

Besides a well-translated SAS-CR of 20 items with good reliability and validity proved by Tao and Gao (1994), the survey also contained the demographic items (i.e., gender, location, self-perceived COVID-19 anxiety, COVID-19 information frequency, electronic device amount, social media membership amount). Hypothetically, if college students were equipped with more electronic devices and social media accounts, they would have a higher possibility of receiving COVID-19 information, and the more anxious they would be. Given that, the pilot on the relationship between electronic device amounts, social media amounts and anxiety levels was conducted.

In this pilot, the dependent variables were achieved. The number of electronic devices, and the social media accounts were continuous variables, and the anxiety level was conducted from an interval Likert scale. Moreover, the random sampling was collected online during the Shanghai closure. According to the **Table 1**, three dependent variables: number of electronic devices (M = 1.96), social media accounts (M = 3.69), and anxiety levels (M = 46.35) fell into the 95% Confidence Interval yet test of normality should be followed. According to the **Table 2**, the Shapiro-Wilk of both electronic de-

Table 1. Descriptives (N = 95).

				95% Confidence Interval	
	Mean	Std. Error	Std. Deviation	Lower Bound	Upper Bound
Electronic Devices	1.96	0.073	0.713	1.81	2.10
Social Media Accounts	3.69	0.400	3.903	2.90	4.49
Anxiety Level	46.35	0.996	9.710	44.38	48.33

Table 2. Test of Normality (N = 95).

	Kolmogorov-Smirnov*			Shapiro-Wilk		
	Statistic	df	p	Statistics	df	p
Electronic Devices	0.361	95	< 0.001	0.676	95	< 0.001
Social Media Accounts	0.332	95	< 0.001	0.349	95	< 0.001
Anxiety Level	0.101	95	0.018	0.981	95	0.171

**. Lilliefors Significance Correction*

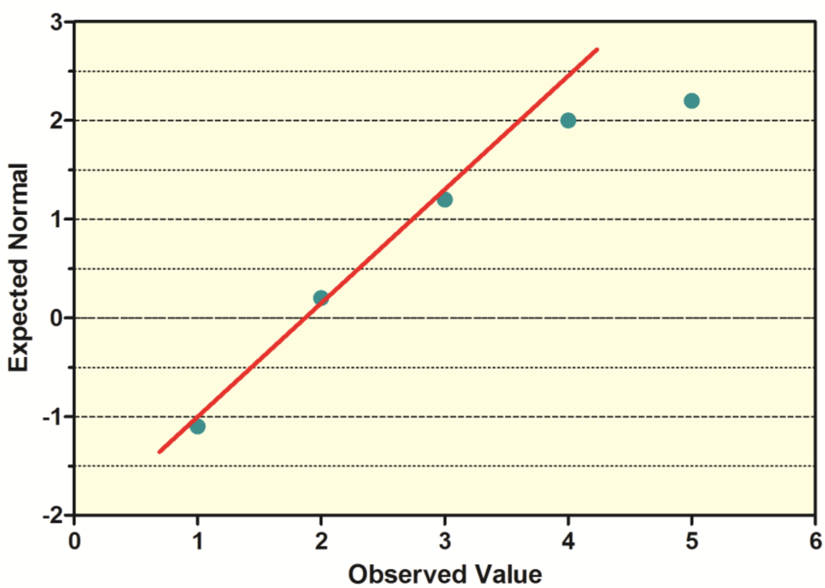

Figure 3. Q-Q Plot of Electronic Devices.

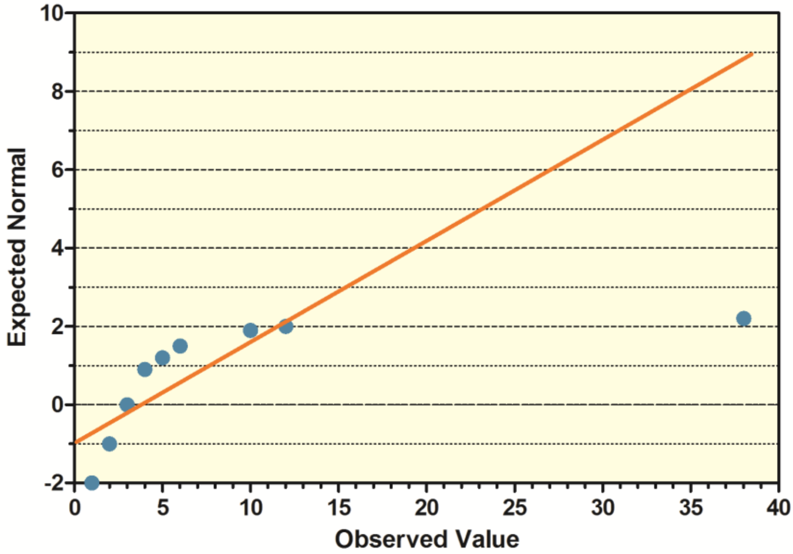

Figure 4. Q-Q Plot of Social Media Accounts.

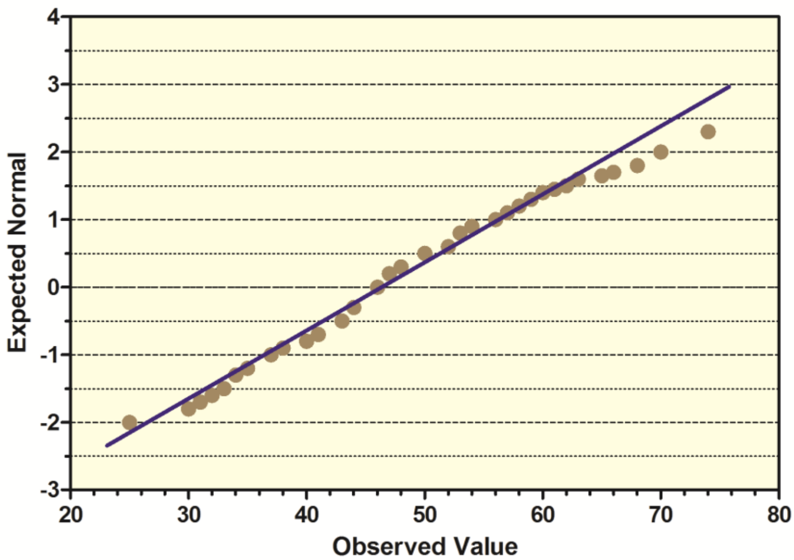

Figure 5. Q-Q Plot of Anxiety Levels.

vices and social media accounts suggested the violation of normality with the significance of 0.000, while a non-significant result of 0.171 ($p > 0.05$) in anxiety level was achieved, meaning a normal distribution (Pallant, 2020). Furthermore, since a reasonable straight line of the Q-Q Plot manifests a normal distribution (Pallant, 2020), the **Figures 3**, **4**, and **5** display the non-normality and the homogeneity of variance could not be attained. Therefore, a non-parametric hypothesis analysis, the Kruskal-Wallis test, should be applied (Pallant, 2020).

The study was performed using SPSS 26. Firstly, the Chi-square would testify to the possibility between COVID-19 information frequency on social media and self-perceived anxiety. Consequently, the Kruskal-Wallis ANOVA (Kruskal-Wallis Test - An Overview, n.d.) tests would assess the differences among electronic devices, the number of social media accounts, and anxiety levels.

Results

According to the survey, 68 ($N = 95$) students were in their dormitory when the closure was initiated. The descriptive analysis demonstrated that 90.53% have constantly received COVID-19 information via social media, while only 45.26% perceived their concern. Then, a Chi-square test was conducted to compare two groups: the self-perceived COVID-19 information anxiety (yes and no) and highly COVID-19 information receiving (yes and no), which said that out of all 86 subjects that frequently get COVID-19 information, 50% were anxious, and 50% did not feel anxious ($p = 0.004$, $\alpha = 0.05$. The 68.4% of students equipped with two electronic devices ($N = 95$) exceeded the other groups with one device and three or more devices, respectively, among which 54 out of 65 were female. The Kruskal-Wallis test offered that students with only one electronic device had the highest anxiety level, with an anxiety median of 50. Though the p-value was 0.096, we could say that it was marginally significant. Due to its marginal significance ($p = 0.096$, $\alpha = 0.1$), there would be at least one of the groups with a different anxiety level (**Figure 6**).

Besides, the number of social media accounts was analyzed. The students with three social media accounts ranked at the top with 35.1%, followed by the two account owners with 26.6%. After referring to the independent-samples Kruskal-Wallis test, we found that the group with only one social media account got the highest median of 50. However, it was not statistically significant, with a p-value of 0.608 ($p > 0.05$; Pallant, 2020) (**Figure 7**).

In addition, given the anxiety classification presented by Zung (1971), the self-rating anxiety data could be divided into three groups: 1 = less anxious students (63.2%), 2 = mildly anxious (26.3%), and 3 = moderate and

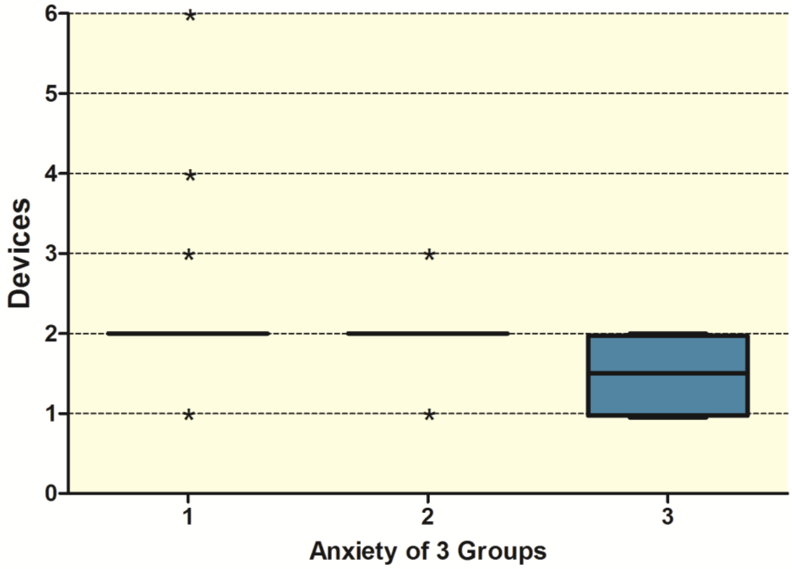

Figure 4. Kruskal-Wallis Test of Electronic Devices and Anxiety Groups.

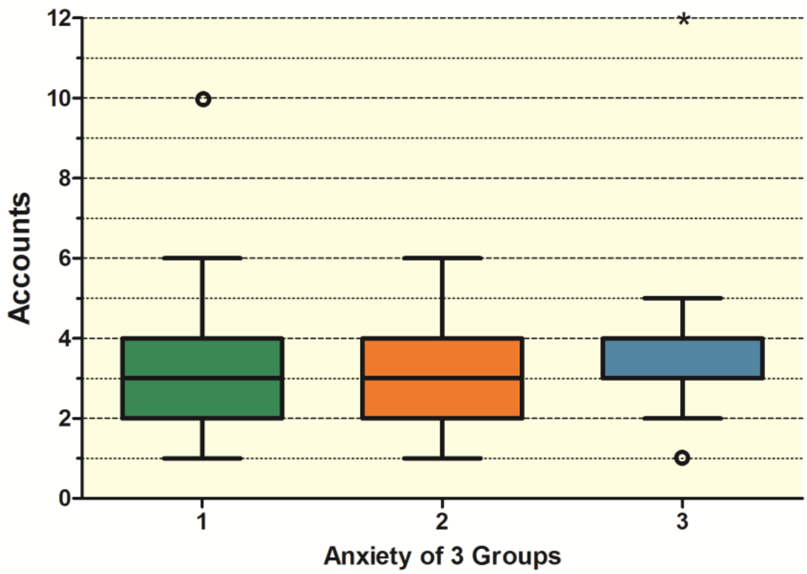

Figure 7. Kruskal-Wallis Test of Social Accounts and Anxiety Groups.

Table 3. Hypothesis Test.

Null Hypothesis	Test	Sig.	Decision
The distribution of electronic devices is the same across categories of anxiety groups.	Independent-Samples Kruskal-Wallis Test	0.027	Reject
The distribution of social media accounts is the same across categories of anxiety groups.	Independent-Samples Kruskal-Wallis Test	0.565	Retain

Asymptotic significances are displayed. The significance level is 0.05.

Table 4. Independent-Sample Kruskal-Wallis Test.

Total N	95
Test Statistics	7.255*
Degree of Freedom	2
Asymptotic Sig. (2-tailed test)	0.027

**: The test statistic is adjusted for ties.*

Table 5. Pair Wise Comparisons of Anxiety Groups.

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.*
3.00-2.00	15.360	8.449	1.818	0.069	0.207
3.00-1.00	20.517	7.713	2.660	0.008	0.023
2.00-1.00	5.157	5.375	0.959	0.337	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is 0.05.
**: Significance values have been adjusted by the Bonferroni correction for multiple tests.*

Table 6. Independent-Samples Kruskal-Wallis Test Summary of Social Media Accounts.

Total N	94 (one outlier was eliminated) (N = 95)
Test Statistic	1.142*,†
Degree of Freedom	2
Asymptotic Sig.(2-sided test)	0.565

**: The test statistic is adjusted for ties.*
†: Multiple comparisons are not performed because the overall test does not show significant differences across samples.

Table 7. Devices * Anxiety Cross Tabulation.

			Anxiety				Total
			Less	Mild	Moderate	Severe	
Devices	1	Count	24	5	1	2	32
		% Within Anxiety	34.8%	25.0%	33.3%	50.0%	33.3%
	2	Count	36	12	2	2	52
		% Within Anxiety	52.2%	56.0%	66.7%	50.0%	54.2%
	3	Count	8	2	0	0	10
		% Within Anxiety	11.6%	10%	0%	0%	10.4%
	Others	Count	1	1	0	0	2
		% Wihin Anxiety	1.4%	5.0%	0%	0%	2.1%
Total		Count	69	20	3	4	96
		% Within Anxiety	100%	100%	100%	100%	100%

Table 8: Accounts * Anxiety Cross Tabulation.

			Anxiety				Total
			Less	Mild	Moderate	Severe	
Accounts	1-2	Count	22	5	1	0	28
		% Within Anxiety	31.9%	25.0%	33.3%	0%	29.2%
	3-4	Count	31	11	0	2	44
		% Within Anxiety	44.9%	55.0%	0%	50.0%	45.8%
	5-6	Count	11	3	2	1	17
		% Within Anxiety	15.9%	15.0%	66.7%	25.0%	17.7%
	Others	Count	5	1	0	1	7
		% Wihin Anxiety	7.2%	5.0%	0%	25.0%	7.3%
Total		Count	69	20	3	4	96
		% Within Anxiety	100%	100%	100%	100%	100%

severe tense students (10.5%). Non-parametric tests were applied to determine whether the amounts of students' electronic devices and social media accounts would be different among the three anxiety groups.

The Kruskal-Wallis test revealed that a statistically significant difference in device distribution across three different anxiety groups (Group 1, n = 60: less anxiety, Group 2, n = 25: mild anxiety, Group 3, n = 10: moderate and severe anxiety) (**Figure 6**), χ^2 (df = 2, n = 95) = 7.26, with a p-value of 0.027 ($p < 0.05$); while the social media distribution among anxiety groups was not ($p = 0.565 > 0.05$; Pallant, 2020). According to **Table 3**, the first null hypothesis will be rejected ($p = 0.027$) while the second one will be retained ($p = 0.565$). Thus, electronic device numbers have an impact on students' anxiety levels.

To further explore the significance of this study, the Bonferroni adjustment was conducted, and the result showed that the anxiety levels among different amounts of social media accounts and electronic devices do not differ significantly from each other at the 0.05 level (**Tables 4-6**).

Nonetheless, considering a small sample size of this pilot study, sample size estimation is a necessity for future research in this regard. According to the one-way ANOVA between two groups (the device amounts and anxiety groups), the devices in the less anxious group ($M = 2.07$, $n = 60$), mild anxiety ($M = 1.88$, $n = 25$), and moderate and severe anxiety ($M = 1.50$, $n = 10$), $F (2, 92) = 3.03$, $p = 0.05$ (**Tables 7** and **8**). Thus, to reach an adequate power of 80% (three groups, $\alpha = 0.05$), G*Power (Faul et al., 2007) was conducted, suggesting that the sample size of future research should be at least 159, with around 53 participants in each group (eta squared = 0.25, N = 159).

Discussion and Conclusion

This pilot study exposed the social media impacts on students' COVID-19 anxiety. Hypothetically, students with more electronic devices could be more anxious than others. However, considering the presented result, the students with only one electronic device had the highest anxiety level, which ran counter to the development proposed by Balaban Sali and Simsek (2014), holding that the more electronic devices owned resulted in higher anxiety. The reason for this reverse result could be correlated to the closure, where students were isolated in situ, most of whom lived in a quadruple room of around 28 square meters, where they were confined in a room with lower access to physical activities and higher access more electronic devices (Qin et al., 2020; Xiang et al., 2020; Zhang et al., 2021). Therefore, the findings provided valuable insights into the correlation between students' social media usage and their anxiety during the closure, when they were isolated and received floods of negative COVID-19-related information (Balaban Sali & Simsek, 2014; Luo et al., 2021; Tuck & Thompson, 2021; Zhong et al., 2021). In the future, the relationship between the number of devices and the level of addiction could be figured out when the Bergen Social Media Addiction Scale (BSMAS) is used to assess students' social media addiction levels (Luo et al., 2021), given that there is a negative relationship between social media addiction and college students' mental health and academic efficiency (Hou et al., 2019).

Considering the special life scenarios caused by the epidemic closure, the possibility of physical activity was significantly reduced (Qin et al., 2020;

Xiang et al., 2020). Accordingly, it is reasonable to assume the physical activity as a control variable due to the pandemic. Thus, the consequent longer screen time and more access to social media for negative information have become the main factors of psychological anxiety and depression among college students (Change et al., 2020; Maras et al., 2015; Hrafnkelsdottir et al., 2018; Liu et al., 2021; Zhang et al., 2021).

Thus, this pilot study can pinpoint whether the number of electronic devices and the number of social media accounts are associated with the level of anxiety among college students during sequestration, providing a reasonable basis for future research in this area. The results showed that compared with the social media accounts, the electronic devices could influence students' anxiety. Also, students with only one electronic device during the pandemic may have a tendency to be more easily addicted to social media and more anxious than others. Therefore, in the future, social media platforms and accounts should promote positive outbreak-related messages to guide young people to face the epidemic properly and positively (Change et al., 2020). Additionally, the research on supports for stressed college students (Varma et al., 2021) and immediate psychological interventions are necessary (Change et al., 2020). Besides, the latest study by Jiang (2021) suggested that psychological capital and academic burnout could moderate college students' problematic social media usage and anxiety during the pandemic, which could be a future orientation.

As for the limitation of this study, it was unknown whether students were already suffering from severe anxiety or other psychological problems before the closure of Shanghai and to what extent COVID-19 anxiety took up the general stress. However, the students have been experiencing continuous closure throughout this study. This long-term closure could provide relatively accurate and realistic psychological data, preparing for future research on social media addiction and anxiety during and post-epidemic comparison. Although this pilot study included a small sample size ($n = 95$), it provided a link between anxiety and device usage during the recent closure. Future studies looking to generalize these results to a larger population of undergraduate students in Shanghai, should consider a minimum sample size will be 159, with around 53 participants in each group (eta squared = 0.25, $N = 159$) to achieve an adequate power of 80% ($\alpha = 0.05$). More than that, a comparative study is suggested for future work, conducted using collected samples from different demographic characteristics (e.g., majors and university type).

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ORIGINAL ARTICLE

A Mixed-Methods Study of Secondary Student and Teacher Attitudes to Mobile Education Apps in Lagos, Nigeria

Sarah Krochinak,[1] Sunny Cui,[2] Babatunde Ajayi,[3]
Remare Egonu,[3] Esther Kim[1]

1. *University of Toronto, Toronto, Canada*
2. *Dartmouth College, Hanover, United States of America*
3. *Lagos State University, Lagos, Nigeria*

Abstract: *With the advent of smartphones, laptops, and other various portable devices, the ability to incorporate technology into the classroom has increased dramatically in the last few decades. This study evaluates the perceptions and attitudes of both students and teachers in relation to mobile apps that assist in classroom learning. The research used a mixed-methods approach that collected demographic information and conducted qualitative interviews to determine the perceptions of mobile apps to students and teachers. Cross-sectional data was collected from participants and analyzed for associations. 43 students and 6 teachers were recruited and interviewed. The participants were asked about their thoughts on mobile educational apps, and their interviews were audio recorded and transcribed. Inductive thematic analysis was used to analyze the data. For students, themes were centered on barriers to educational app adoption, barriers to continued use of education apps, tracking progress, credibility, and goal setting/reminders. For teachers, themes identified that influenced mobile app use, and criteria used for mobile app selection was identified. Future research should aim to assess quantitative improvements in mobile educational app use within the classroom.*

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About the Authors: *Sarah Krochinak, University of Toronto, Toronto, Canada. E-mail: skrochinak@utoronto.ca*

Babatunde Ajayi, Lagos State University, Lagos, Nigeria. E-mail: babatunde.ajayi@lasu.edu

Remare Egonu, Lagos State University, Lagos, Nigeria. E-mail: remare.egonu@lasu.ng.edu

Esther Kim, University of Toronto, Toronto. Canada. E-mail: ekim@utoronto.ca

Sunny Cui, Dartmouth College, Hanover, New Hampshire, USA. E-mail: sunny.cui.24@dartmouth.ng.edu

Correspondence to: *Dr. Sunny Cui at Dartmouth College of the United States of America.*

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Introduction

MOBILE learning, defined as using handheld technologies such as phones for educational use has progressed rapidly in the past decade (Bomhold, 2013; Mohtar et al., 2022; Sonal e al., 2013). An integration of mobile technology with classroom has allowed for a broadening of learning opportunities, allowing students to develop customized performance, enhance learning needs, and provide students with authentic learning practices when alternative teaching methods fail (Doucet et al., 2019; Ramirez-Donoso et al., 2017; Shokirovch, 2022; Voshaar et al., 2022; Wang, 2017). By extension, mobile learning by its nature offers a greater personalized experience, as individual profiles can be taken into account and miniature sized phones or laptops allows for more flexible studying (Criollo et al., 2021; Eppard et al., 2019; Uther, 2019). Educational apps are the most common method of mobile learning. These apps may include simple note apps, language learning apps, or apps intended to heavily integrate with the classroom. While there has been rapid growth in educational app development, research on the use of mobile apps for the purpose of education is scarce, despite schools, governments, and companies regularly using them to train and teach employees and students.

There are few studies that have evaluated the perceptions of educational mobile apps by those that use it. Previous researches on educational mobile apps have adopted a content analysis approach (Bagci & Akpinar, 2018; Kondracki et al., 2002). Although these approaches provide valuable insight on what parts of an app are being used, and the capabilities of such an app, there are very few that have examined the themes, perceptions, and accessibility of these apps. Thus, qualitative studies have been sparce in this area. It is important that research extends beyond just a content analysis stage, in order to not only examine the differences between apps but also the differences amongst users and consumers (Draper et al., 2014; Ok et al., 2016). By designing and examining the user experience of educational apps, researchers can better develop classroom tools to be effectively employed in a low cost setting in developing countries.

Research Questions

This research is aimed at answering the following questions:

1. *What are barriers and motivators for students to use mobile apps that enhance or augment learning in the classroom?*
2. *What are barriers and motivators for teachers to adopt new mobile apps that enhance or augment student's learning in the classroom?*

Literature Review

Learning is described as the ability to acquire or transform pre-existing knowledge, skills or behaviours, usually as a result from experience or training. For humans, the most common form of learning is learning through school education or self-education, in both implicit and explicit ways (Darling-Hammond et al., 2020). E-learning is learning that incorporates technology to enhance knowledge dissemination that began in the 1960s as a result of the Programmed Logic for Automated Teaching Operations (PLATO) project (Pereira & Rodrigues, 2013). In the 70s, the Time-shared, Interact, Computer-Controlled Information Television (TICCIT) increased the development of E-learning (Yan et al., 2010). By the late 80s and early 90s, E-learning encompassed all forms of teaching, and was an emerging and integral piece in workplace onboarding and post-secondary education (Svetlana & Yonglk-Yoon, 2009). E-learning can include virtual classrooms, computer-based education, language learning applications, and web-based learning. Content includes any form of media that can be displayed electronically, allowing the ability for video, animation, images, and audio to be used in the learning process.

In recent years, education has seen a rapid increase in mobile technology adoption (Al-Emran & Shaalan, 2015). The combination of E-learning with mobile solutions has led to “M-learning”, emerging as a new research trend that addresses mobility in several dimensions: mobility of educators, learning, students, and technology (Peters, 2007). Thus, it is imperative M-learning technology is understood and investigated before it is applied to the learning process. M-learning devices can include smartphones, personal digital assistants, cell phones, laptops, tablets, consoles, E-book readers, and more. Notably, M-learning can provide all the advantages of E-learning with the additional ability to be portable and motile.

While the definition of M-learning is not exactly agreed on, it often encompasses mobility of the learner in combination with a learning device, with a degree of personalization to the learner. Hutchison, Beschorner, and Schmidt-Crowford have adopted Traxler’s (2009) definition that is defined as any learning that is “supported or delivered by a handheld device”. Other definitions include Melhuish and Falloon, which define it as “just-in-time, situated learning, mediated through digital technology in response to the needs of the user (2010). Still others, such as Quan et al., suggest a precise definition is impossible, but instead M-learning share a group of characteristics that “enables knowledge building by learners in different contexts, enables learners to construct understandings, and the mobile technology often changes the pattern of learning/work”.

There are several pedagogical methods that relate to mobile learning. Behaviourist theories such as Pavlov and Skinner are relevant to mobile learning due to the nature of stimuli presented from the mobile device (Naismith et al., 2004). Constructivist methods as a result of immersive experiences are analogous to those proposed by Bruner, Piaget, and Papert. Such use of interactive learning increases self-control of the learning process (Evagorou et al., 2008). Furthermore, collaborative learning through group discussions and online chat or video becomes possible over large distances with the advent of the internet, and has been shown to parallel the effects of in-person collaboration (Franklin et al., 2007). The primary advantage of M-learning is the ability to allow learning to be ubiquitous, with access to real-time data from others, content, or learning resources (Churchill & Hedberg, 2008; Naismith et al., 2004; Savill-Smith, 2005). Mobile devices may also be used to gather information, and has shown to be helpful in knowledge consolidation in science classrooms where students were required to learn particularly challenging content that required internet research (Evagorou et al., 2008). Equivalent progress in learning have been found when students are required to gather data on a mobile device compared to a paper and pencil control group. In another case study, students were able to solve a problem set sooner with a drawing tablet as opposed to pencil and paper due to speed and ability to retract changes on the tablet (Lai et al., 2008). Particularly in developing countries, mobile users often vastly outnumber users that are wired, and thus provide an effective means for knowledge translation in poor areas (Yu et al., 2007). Due to pervasive use of mobile phones in much of the developing world, M-learning often occurs without the pre-existence of E-learning (Motlik, 2008).

Even outside of developing countries, mobile use is extremely prevalent. *Project Tomorrow* released a "Speak Up" Report in 2013 that provide statistics on the prevalence of technology use by children and youth within the United States. They found that 65% of middle-school students and 80% of secondary students used a smartphone. The Horizon Report published by the New Media Consortium found similar results (2021). All available statistics agree that mobile device use throughout society, across all parts of the world, is increasing. Consequently, it is understood that this is the primary driver in increased mobile app use for learning.

Various constraints of mobile learning exist, however. Particularly, there is growing debate that mobile technology was not designed for the education industry in mind. Koszalka and Ntloedibe-Kuswani (2010) suggest that mobile phone usage growth is the primary driver for mobile learning growth. Other authors such as Terras believe the technology used for mobile apps were not optimize for "user psychology, habits, needs, behaviours, and socio-cultural habits" in relation to learning. Traxler (2010) has noted that "We can say only that the devices owned by students will be, at best, poorly suited to learning. They will all be different; they will be changing often for reasons that are not technical, not educational and probably not even rational or foreseeable". In general, there is an understanding that mobile devices, while effective in aiding learning, were not designed for educational purposes. Thus, understanding mobile apps, which function as the vehicle that convert mobile devices into learning tools, is critical.

Research Methodology

Research Design

This study utilized a mixed-methods research design that contained both quantitative and qualitative components. The qualitative component used an explanatory design, where group interviewers were conducted with students and individual interviews were conducted by teachers to determine student and teacher perspectives respectively. The quantitative part of the study included administering a questionnaire to all participants for the purposes of collecting demographic information that supplemented findings from the qualitative part of the study.

Participants

Participants were either students or secondary school teachers from 4 local secondary schools located in Lagos, Nigeria. For teacher recruitment, teachers were recruited through a criterion-based sampling method. Inclusion criteria for teachers were defined as follows: teacher had to teach at a senior or junior secondary level, had to have at least implemented one classroom activity through the use of a classroom-educational mobile app, have had experience in using educational mobile apps in classroom contexts; have at least one kind of mobile device (Phone, Tablet, Computer); was a native English speaker. The participants included 6 full-time teachers (2 male, 4 female) that taught a combination of the following subjects: science, physics, chemistry, history, religion, and math. Three of the teachers had post-secondary degrees. 4 of the teachers were employed in schools that were in city centres, while the remaining two were part of country towns. All had indicated they had used educational mobile apps in some shape or form in their classroom to enhance learning. Self-reported time usage on mobile tools was approximately 2-4 hours per week. Teachers used a varying number of different technological devices, including smart phone (4), laptop (6), smart watch (1), and tablet (2). These devices served as dual-function products for personal use, as all participants stated that the device's primary purpose were for personal use.

Student recruitment was done by providing the university administration with an email list of interested teachers, and students in the classes of teachers that agreed to do the study were recruited. Student recruitment consisted of 43 individuals, with 15 randomly selected to be put within interview groups due to limitations required by participating secondary student institutions. 3 groups were made in total with 5 participants each. All participants were provided with a demographic questionnaire to fill out. All the consented participants completed the study. Inclusion criteria were the ownership and regular use of a smartphone; enrolment in a secondary school in Lagos, Nigeria; between the ages of 14-18; had consistent access to internet; and spoke English as a native language. To get a well-rounded picture about why people used or did not use educational apps, both individuals with and without prior knowledge or usage of educational apps were included. All interview groups consisted entirely of Nigerian secondary school students.

Procedure

The institutional review board of Lagos State University approved this study. After obtaining consent from participants, each participant filled out a form on smartphone usage, mobile app usage, demographics, mobile app proficiency, and perceptions on learning and education. A total of three research assistants were in contact with participants. One research assistant served as a moderator, while another transcribed interviews verbatim. The third research assistant conducted interviews. All members of the study team involved in data collection were trained in qualitative analysis and were graduate students. Only the author and participant were ever present throughout the process of data collection. There was no prior relationship between moderators and interviewee. The authors had positive attitudes towards educational mobile apps, but remained neutral in conversation. Small group interviews were conducted at Lagos State University in a set meeting room, with sessions running lasting between 60-120 minutes long. All participants were provided a cash incentive of 8,000 Naira. All interviews were conducted in the same meeting room at Lagos State University Law Library. All interviews were audio recorded and transcribed.

Data Collection

Participants were given a brief summary on the purpose of the study, and asked questions about their knowledge of educational apps, their general app usage, the different kinds of educational apps they may use, and reasons for liking or disliking the apps. Participants were given the opportunity and encouraged to freely discuss own experiences. To facilitate and guide conversation, he interviewer and moderator adhered to a discussion guide.

A demographic information form was provided to both students and teachers. Each participant was asked to fill in said forms before interviews, and requested information with regards to gender, subject being taught/teaching, age, their school district, family income, city, degree, years of teaching experience (if applicable), school name, in addition to mobile educational app usage.

Participants who specified that they have no prior experience or knowledge in using educational apps were given a set of trigger materials to familiarize themselves. These materials were screen captures of several features of education app. These included: 1) tracking study time and information (progress visualization, behaviour monitoring and/or tracking, goal setting), 2) involving teachers and various educators (sending and receiving information to teachers, parents, or school district), 3) taking advantage of social networking, 4) increasing access to educational learning such as coaching, tutorials, etc., 5) the use of entertainment to keep students engaged (gamification), and 6) linguistic learning apps. Participants had the opportunity to explore these categories by accessing these apps on their devices or asking questions. Participants were then asked to discuss thoughts on them, going into as much detail as possible, elaborating on any dislikes they had with the particular apps, and whether or not they had used certain apps and reasons for continuing/discontinuing use.

Data Analysis

The verbatim transcripts were imported and coded with MAXQDA qualitative data analysis software. Inductive thematic analysis was adopted to analyze the data according to Nowell et al.'s 6 phase frameworks (2017). The interview transcriptions were analyzed as a whole. Each recording was coded separately by at least two authors who independently came up with labels to attach to text segments that appeared to indicate important user perspective. Then the team came together to compare their codes and revise the codes in an iterative fashion to develop a set of themes that captured the essence of the discussions or interviews. Finally, the raw data were compared with the emerging theme labels and definitions, and further refined by merging, adding, and removing redundant themes. Then, themes and sub-themes were identified. Demographic data was imported, organized, and aggregated using Microsoft Excel. Certain descriptive statistics including percentage, frequency, and mean values were applied to any relevant data.

Results

Demographic Data

Table 1 summarizes demographic information on app usage for participants. All 43 participants completed the demographic questionnaire. There was a roughly even split between student grades amongst our sample, with 14, 14, and 15 individuals in year 10, 11, and 12 respectively. The sample had an even split between gender (51.2% male) and the majority of users used iOS/Apple devices, while other operating systems included Ubuntu Touch

Table 1. Demographic and Participant Usage of Smartphones and App Usage.

Grade	**Count (%) (43)**
10th	14 (32.5%)
11th	14 (32.5%)
12th	15 (34.9%)
Total	43 (100%)
Gender	
Male	22 (51.2%)
Mobile Device Operating System	
iOS	25 (58.1%)
Android	16 (37.2%)
Other	4 (9.3%)
App Usage/Proficiency	
Number of Apps on Smart Phone (mean)	32 (SD = 11)
Daily Smartphone Usage	4.2 hrs (SD = 2.9 hrs)
Total Mobile Device Usage	7.4 hrs (SD = 3.7 hrs)
Number of Education Apps Used Weekly	3.5 (SD = 3)
% Students that Personally Used Educational App	14 (32.5%)

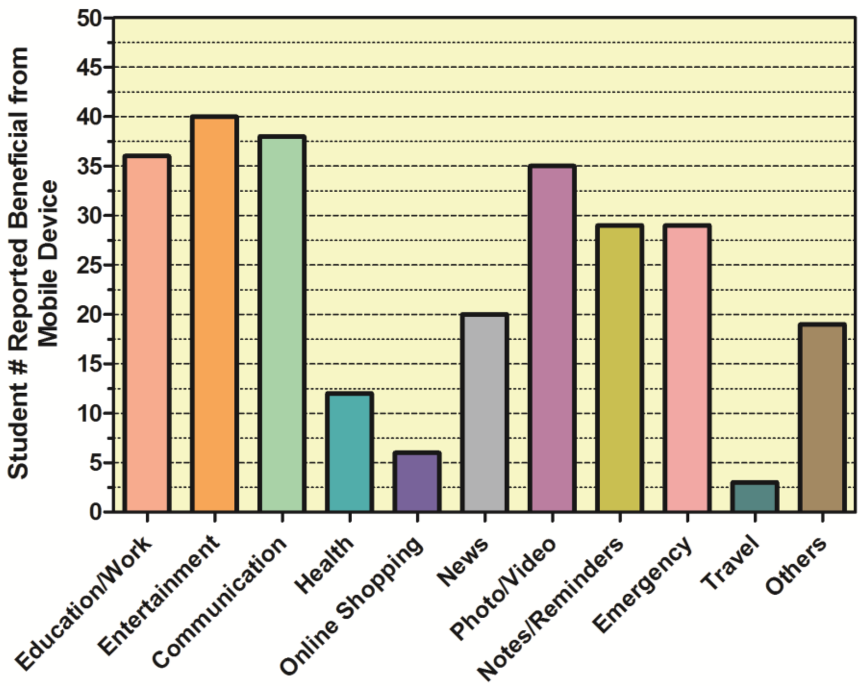


Figure 1. Reported Perceived Benefits of Having A Mobile Device (Students).

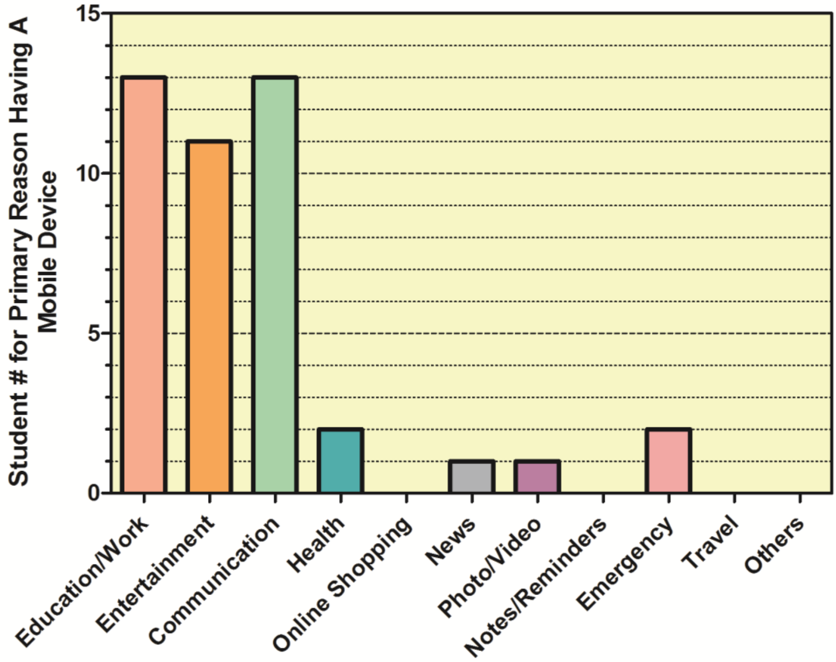
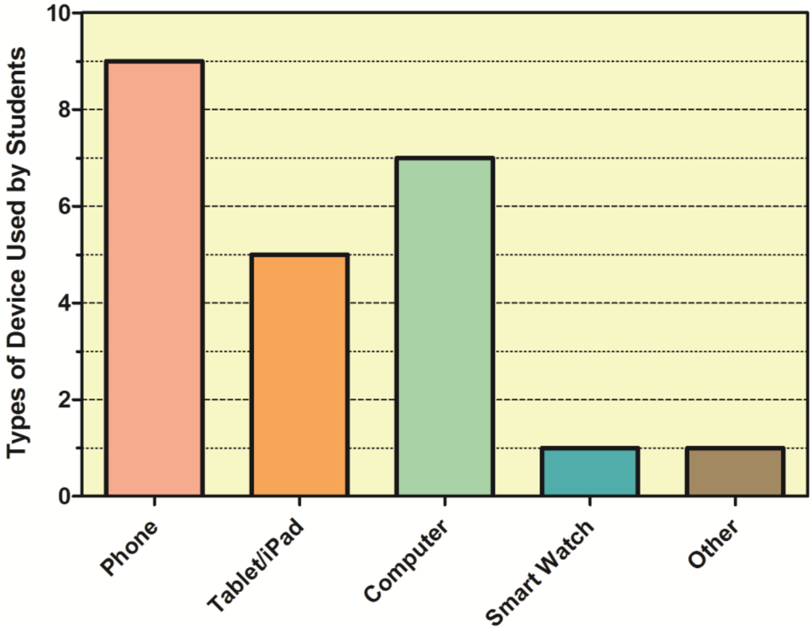


Figure 2. Primary Reason for Having a Mobile Device.

and Blackberry. Only two students had more than one mobile device. Average daily screen time for students was 4.2 hours, and average total screen time was 7.4 hours (**Table 1**). Although the students used an average of 3.5 education apps weekly, most were from the classroom and only 32.5% of students used a personal educational app on their mobile device.

Students were asked to check the boxes in which activities they felt that having or using a mobile device benefited them in (**Figure 1**). The most commonly cited benefits of using a mobile device from students was for the purposes of entertainment, followed by communication purposes defined as "any form of texting, calling, and social interaction facilitated with your mobile device". The least commonly reported reasons of having a mobile device was for travel planning and shopping, likely due to the fact that these activities can be done on a non-mobile device. "Other" reasons of using a mobile device included responses such as: "alarms", "calculator", "for camping", and specific mobile apps such as "Instagram" or "Strava".

In the next question, students were asked to select the benefit they believed was the single most important reason for having a mobile device. Education and communication were the top two most selected reasons, followed by entertainment (**Figure 2**). While students felt that photo/video, A.



B.

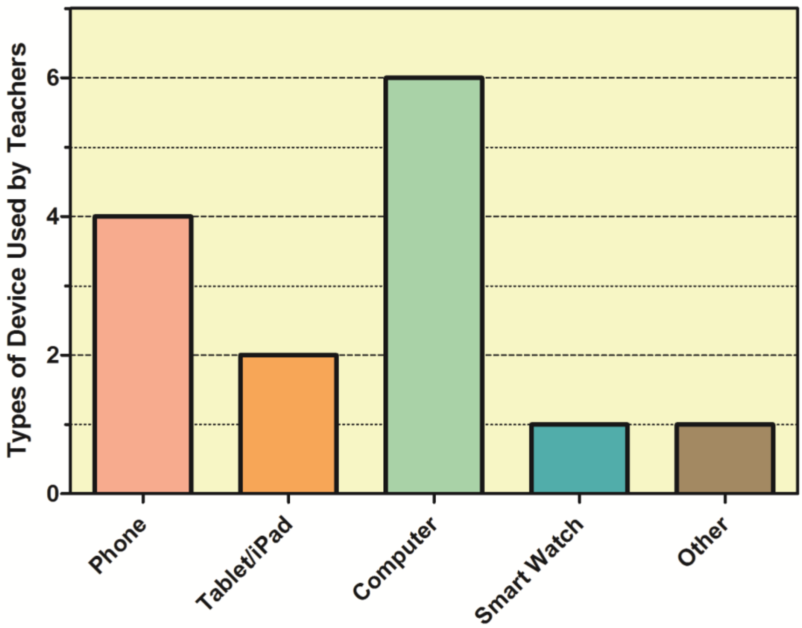


Figure 3. Types of Devices Used by Students and Teachers.

notes/reminders, and emergency use were positives of mobile device use, they were rarely the primary reasons for possessing the device.

Students and teachers who were interviewed were asked what kinds of mobile devices they used. Device usage patterns were similar across both teacher and student groups, with the biggest difference being that students used their phone more often relative to teachers (**Figure 3a**). Particularly, all 6 teachers stated they regularly used their computers during class for educational/work purposes (**Figure 3b**). For both groups, smart watches and other devices (i.e. recorder, audio player) were used the least.

Qualitative Interviews – Students

Motivators for Using Educational Apps

One commonly expressed external motivator was social competition, where students would be encouraged to engage when they saw peers in the classroom use the app. This would take the form of being motivated in beating a study streak or getting points on tutorials. However, participants expressed that it may be demotivating if individuals were too far behind others, and could create stress or urgency that was perceived negatively. A student explains in this following way:

> *I compete with my friends to see who can get the highest scores.*

Furthermore, students also reported that academic progress was a strong external motivator. When they saw time commitment improvements or grade improvements that could be logged on certain apps for each of their subjects, some students expressed feelings of confidence and happiness. A student describes it:

> *Last year I would only be scoring around a 60%, but after every test and exam I can log in and see the improvements I've made. It also helps let the teacher know that I've been trying, and now I'm around 83%, which is really just a big jump and has made me think that I can do other things in life, of that sort.*

Many participants site admission into university to be an important factor for using the apps, as a means to make academic progress, improve grades, or pursue a more economically prosperous career. One student put it:

> *I really want to go to Lagos State University one day, and you need at least a decent enough level of academic ability to have a shot at there. I think it will improve my chances and that is why I use the app. I hope to one day get a good job.*

Many educational apps provide users with intangible rewards such as progress meters and fake currency for unlocking certain perks or badges. Such progress markers are designed to incentivize users to learn more, and were effective for some students. A student stated:

> *Earning badges was helpful, it made it seem more fun and I treated it almost as a video game.*

However, some students were not interested in tangible rewards. Instead, many preferred it when a teacher associated an intangible reward built into the app with a tangible reward administered by the teacher or school. In this way, students could unlock achievements or milestones in the app and consequently be awarded various materialistic perks (i.e. candies, chocolates, pencils) at the teacher's discretion. An interviewed student describes:

> *I don't really care about the badges, but for me what I think was kind of helpful was that you could get some snacks and food with new progress. It would be like a treat, every day I could come into class and as long as I did the homework, I got a little chewing gum. It's not much but it's convenient.*

Most students agreed that in order to be successful in using an app to augment learning, one must have a certain level of internal motivation, since studying was generally seen as a mentally strenuous and time-consuming activity. Ultimately, an individual must be internally motivated to pursue educational attainment in order for serious behavior change and learning to occur. Accordingly, those who felt that they did not have the intrinsic motivation to study believed that a mobile app would not change or improve their learning habits. For instance, a student said:

> *Apps are helpful, but in order to stick with it I think I would have to want to study in the first place.*

Barriers to Adoption of Education Apps

Of the participants, 32.5% had presently used education apps (**Table 1**). Two main reasons were identified by the researchers for why adoption of education apps was not used. (i) No knowledge of the existence of education apps: more than half of the participants were largely unaware of or did not believe that educational apps are available. (ii) Lack of belief in education app effectiveness: students largely did not feel that there was any benefit in using a classroom assistance app for educational purposes, with most commonly cited reasons of preferring more traditional studying methods such as pen and paper compared to using an online or mobile resource. One of the participants said:

> *I don't think it will help. It's just an app that I have to use mental focus on. I like having my stencil and sheets of paper, there is not much I need to do. And I don't have much to do outside the classroom either, I do most of my studying when I go to school, and we can't use phones in the classroom.*

Alternatively, one point brought up repeatedly was that students did not feel it was a necessity to use a mobile app if they had already developed strong study habits, or the participant did not have a belief that strong study habits could be developed from education apps for themselves specifically. However, the majority believed that an education app could be helpful for certain individuals, and generally had positive impressions on the utility of such apps. A skeptic participant said:

> *I don't think [a mobile educational app] can help me… I do well enough in school, I don't need to catch up or use a tutor.*

Barriers to Continued Use of Education Apps

Students who did have educational apps presented a number of barriers to their use. Specifically, a primary reason was that use of educational apps was too time consuming and a "hassle". One secondary school student said that you "must always put in every time you study, and I just prefer to study whenever I want, when I feel like it". Thus, students universally indicated that ease of use and simplicity are highly desired features. One student said:

> *If an app is too complicated, or it takes too long to learn, I think I'd delete it just because you don't really need it to study.*

Such sentiments were echoed by other participants:

> *I don't like a lot of apps these days that require you to sign up, or have ads, and stuff like that. I prefer something that I can open up and boom, there it is.*

Students interviewed felt that individuals who already had the motivation to use educational apps would have the sufficient motivation to do well in school, and therefore not require them in the first place. One described:

> *If someone can use a health app, I must ask, why they cannot just spend that time studying.*

And another said:

> *I really feel that if someone was focused enough to log time in, or watch tutorials, couldn't they have enough time to talk to the teacher or stay after school?*

Additional barriers mentioned included storage space, economic barriers of having a phone, and excessive screen time, either to the concern to the student or the teacher.

Tracking for Awareness and Progress

Most students, who used educational apps like Teach the Need, specified that having a built-in feature to track user progress was extremely important. For instance, users could include the different subjects they were taking, the grades they received, and even access online Canvas or Google Classroom pages via the app and import assignments. This way, there could be an easily accessible way to keep progress advantageous over more traditional methods of note keeping. Most students enjoyed having a tracking feature as it provided a self-monitoring technique that increased awareness. One student put it bluntly:

> *Helps me keep track of my progress.*

And another said:

> *I love to see when my graph is trending upwards and see the grade changes over the years, I definitely build by confidence.*

However, the tracking feature could be abused as a result of stressors in the form of social competition. Some students would lie in order to bolster to their classmates their commitment when the reality may be contrary. One student declared:

> *I had a friend who would keep the app on and just speed through the tutorials at 2x speed.*

Tracking was generally perceived as a positive trait to students. However, others believed that tracking was only beneficial in the beginning. After a while some students felt that the tracking was redundant, as the habits and routine were already developed. Furthermore, it could become a negative aspect of the app, as some users felt they were obligated to keep on tracking even when the usefulness was long gone. One apprehensive student said:

> *When I first started I would track it a lot, but after a while it got boring and I felt like I was supposed to do it even though I didn't really want to. After a while I just stopped using the app.*

Goal Setting and Reminders

Many participants enjoyed the goal setting features used in these education apps. In their eyes, they saw that goal setting, in particular with the use of small daily and weekly goals could allow them to discipline themselves. These included targeted grades and hourly study milestones. A student reflected:

> *Having an app that allows me to goal set is very beneficial.*

Furthermore, liked by most participants, having a notification system that could remind students for class or study times was incredibly beneficial. This feature was particularly helpful to individuals who described their day as busy or tended to forget things. The caveat was that reminders must be easily settable and well designed, with personalization features that allowed a quick and reliable way of putting in dates, which many classroom apps seemed to lack.

Important Characteristics

At the end of each interview, participants were asked to give a rating of 1-4 of which features they felt were the most important. A summary of features in hierarchical importance to students is presented in **Figure 4** with the most important traits at the bottom, increasing at 1-point increments.

The most important features students felt should be included in an educational mobile app were freeness and ease-of-use, reflecting the importance of adoption. Conversely, features related to rewards, credibility, and quality of tutorials were not viewed as comparatively important.

Qualitative Interviews – Teachers

Mobile App Use - Teachers

Teachers were invited to explain what kinds of mobile apps they used and for what purpose they were used for teaching. The most commonly described apps included Plickers, Kahoot, Anatomy4D, Elements4D, Quiver, and others. **Table 2** shows the different apps used and the frequency used by teach-

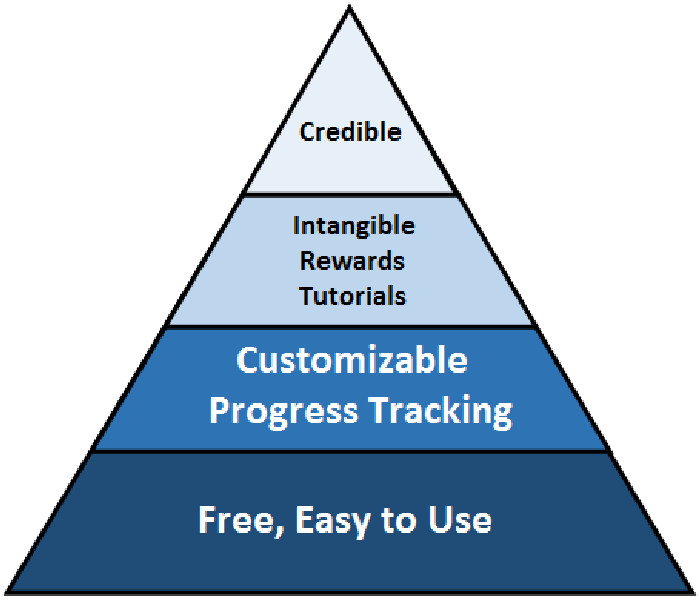


Figure 4. Hierarchical Triangle for Important App Features.

Table 2. Common Apps Recommended and Used by Teachers.

App Name	Frequency
Plickers	2
Kahoot	6
Anatomy4D	1
Elements4D	1
Quiver	2
Algoodo	3
Powtoon	2
App Inventor	4
Google Science Journal	2
Teach the Need	4
Google Classroom	6
Google Drive	6
Class Dojo	4
Codecademy	5

ers. Across the entire range, apps focused on pre-test/post-test, behavioural assessment, data storage, student tracking, and information presentation were the most common.

Criteria for Mobile App Selection

As teachers are the primary influencers in which educational apps students will choose to use, we asked what criteria they used to select for mobile apps for their students. We identified 4 categories that were used for selecting mobile app use: evidence-based teaching, ease of use, content/relevancy to existing course content, and the extent of community building.

Evidence-based teaching: teachers cared about how much an app supported traditional and proven learning methods. Particularly, the difficulty and speed of the app had to be aligned with the ability of the students, in combination with being stimulating enough to keep the attention of students. This included an apps ability to have multimedia design, several content representations, and an entertaining learning environment to invoke as much intrinsic rewards as possible. A teacher explains the following way:

> *For me, the most important thing is that whatever app I choose, that app I can actually use in the classroom. If the app can't be used in the classroom, why use it? For example there was this app I used that taught mathematics but the way they teach it is different and you couldn't change the order of videos around, so my students were moving back and forth from my curriculum to jump to some midway in the app's program. I don't like.*

Ease of use: most evaluations done by teachers were through the perspective of a student's lens. Essentially, a teacher's desire to introduce an app to a student was based on that teacher's belief of how accessible such an app would be to their own student. Furthermore, 3 teachers believed that an app's ability to contact the teacher were particularly important during selection. A teacher said:

> *Students like apps that are easy to use. It shouldn't take too much Wi-Fi or time to download. And I don't want to teach an app for that long.*

Another mentioned:

> *I want an app where I can learn easily. Things like icons and pictures, they are nice.*

Content relevancy: as teachers predominantly used apps to enhance the existing curriculum taught in class, content relevancy with relation to the in-person course was an important factor in 5 of the 6 teachers. This included how much the app's content and literature was relevant and could be understood by students. Particularly, tutorial videos from mobile apps were almost exclusively in either British or American accent, which teachers found could be difficult for younger students to understand at the pace of speech. Thus, many teachers emphasized that apps that allowed customization were important, even preferring apps that allowed an administrator to build a curriculum from the ground up as opposed to having a ready-made curricula. One of the science teachers stated:

> *The content can't be too hard or too easy. That can be difficult, sometimes it's in different languages, a lot of times the content is borrowed from other curriculums like IB. I have to spend a lot of times to go through the videos to make sure all of them align.*

Another teacher shared similar sentiments:

> *I really like Drive and Classroom, they allow me to customize as much as I want. If I want to add this, boom, I can add it. It is not the same with others. Some you just can't do that.*

Classroom Connection: finally, the ability for there to be classroom connection was interestingly an important factor as well. Apps like Google Classroom or Kahoot which allowed students to play with each other were generally seen as a positive.

Discussion

This mixed-methods study on educational app user perception was done with a pool of Nigerian secondary school students and teachers located in Lagos, Nigeria. Our findings suggest that user experience and perspective on mobile app education is understudied. We identified barriers to adoption and use of educational classroom apps within mobile devices. Through participant experience and display of common features amongst educational classroom apps, a summary of motivating features and factors of use were identified. Many of our themes that were identified were consistent with Dennison et al.'s findings related to mobile health app usage, which draws many parallels and can be considered a subcategory of "education" apps. In particular, Dennison et al. emphasized the use of using smartphones as information sources, tracking progress, importance for ease of use, and credibility (2013). A significant barrier in using or adopting educational apps stems from the required time commitment (Ali et al., 2020).

Due to our study targeting mainly lower-economic individuals who would benefit the most from such an educational app, we identified several risk factors. First, low app literacy and low app awareness were two factors related to non-adoption, suggesting that greater knowledge of educational app use or mobile use in general within Nigeria would improve acceptance. Students also emphasized the importance of having the option for customization, related to their courses, schedules, and even the interface of the apps. Students were generally not comfortable with revealing private information, but very few educational or classroom assistance apps required information beyond names and date of birth. Automatic detection or non-voluntary adjustment to user behaviours was a commonly stated feature that users felt these apps lacked. Finally, barriers to adoption such as cost of the app were identified, as well as motivators, such as money, intangible goals, and intrinsic motivation.

Previous studies have examined the effect of using mobile apps for ESL or language learners in the classroom (Ali et al., 2015; Heil et al., 2016; Steel, 2012). Similar to this study, most commonly cited advantages of using those apps over traditional study methods included the ability to track progress and extrinsic motivation in the form of gamified learning (Al-Jarf and Reima, 2020; Heil et al., 2016; Steel, 2013). Furthermore, classroom assistance apps focused on STEM education have found improvements in student grade and attitudes towards education after introduction of mobile education apps. However, the most significant barrier to mobile app adoption remains to be the cost associated with implementing mobile learning if students were unable to afford or have existing phones/tablets, particularly for low-income households or countries (Domingo & Gargante, 2016; Falloon, 2017; Grant & Barbour, 2013; Pan et al., 2021). Lack of curricula, lack of customizability, and steep user interface learning curves are also commonly cited reasons (Al-Kathiri, 2015; Chistensen & Knezek, 2018; Heil et al., 2016). An abundance of research related to mobile health app use corroborate these themes, and present significant overlap between user motivations for continued health and education app use, though differences exist in usage training. For instance, although Author et al. also conducted a qualitative assessment on user attitudes towards mobile apps in Nigerian, the focus on health apps lead to user-training to be one of the most important factors for app adoption, despite not being a concern for participants in this study (Kenny et al., 2017).

Overall, this study aims to expand the current research on user experience and perspectives on classroom assistance/educational mobile apps. Limitations included not having many participants from outside the research setting, with the majority of our participants being students. Furthermore, the participant pool came exclusively from four secondary schools. As research was done on a low-income area, participant experiences and attitudes may differ from individuals in more developed nations, and not all participants had constant access to a personal mobile device. Furthermore, the apps we selected tended to be the most popular educational apps on the app stores, and did not sample the entire range of educational apps available. Purposeful sampling for student participants may lead to lack of data saturation. Furthermore, the teachers and students participating in this study were only concentrated within four schools, and therefore the research sample is relatively small. Future works should conduct studies with larger statistical power. Despite these limitations, this is the first kind of research with qualitative evidence on the field of educational apps and brings insight to the perceptions of young students in an area that may benefit the most from a low-cost and highly accessible form of education.

Conclusion

The advancement of new technologies related to mobile education creates new opportunities that students and teachers can use to augment learning processes. Thus, this study which uses a mixed-methods design in understanding the concerns and problems that users of such mobile educational apps have is particularly pertinent for the future development and optimization of new apps. Additionally, it serves to inform a more detailed understanding of the perceptions that individuals in developing nations such as Nigeria may have on mobile educational apps. The researchers recommend that future development of mobile educational apps should focus on integrating ease to use, ease of access, and customization. App selection for incorporation into the classroom from teachers should prioritize relevancy to course content and low-cost solutions to maximize student engagement. Future research should also aim at quantitatively assessing the magnitude of improvement associated with providing classrooms with mobile educational apps.

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REVIEW

Giant Baby Syndrome in Chinese College Students

Ming Zhou

Jiangnan School, Zhenjiang 212008, Jiangsu, China

***Abstract**: The term "giant baby" became popular among Chinese people after Zhihong Wu's book The Country of 'Giant Babies': A Domestic Psychologist Examining the Chinese National Character was published. An adult who fits this description is considered to be cognitively and psychologically immature. Researchers have discovered that this condition, known as "Giant Babies," also affects the educational system, as some students' psychological growth lags behind their physical development. This article outlined the behavioral traits of giant baby symptoms among Chinese college students, such as excessive reliance on others, egocentrism, and bigotry, and explained the underlying causes from the perspective of school education in an effort to pinpoint pertinent issues with Chinese education and provide recommendations for the development and education of more socially mature talents.*

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***About the Author**: Ming Zhou, Jiangnan School, Zhenjiang 212008, Jiangsu, China. E-mail: 929883506@qq.com*

***Correspondence to**: Ming Zhou at Jiangnan School of China.*

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Introduction

ERIKSON'S theory states that a person's personality develops throughout the course of their entire life in eight stages: infancy, toddlerhood, preschool, school, adolescence, early adulthood, middle age, and elder adulthood. Each stage builds on the ones that come before it and prepares the way for the periods of development that follow (Guo, 2010). The truth is that some adults' mental development does not correspond to their age. The fact that an adult who is physically an adult is nevertheless psychologically a baby is a notable phenomenon.

Zhihong Wu, one of the first Chinese researchers to pay attention to this phenomenon, addressed the subject of Chinese people's psychological development from a cultural viewpoint in his best-selling book *The Country of 'Giant Babies': A Domestic Psychologist Examining the Chinese National Character*. Initially, the word "giant baby" refers to a medical term. Giant babies are those who weigh more than 4,000 grams at birth. Giant babies are adults who retain baby features in terms of behavior, emotion, and mentality, according to Wu's (2016) book. These giant babies are self-centered, unable to predict the potential impact their words and actions may have on others; overly reliant on others, to the point where they sacrifice integrity for others or institutions; and manipulative in interpersonal and social relationships, unable to give or receive love due to undue manipulation.

The term "giant baby," coined by Wu, was subsequently used in Chinese educational research. Studies discovered that a serious problem among students is the enormous disconnect between people's psychological growth and their physical progress. Scholars have examined this phenomenon in the educational field over the last several years from a variety of perspectives. Chen et al. (2018) examined the underlying causes of the "giant baby" problem among Chinese college students and made the case that parenting practices must be changed, parent-child interactions must be improved, and the school system's practice of "emphasizing academic abilities over emotional skills" must be changed. Chen (2018) examined the giant-baby phenomenon in private colleges and universities and expounded on the four traits of "giant babies" in an effort to raise the attention of academics. In their research, Ni et al. (2020) showed the possible harm caused by college students' giant-baby attitudes from the social, familial, and individual viewpoints. Zhang (2021) investigated the reasons behind high school students' baby-like actions and proposed methods for moral instruction of senior secondary school students. Ting Zhang (2021) studied visual design pieces with the "giant baby" as the central theme, exhibited a variety of baby behaviors, and determined the reasons at the familial, educational, social, and cultural levels. This article focuses on studying the giant-baby symptoms in college students and exploring the causes in the educational setting based on the review of prior "giant baby" studies.

Giant-Baby Symptoms among College Students

Abnormal Symbiotic Relationships

The 20th-century psychiatrist Margaret Mahler, who created the idea of individuation and separation, held the view that a child experiences a typical symbiotic period throughout the first six months of life. During this time, the baby does not yet feel like an individual but rather that they are inseparable from their mother (Wu, 2016). The baby may exhibit various psychological traits typical of their age in addition to their symbiotic bond with their mother. After this time, symbiotic relationships and early-month psychological traits that reappear later in life are seen as aberrant.

The large family, collectivism, disrespect for privacy, rejection of going Dutch, unified thinking, and other manifestations of abnormal symbioses are not uncommon in real life. Overdependence on others and an inability to accept responsibility are the most prominent indicators of college students' improper symbiotic connections with others. According to the Study of Giant-Baby Mentality in College Students, 59.47% of college students said the most common giant-baby indicators among their peers are a lack of self-regulation, excessive reliance on classmates at school, and excessive reliance on parents at home (Ni, 2020). Their childish tendencies are partly due to family codependency: they become accustomed to the family's planning and interference in their lives, and they frequently allow parents and other family members to make decisions for them on a variety of issues ranging from basic needs to education, relationships, and career choices (Chen, 2018).

Narcissism and Self-absorption

In his book, Wu (2016, p. 171) argues that one of the main characteristics of a "giant baby" is narcissism, the belief that "I am the omnipotent god, and the world should run according to my will; otherwise, I will become a fierce and destructive devil, wishing to destroy the world or myself."

Egocentrism is a prevalent trait among college students today. According to the family planning policy, the majority of college students born in the late 1990s or early 21st century are their parents' only child, who is the apple of their eyes. The parents concentrate all of their affection and care on one child, attempting to meet all of his or her requirements. Once they fail to do so, the "giant baby" will use frustration and rage to force others to comply with his or her demands. Over time, it will enhance the child's omnipotence mindset, causing him or her to become progressively egocentric.

Chen (2019) suggested that these man-child college students lacked communication with others, particularly their classmates, throughout their earlier stages of development because they were overprotected by their families. As a result, they become egocentric and have difficulties discerning the boundaries between themselves and the outside world, as well as forming connections with others on an equal level.

Bigotry and Intolerance

In Wu's book, bigotry is defined as the refusal to adjust one's strong, irrational beliefs or attitudes; an intolerant person is one who maintains extreme views of the world and is unwilling to accept and tolerate variations in opinions (Wu, 2016).

Being bigoted and intolerant can disconnect a person from reality and weaken their connection to the real world. Giant-baby college students have lived in a greenhouse-like home setting and have had limited social interactions, rendering them unable to distinguish between the real and imagined worlds. They lack a sense of social responsibility because they lack a proper understanding of the relationship between the prospects of people and societal progress (People's Daily, 2018). Unreasonably high educational expectations, excessive parental involvement, and unscientific school instruction all contribute to their defiant attitude and reinforce their intolerance. During the prevention and control of COVID-19, for instance, a female student made a scene in a quarantine camp because she could not survive without mineral water in bottles. Wilful adolescents like her have a difficult time integrating into society, let alone achieving self-actualization and contributing to the community.

Behavioral Characteristics of Giant-Baby College Students

The majority of college students are between the ages of 18 and 22. In this stage, individuals with typical psychological development should have a strong sense of identity, be assertive in problem-solving, and be able to live independently. Many Chinese college students, however, have not attained this psychological level.

Unable to Break Away from Maternal Influence

In Chinese culture, the term "mommy's boy" describes a man who, as an adult, still has a close bond with his mother but finds it difficult to run his own social and financial affairs and form symbiotic connections with other people (Chen, 2017). According to Zhou's (2016) portrayal of the "mommy's boy," his mother overprotected and engaged him excessively, which impeded his mental development. Psychologically, this group is in an unconscious condition of delayed individuation (Xin, 2017). Current research agrees that a high level of reliance on the mother is the scourge of "mommy's boys." They often exhibit less maturity and confidence than their classmates and, to varying degrees, suffer from avoidant personality disorder.

Low Self-Efficacy

Narcissistic and self-centered "giant babies" are extremely sensitive to any loss of control. Any unpredictable scenario might plunge them into despair and powerlessness (Wu, 2016). Giant-baby college students generally have low self-efficacy and are unable to convince themselves of their worth to those around them. At the same time, they have significant feelings of vulnerability and helplessness, and as a result, they tend to give up or rely on others whenever they face difficulties and failures. They are unable to accept responsibility for their own academic success and must rely on their classmates to finish assignments. They gradually lose the ability to make independent judgments and appropriately manage their college lives.

Being Conformist and Unwilling to Take Risks

Entrepreneurship, ingenuity, pressure resistance, and perseverance are traits that young people must possess to thrive academically and professionally in a society that is rapidly evolving. Numerous college students are afraid to question what is taught in textbooks and by lecturers because of their ingrained, reliant, docile mindsets. They are prepared to lead a life of conformity and do not value the spirit of entrepreneurship; instead, they look forward to stabling employment in the future.

Educational Causes of Baby Behavior in College Students

The giant-baby phenomenon in colleges and universities has a number of causes, including outmoded traditional beliefs and improper family education. This paper focuses on investigating the fundamental causes of this problem from the perspective of academic instruction.

Test-Oriented Education Stunts Student Psychological Development

The Gaokao (China's national college entrance examination) system, which restricts the multifaceted operation of education and creates a number of social issues, relies solely on test scores as a selection criterion (Zhang, 2019). Gaokao is a crucial link between basic and higher education; as a selection method based on competitive tests with high stakes, it has a significant impact on basic education. Because higher education institutions "evaluate candidates only by their Gaokao results," it is inevitable that the test results become the dominant criterion for evaluating student development level, instructor effectiveness, and school management at the early education stage. This has led to the ludicrous occurrence in basic education, where teachers only cover material that is likely to be examined in exams and students only learn that. Until now, the Gaokao has been a written test, which may be a useful tool for determining students' academic standing but cannot be used to assess their social and emotional intelligence or psychological traits. At the same time, it has increased the focus on test scores in secondary schools, where only an intellectual education is valued and the development of morality, character, and appropriate behavior is ignored. This has been the backdrop for the college students' early development as giant babies.

One-sided Pursuit of Theoretical Knowledge Deprives Students of Life Experience in the Process of Growth

Life events serve as catalysts for individuals' mental development and the formation of self-consciousness. They internalize the meaning and worth of life experience by perceiving and digesting life events, establishing the groundwork for the reconstruction of experience in subsequent growth. The most crucial aspect of adolescent life is education. Education and life are inextricably linked for teenagers, as Dewey (2001) noted in Democracy and Education that life is education and education is the change of experience. Yet, the link between education and life is not adequately addressed in present school instruction. Because of the pressures of school competitiveness, acquiring theoretical knowledge takes precedence over practical experience in the lives of adolescents.

According to the survey results of Sun and Zhang (2018), the top five communication subjects (in order of priority) between Chinese students and their parents are academic issues (71.8%), school matters (69.6%), interests and hobbies (35.4%), friends (31.7%), and personal prospects (31.6%). School matters (58.4%), interests and hobbies (42.5%), friends (40.1%), academic issues (38.1%), and personal prospects (27.7%) are in that order among their American peers. The top five topics for their Japanese counterparts are school matters (76.7%), friends (52.3%), academic issues (42.3%), interests and hobbies (34.7%), and social issues (27.1%). School matters

(83.6%), academic issues (53.4%), friends (48.1%), interests and hobbies (44.0%), and social issues (26.4%) are the top five subjects in South Korea. It demonstrates that the five key child-parent communication subjects in China, the United States, Japan, and South Korea essentially overlap but are prioritized differently. Clearly, there is a tendency in Chinese education to emphasize academic achievement while ignoring life experiences in the real world. Human development and growth are attributed to the combined impacts of knowledge, practice, and experiences. Individual development can be distorted if just conceptual knowledge is taught without emotional experience or behavioral verification in practice. Education that lacks a balanced moral, intellectual, physical, artistic, and social education sets the stage for the birth of giant babies.

"Nanny-Style Education" Hinders the Implementation of Competence-Oriented Training

Some researchers characterized "nanny-style education" as an educational strategy in which teachers oversee everything for students and, in doing so, impair the possibility of unrestricted student development (Xin, 2008). Nanny-like educators provide college students with both explicit and intangible "nanny-style service". Explicit "nanny-style service" refers to actions taken by professors and administrators to ease the college experience for students. For instance, some teachers purposefully create the test questions to be as easy and simple as possible in order to ensure that students pass the exam without difficulty. Other teachers may identify the essential concepts for pre-exam preparation or even reveal the test questions in advance. Some college supervisors who oversee students' extracurricular activities must function as "nannies," ready on the scene to handle emergencies. Supervisors must provide specialized lectures to instruct students on how to meticulously complete the application forms in order to aid them in applying for scholarships and grants. Each student may receive a template that needs to be filled out and followed. The term "intangible nanny-style service" describes instructional strategies like rote learning and cramming that do not call for critical thought.

This kind of "nanny-style education" goes against the foundational idea of competence-based education. Competency-oriented education is defined by its emphasis on maximizing students' potential talents, cultivating their inventive consciousness, and equipping them to face the difficulties of a society that is always evolving (Li & Li, 2001). Young people's development of critical skills is essential to their healthy development and the success of society. Nonetheless, "nanny-style education" methods have hampered the spread of competence-oriented education, lowered children's chances of survival, and increased the number of giant-baby college students.

Conclusion

The detrimental effects of social experience on the growth process of individuals have produced "giant babies." Without a doubt, adults who are dependent, self-centered, and intolerant disrupt the regular functioning of families and societies. There are numerous explanations underpinning the problem, but one prominent one is unscientific school instruction. Despite the fact that China's education has experienced rapid development and reached a substantial scale over the past several decades, the existence of "giant babies" reveals the shortcomings of Chinese education, reminding us that we should not only focus on the scale and speed of educational development but also on the quality of education. While examining the outcomes of education and identifying its flaws, it is necessary to investigate their causes and discover remedies in an effort to enhance the quality of education.

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