Education and Information Technologies (2024) 29:10899–10929
https://doi.org/10.1007/s10639-023-12242-1

Flipped TRIZ-STEM: Enhancing teacher training through innovative pedagogy?

Bekir Yıldırım[1]

Received: 26 May 2023 / Accepted: 26 September 2023 / Published online: 13 October 2023

Abstract

This study aimed to examine the effects of TRIZ-STEM applications within an online flipped learning model on teachers' problem-solving skills, creative thinking dispositions, STEM teaching, and their understanding of the nature of engineering. The sample consisted of 57 teachers (24 in the control group and 33 in the experimental group) recruited using purposive convenience sampling. The study adopted a mixed embedded design. Quantitative data analysis included independent samples t-tests, paired samples t-tests, Wilcoxon signed-rank tests, and effect size calculations. Descriptive statistics were used to analyze qualitative data, including the nature of the engineering questionnaire and lesson plans. The experimental group engaged in TRIZ-STEM activities using an online flipped learning model, while the control group engaged in face-to-face TRIZ-STEM education activities. The results showed that online TRIZ-STEM education had a greater positive impact on teachers' perspectives on engineering nature than face-to-face TRIZ-STEM education. On the other hand, face-to-face TRIZ-STEM education was much more effective in helping participants develop problem-solving skills than online flipped learning TRIZ-STEM education. However, the online flipped learning model did not show superiority in improving teachers' creative thinking education and STEM teaching compared to the face-to-face approach. Based on the results, suggestions for future research were provided, emphasizing the potential of online flipped learning models for STEM teacher education.

Keywords STEM education · Flipping learning · Mixed research · Teacher

---

✉ Bekir Yıldırım
bekir58bekir@gmail.com

[1] Department of Mathematics and Science Education, Faculty of Education, Mus Alparslan University, 49250 Muş, Turkey

1 Introduction

Technological advancements impact many areas of our lives, from health to the economy (Yoo & Yi, 2022). Education is one field that is affected by technological developments. Countries are integrating technology into their education systems (Lu et al., 2022). Technology enriches education, making learning more effective and lasting. One of the educational technologies is the flipped learning model.

The teacher utilizing flipped learning uploads lesson content to an online platform. Students study online and come prepared for class. During class, students engage in activities guided by the teacher (Bergmann & Sams, 2014). In the flipped learning model, students perform what was traditionally done in the classroom at home, while classroom time is allocated for completing homework (Bergmann & Sams, 2012). The teacher delivers theoretical knowledge online, and students actively participate in activities reinforcing the theoretical knowledge in the classroom.

Additionally, videos facilitate self-paced learning for students (Abeysekera & Dawson, 2015) and enable them to review course content as needed (Enfield, 2013). In the classroom, students actively participate in their learning process through activities (Baker, 2000). In this process, students assume responsibility for their learning and can access the course content at their convenience (Thoms, 2012). The features of the flipped learning model facilitate easy comprehension of the content for students with a slower learning pace (Bergmann & Sams, 2012). Furthermore, the flipped learning model aligns with Bloom's taxonomy (Williams, 2013). Implementing the flipped learning model motivates students to employ higher-order thinking skills (Bergmann & Sams, 2012; Strayer, 2012; Williams, 2013).

Flipped learning promotes teacher-student and student–student interaction in classroom activities (Yorgancı, 2020). In the flipped learning approach, students engage in three stages: (1) pre-lesson, where they watch course content online; (2) in-lesson, where they receive feedback and participate in activities; and (3) post-lesson, where they reflect on their learning and apply it to new situations (Merrill, 2015). In flipped learning, teachers access theoretical knowledge online and actively participate in activities during the lesson, contributing to developing their professional skills. As a result, online professional development programs can be employed to enhance teachers' professional skills.

In online flipped learning, students can view course content at their own pace and according to their preferred schedule. After watching the videos, they engage in assignments and activities online or use materials provided by instructors to deepen their understanding of the topics (Kozikoğlu et al., 2021). These activities reinforce the learned material and facilitate student collaboration and discussion of thoughts and ideas related to the topics (Bergmann & Sams, 2012). During the online and live lesson process, teachers participate in discussions to address challenges and questions, deepen their understanding of the topics, and interact with each other. Teachers can also receive feedback on their teaching practices

(Nederveld & Berge, 2015). Therefore, the online flipped learning model can provide professional development opportunities for teachers in STEM education that include theoretical knowledge and practical training. This approach ensures the professional growth of teachers in STEM education, as they acquire the necessary theoretical information before training, which is tailored to their specific needs, time availability, and learning pace. Throughout the training process, teachers effectively engage with feedback and activities related to the acquired knowledge (Staker & Horn, 2012). Consequently, this approach positively impacts the professional development of teachers in STEM education, considering their primary responsibility to deliver STEM education in the classroom (Wang & Cheng, 2023).

Effective implementation of in-class activities by teachers relies on adequate training in STEM education (Stohlmann et al., 2012). However, due to their weekday commitments and limited availability, teachers often face challenges accessing long-term STEM teaching opportunities (Yıldırım et al., 2022). To address this issue, the online flipped learning model can be employed for STEM teaching, as it offers a flexible approach that allows teachers to engage in interactive activities and deliver customized lessons tailored to students' individual needs (Talley & Scherer, 2013). Furthermore, flipped learning enables teachers to access various learning materials and learn from diverse sources presenting different perspectives, thereby enriching their professional development (Talley & Scherer, 2013).

Online flipped learning in STEM education actively engages teachers in learning, fostering their interest in STEM fields and enhancing their professional skills (Fung, 2020). Consequently, STEM educators should strive to enhance students' learning experiences by incorporating innovative teaching methods like the flipped learning model (Fung et al., 2022). Furthermore, *Teoriya Resheniya Izobretatelskikh Zadatch* (TRIZ; Intuitive Problem Solving Theory; Shih et al., 2013) can be employed to enrich teachers' learning experiences and cultivate their problem-solving abilities, as it serves as a valuable tool in STEM education and facilitates the development of students' problem-solving, creativity, and innovation skills (Bozhik et al., 2023). Numerous researchers highlight that TRIZ supports the cultivation of students' problem-solving and creative thinking skills (Yao et al., 2022). Consequently, teachers can utilize TRIZ to stimulate students' imagination, foster creativity, and empower them to develop future professional and life skills. As a result, TRIZ can be effectively employed in teacher training programs (Park, 2023).

No research has directly compared the effectiveness of online flipped learning models with face-to-face learning in STEM teacher education programs. Similarly, a dearth of studies have investigated the integration of TRIZ, STEM activities, and online flipped learning. Additionally, there is a lack of research examining the impact of TRIZ-STEM activities on teachers' problem-solving skills, creative thinking dispositions, STEM teaching practices, and the understanding of engineering concepts within the context of online flipped learning. In a study by Park (2023), the importance of incorporating TRIZ in teacher training was emphasized. Consequently, the present study aims to assess the influence of TRIZ-STEM activities within the online flipped learning environment on teachers' problem-solving skills, creative thinking dispositions, understanding of engineering, and effectiveness in

STEM teaching. To comprehensively address these research objectives, the primary research question was: "What are the effects of TRIZ-STEM activities in online flipped learning on teachers' problem-solving skills, creative thinking dispositions, understanding of the nature of engineering, and effectiveness in STEM teaching?" Subsequently, the study will seek answers to the following specific research questions:

1. How do online flipped learning TRIZ-STEM activities affect teachers' problem-solving skills?
2. How do online flipped learning TRIZ-STEM activities affect teachers' creative thinking dispositions?
3. How do online flipped learning TRIZ-STEM activities affect teachers' views on the nature of engineering?
4. How do online flipped learning TRIZ-STEM activities affect teachers' views on STEM teaching?

1.1 Literature review

1.1.1 Flipped learning

The concept of flipped learning was originally introduced by Jonathan Bergmann and Aaron Sams, who were chemistry teachers at Woodland Park High School in Colorado. In this model, teachers upload lecture videos to an online platform, which students watch prior to attending class, where they engage in activities facilitated by the teacher (Bergmann & Sams, 2014). Essentially, students now complete what was traditionally done at home in the classroom while their homework is done during class time (Bergmann & Sams, 2012). According to Honeycutt and Garrett (2014), flipped learning involves students engaging in traditional out-of-class activities and focusing on homework during classroom sessions. The flipped learning model enables students to access course materials online from home at their convenience, while in-class activities aim to enhance their learning experience (Tucker, 2012). Bergmann and Sams (2012) state that flipped learning allows students to catch up on missed lessons, learn at their own pace, review lessons, interact with peers, achieve qualitative and lasting learning outcomes, gain different perspectives on classroom methodologies, and easily utilize technology.

Consequently, flipped learning facilitates the learning process. This model can also be applied to teacher training as educators strive to develop lifelong professional skills, incorporate classroom activities, and acquire new instructional approaches. Therefore, flipped learning can be utilized in teacher training programs. For instance, teachers can create and upload videos to online platforms, enabling them to engage in online learning. They can then reinforce their learning by participating in face-to-face activities during in-person sessions (Jung & Hong, 2020). In summary, teachers can learn online at their convenience and actively participate in classroom activities. Online flipped learning can also enhance teachers' understanding of STEM fields

(Fung et al., 2022). Thus, flipped learning holds the potential for STEM teaching purposes (Weinhandl et al., 2020).

1.1.2 STEM education and flipped learning

Technological advancements, including deep learning, data mining, and artificial intelligence, have brought about significant changes in education, prompting countries to reevaluate their educational systems. As a result, they have been implementing and refining new educational approaches such as TRIZ and STEM to equip students with the necessary skills for the twenty-first century (Park, 2023). Integrating STEM education into national curricula allows students to cultivate 21st-century skills such as problem-solving, critical thinking, algorithmic thinking, and computational thinking. It also encourages them to adopt interdisciplinary perspectives and gain proficiency in STEM disciplines.

Teachers play a crucial role in delivering quality STEM education. The competence of teachers in STEM subjects directly impacts students' learning outcomes. Research by Hibpshman (2007) highlights the importance of having knowledgeable and skilled teachers in math and science for effective learning. Therefore, teachers must receive adequate STEM teaching to deliver STEM education effectively. The U.S. Department of Education (2010) emphasizes the need to develop STEM curricula tailored explicitly for K-12 teachers.

Consequently, there is a demand for robust professional development programs that cater to the needs of teachers to implement STEM education in their classrooms (The President's Council of Advisors on Science and Technology [PCAST], 2010). However, there is a shortage of professional development programs that offer comprehensive STEM teaching for teachers. Moreover, existing programs often coincide with busy academic semesters, making it challenging for teachers to participate (Ejiwale, 2013; Yıldırım et al., 2022). In this context, flipped learning emerges as a viable approach for STEM teaching (Fung et al., 2022) due to its compatibility with STEM fields. Flipped learning empowers teachers to actively engage in learning, develop problem-solving skills, foster creativity, and implement innovative practices in their classrooms (Puspitasari et al., 2020). By leveraging flipped learning, teachers can enhance their professional skills and take ownership of their own learning journey (Fung, 2020).

Flipped learning in STEM education offers numerous benefits, including increased opportunities for students to participate in interactive activities and allowing teachers to deliver personalized instruction tailored to individual student needs (Jung & Hong, 2020). By shifting the traditional learning paradigm, flipped learning empowers students to actively engage with the course content outside the classroom, enabling them to arrive prepared and ready to participate in collaborative activities and discussions during class time. This active involvement enhances student engagement and understanding of STEM concepts. Simultaneously, teachers can utilize in-class time to provide targeted support, address student questions, and facilitate meaningful interactions that deepen students' comprehension and problem-solving skills in STEM subjects. The flipped learning model thus promotes an interactive and student-centered approach to STEM education.

In short, delivering theoretical information about STEM education through online platforms and conducting application-based activities in face-to-face settings can effectively provide teachers with training opportunities (Park, 2023). Online environments allow teachers to access and acquire theoretical knowledge at their convenience and pace. They can engage with online resources, watch instructional videos, and explore relevant content to deepen their understanding of STEM concepts. Subsequently, in face-to-face interactions, teachers can actively participate in activities that focus on applying the knowledge they have gained. These activities may involve problem-solving exercises, hands-on experiments, collaborative projects, or discussions to reinforce their understanding and develop practical skills in STEM education. Combining online and face-to-face elements, this blended approach offers a comprehensive training experience supporting teachers' professional growth and competence in STEM education.

1.1.3 TRIZ (ıntuitive problem solving theory)

TRIZ, recognized as a theory of innovative problem-solving (Madara, 2015), serves as a systematic approach for fostering creative solutions across diverse domains (Cerit, 2014). Rooted in fundamental principles of inventive processes essential for technological advancement (Alkasem & Tilfarlioğlu, 2023), TRIZ employs a structured problem-solving methodology. This method hinges on harnessing a knowledge-based creative problem-solving framework (Savranksy, 2000), wherein scientific insights are leveraged to tackle issues (Kiong et al., 2017). Within this context, issues are effectively resolved, and design enhancements are continually refined (Fey & Rivin, 2005). Addressing design-related challenges involves resolving inherent contradictions, which, in turn, cultivates design refinement (Park, 2023). The applicability of TRIZ extends to education, offering a platform for problems to be solved while empowering individuals to actively engage in the process (Alkasem & Tilfarlioğlu, 2023).

1.1.4 TRIZ in STEM education

STEM education encompasses integrating science, technology, engineering, and mathematics, aiming to equip students with essential 21st-century skills relevant to their everyday lives. In this context, TRIZ holds significant potential as a valuable tool for enhancing STEM education by fostering innovative and creative problem-solving abilities (Fey & Rivin, 2005). TRIZ employs systematic methodologies rooted in scientific principles to generate inventive solutions and is widely utilized in engineering and design fields (Savranksy, 2000). Its knowledge-based approach aids in addressing conflicts arising from problem-solving processes and product design/development endeavors (Park, 2023). By following a systematic problem-solving path, engineers gain new perspectives on challenges and generate fresh ideas while solving new problems (Fey & Rivin, 2005). Moreover, TRIZ has demonstrated its effectiveness in enhancing science, engineering, and technology education, as evidenced by various studies (Chang et al., 2016; MalAllah et al., 2022).

While TRIZ has primarily been employed in the engineering domain, its application extends to the field of education, particularly in the context of STEM education. This study utilized TRIZ as a framework for developing and redesigning products generated during problem-solving activities in STEM education. In the STEM education setting, TRIZ is employed similarly to the engineering design process, where students engage in the creation of novel products. Within this framework, students can utilize TRIZ to identify and analyze problems and propose and implement innovative solutions. By employing TRIZ, students are empowered to generate creative and inventive solutions, thereby addressing challenges in science, engineering, and technology.

2 Method

2.1 Research design

This study sought to integrate TRIZ, STEM education, and online flipped learning, incorporating an ontological and epistemological perspective to explore all dimensions of the phenomenon (Twining et al., 2017). By combining empirical and interpretive paradigms, the study investigated the impact of TRIZ-STEM activities within online flipped learning on teachers' problem-solving skills, creative thinking dispositions, views on the nature of engineering, and STEM teaching. A nested embedded design was adopted to address this research question comprehensively, utilizing a mixed research method that incorporated both qualitative and quantitative approaches. The qualitative component employed a single case study design, while the quantitative component utilized a pretest–posttest control group quasi-experimental model to provide a well-rounded analysis of the topic.

2.2 Study group

Participants were recruited using purposive convenience sampling, a non-probability sampling method. In convenience sampling, researchers enroll participants based on their availability and accessibility (Balcı, 2016). Convenience sampling is a time- and cost-effective method used to choose the most appropriate participants (Patton, 2002). The sample consisted of 57 teachers (control group: 24 and experimental group: 33). Participants were assigned codes (P1, P2, etc.) to ensure confidentiality and anonymity. Table 1 shows all participants' sociodemographic characteristics.

2.3 Data collection tools

2.3.1 Marmara creative thinking dispositions scale

The Marmara Creative Thinking Dispositions Scale (MCTDS) was developed by Özgenel and Çetin (2017). The scale comprises 25 items and six subscales (self-discipline, innovation search, courage, inquisitiveness, doubt, and flexibility). The

Table 1 Sociodemographic characteristics

Theme	Categories	Codes	Experimental *f*	Control *f*
Sociodemographic characteristics	Gender	Woman	26	5
		Man	7	19
	Work experience (year)	1–10	10	10
		11–18	21	11
		≥21	2	3
	School type	Public	31	24
		Private	2	-
	Education (degree)	Bachelor’s	21	24
		Master’s	10	-
		PhD	2	-
	Branch	Science	11	9
		Math	7	5
		Primary School	7	4
		Preschool	5	3
		Chemistry	2	2
		Physics	1	1

items are rated on a five-point Likert-type scale (1 = never, 2 = rarely, 3 = sometimes, 4 = generally, 5 = always). The total score ranges from 25 to 125, with higher scores indicating more creative thinking. In this study, the scale had a Cronbach’s alpha of 0.80.

2.3.2 Problem-Solving Inventory (PSI)

The Problem-Solving Inventory (PSI) was developed by Heppner and Petersen (1982) and adapted to Turkish by Şahin et al. (1993). It assesses how one perceives oneself based on one’s efforts in the face of a problem. It consists of 35 items rated on a six-point Likert-type scale. The total score ranges from 35 to 210, with higher scores indicating less problem-solving capability. Fourteen items (1, 2, 3, 4, 11, 13, 14, 15, 17, 21, 25, 26, 30, and 34) are reverse-scored. In this study, the inventory had a Cronbach’s alpha of 0.80.

2.4 Qualitative data collection tools

2.4.1 STEM lesson plans

The qualitative data were collected using lesson plans ($n = 114$) developed by participants as part of the flipped learning model in STEM education. The lesson plans were evaluated using a rubric (Fig. 1) developed by the researchers based on a literature review (Kim et al., 2015; Wang et al., 2011; Yıldırım et al., 2022).

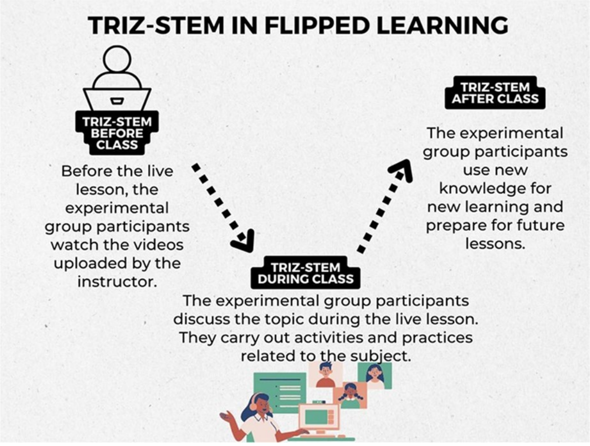


Fig. 1 TRIZ-STEM flipped learning

2.4.2 Nature of Engineering Survey (NoES)

The Nature of Engineering Survey (NoES) was developed by Deniz et al. (2020) to determine what teachers think about the nature of engineering. The survey consists of seven open-ended questions.

2.5 Data analysis

2.5.1 Quantitative data analysis

The quantitative data were analyzed using the Statistical Package for Social Sciences (SPSS). First, normality was tested. The PSI data were normally distributed. Therefore, parametric tests were used. The MCTDS were nonnormally distributed. Therefore, nonparametric tests were used. Normality was checked using (1) skewness coefficients, (2) Q-Q graphs, and (3) Shapiro-Wilks test values. The magnitude of the difference between the pretest and posttest scores was assessed using effect sizes; 0.20 = small effect, 0.50 = medium effect, and 0.80 = large effect (Cohen, 1988).

2.5.2 Qualitative data analysis

The NoES scores were assessed using a rubric developed by Deniz et al. (2020). The NoES questions are rated on a scale of 0 to 4 (Table 2).

Two experts utilized the rubric to evaluate the NoES scores, ensuring interrater reliability. In qualitative research, at least two people should code the data (Miles et al., 2014). Therefore, (1) an expert with a Ph.D. in STEM education and (2) an expert with a Ph.D. in the lesson study model was involved in the process of determining the NoES scores. The interrater reliability was determined to be 82%, which is considered acceptable (Patton, 2002). Descriptive statistics were

Table 2 NoES scoring

No	Explanation	Point
1	No answer, incomprehensible or irrelevant answer, or an answer could not be categorized	0
2	An answer that is not aligned with the description of NOE aspect	1
3	An answer that is partially aligned with the description of NOE aspect =	2
4	An answer that is fully aligned with the description of NOE aspect	3
5	An answer that is fully aligned with the description of NOE aspect. The view is well articulated and/supported with relevant example(s)	4

employed to analyze the nature of engineering, providing readers with insights for interpreting the qualitative data. The lesson plans were evaluated using a rubric developed by the researchers and informed by relevant literature (Kim et al., 2015; Wang et al., 2011; Yıldırım, 2021). Two experts in the field utilized this rubric to assess the lesson plans. One expert had a Ph.D. in STEM education, while the other had a Ph.D. in the lesson study model and research on STEM education (Miles et al., 2014). The interrater reliability, which measures the consistency between the two experts' evaluations, was determined to be 83%, indicating an acceptable level of agreement (Patton, 2002) (Table 3).

Each criterion in the rubric was evaluated by assigning a score of 1 if it was satisfied and a score of 0 if it was not. The "STEM Inclusion" criterion focused on assessing the integration of science, mathematics, engineering, and technology within the lesson plans (Wang et al., 2011). Descriptive statistics were used to analyze the lesson plans, offering readers valuable insights for interpreting the qualitative data. The descriptive data were analyzed using SPSS. Parametric tests were used because the data were normally distributed.

2.5.3 Procedure

The experimental group participated in TRIZ-STEM online flip learning (intervention), while the control group received face-to-face TRIZ-STEM education (Fig. 1).

The videos covered the topics and shared information in TRIZ-STEM, the online flipped learning model. During the live lesson, TRIZ-STEM activities and practices were carried out. Table 4 shows the steps of the intervention.

In the experimental group, the participants accessed the theoretical aspects of STEM education by watching online videos. Subsequently, the teacher and instructor facilitated STEM activities and practical exercises for the participants. All participants utilized materials to create designs as part of the learning process (Figs. 2, 3, and 4).

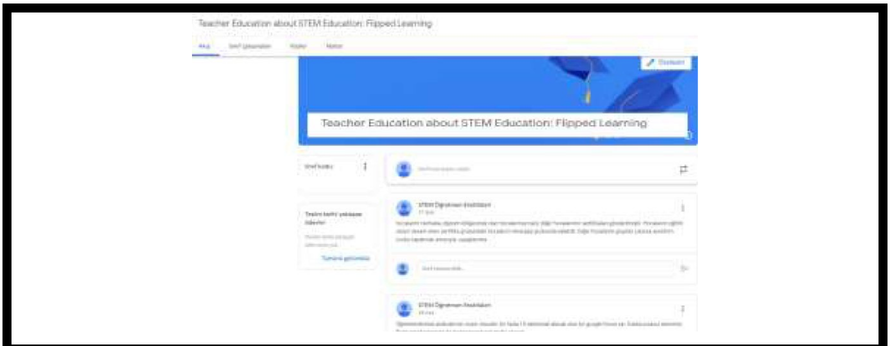
With online flipped learning, the training was conducted systematically using instructional guides. A pilot study was conducted to develop these guides. Based on the feedback received from experts during the pilot study, the guides were revised and finalized. Participants were allowed to ask questions about any challenging parts they encountered. Information about participants' technological infrastructure was

Table 3 Lesson plan evaluation criteria and explanations

No	Criterion	Explanation
	Identifying learning outcomes (ILO)	Specifying learning outcomes precisely
	Target skills (TS)	Specifying target skills
	STEM ınclusion (SI)	The focus of science (FS) The focus of mathematics (FM) The focus of engineering (FE) The focus of technology (FT)
	Identifying the problem situation (IPS)	Includes the specification of a problem situation related to daily life
	Specifying TRIZ process steps (TRIZ-PS)	Includes the specification of the TRIZ process to be used in developing the models emerging within the scope of the lesson plans
	Ensuring interdisciplinary integration (EII)	Specifying the fields of science, mathematics, engineering, and technology
	Suitability to student level (SSL)	The appropriateness of the lesson plans for the student group
	Specifying teaching principles and methods (STPM)	Includes specifying strategies, methods, and techniques in the lesson plan
	Specifying assessment tools (SAT)	Includes the specification of evaluation pathways

Table 4 Intervention

Weekly course process	Experimental group
	Pretest
Preparation	A "Google Classroom" is created for participants to watch STEM education videos before the intervention
Week 1	Participants watch videos on the importance of STEM education, its basic concepts, and its integration into the education system. They take notes on the lessons and prepare questions about the points they have difficulty understanding. They forward their questions to the coordinator
Weeks 2–3	The coordinator divides the participants into groups in online rooms
	Participants seek answers to questions. The coordinator assists each group
	The coordinator asks each group questions about the topic and expands the group work to include the applications of STEM education
Weeks 4–5	Participants watch lesson plan development videos about STEM education, take notes about the lessons and prepare questions about the points they have difficulty understanding. They ask their questions to the coordinator
	The whole class is interviewed about the lesson plan preparation process
	Group rooms are created online. Participants begin to prepare lesson plans
	The coordinator participates in each group's lesson plan development process, and answers related questions
Weeks 6–8	Participants watch videos of STEM education activities, take notes, and prepare questions about the points they have difficulty understanding. They ask their questions to the coordinator
	The coordinator uses the pre-sent sets to carry out the STEM activities
	Participants ask the coordinator about the points they find difficult to understand
	Posttest and interviews

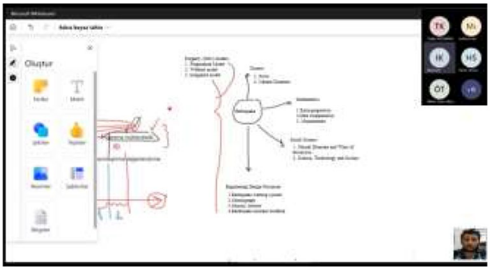


Teacher Education about STEM Education: Flipped Learning

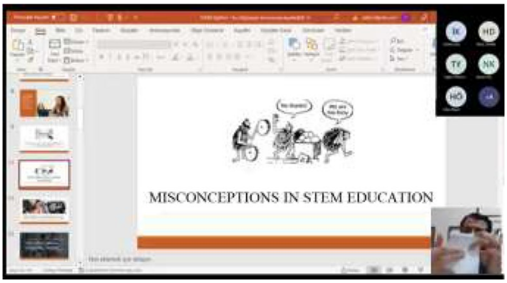
Teacher Education about STEM Education: Flipped Learning

As part of the online flipped learning model, Google Classroom was utilized. Within this framework, instructional videos pertinent to the lesson were uploaded onto the platform. Participants engaged with these videos independently before the lesson, arriving prepared to participate actively.

Fig. 2 Image of the google classroom used for online flipped learning



Sample image of the video uploaded for the theoretical part of the tenth lesson



Sample image of the video uploaded for the theoretical part of the second lesson

Fig. 3 Visuals of the course videos uploaded to Google classroom

also collected, and content was delivered accordingly. Materials were tailored to align with their technology capabilities to enhance motivation and prevent participants from discontinuing the training process.

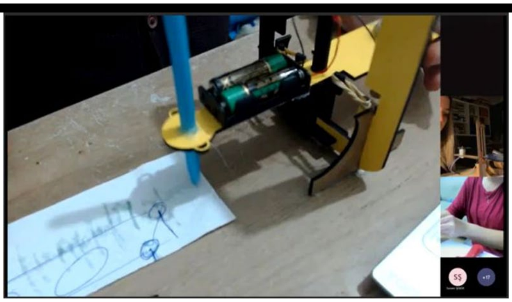
2.5.4 Face-to-face TRIZ-STEM education

Table 5 shows the details of face-to-face TRIZ-STEM education in order to help readers recognize the difference between face-to-face and online flipped learning TRIZ-STEM education.

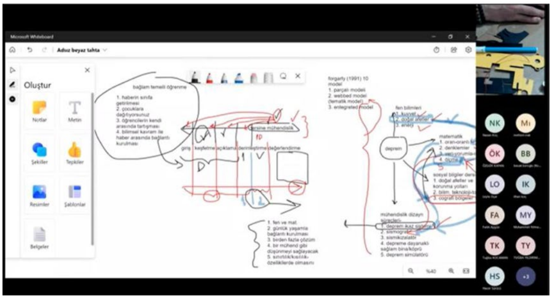
Face-to-face TRIZ-STEM education lasted eight weeks. The control group participants worked in groups throughout the process.

2.5.5 Reliability and validity

Various procedures were implemented to ensure the validity and reliability of the findings. A separate expert generated codes and themes from the lesson plans and NoES results to minimize researcher bias and enhance internal validity. In qualitative research, at least two people should code the data (Miles et al., 2014). Therefore, (1) an expert with a Ph.D. in STEM education and (2) an expert with a Ph.D. in the lesson study model assessed the NoES scores. In this context, intercoder reliability was calculated using Miles and Huberman's



1.Picture of making the seismograph together with the participants during the live lesson



2. Picture of the integration of the seismograph in the lesson

Fig. 4 Visuals of the application lessons of the online flipped learning model during the live lesson process

(1994) formula: [Reliability = (number of agreements) / (number of agreements + number of disagreements)*100]. Additionally, the validity and reliability of the results were strengthened by diversifying data sources by utilizing different data collection tools, as Patton (1987) recommended.

3 Results

3.1 PSI findings

The control group had a significantly lower mean PSI score than the experimental group ($p < 0.05$). The effect sizes also showed a significant difference. These results indicated face-to-face education was more effective than TRIZ-STEM online flip learning. In other words, the control group participants were better at solving problems than the experimental group participants (Şahin et al., 1993) (Tables 6, 7, and 8).

The experimental group participants had a significantly lower mean posttest PSI score than the pretest score ($p < 0.05$), suggesting that the intervention positively affected their problem-solving skills.

Table 5 Face-to-face TRIZ-STEM education

Weeks	Control Group
	Administering pretests
1-3	Providing information about the importance of STEM education, basic concepts, integration into the education process, and STEM teaching-learning processes. During this process, the control group participants worked in groups and interacted on the theoretical knowledge of STEM education. The topics covered in the first three weeks: 1. The history and importance of STEM education 2. Basic STEM concepts 3. Misconceptions in STEM education 4. STEM teaching-learning processes 5. Integrating TRIZ and STEM The control group participants worked in groups and discussed each topic to uncover the aspects they had difficulty understanding.
4-5	Providing information about developing STEM lesson plans. The topics covered in the fourth and fifth weeks are given below. The control group participants worked in groups to develop and present STEM lesson plans. They exchanged ideas during the presentations. 1. The steps of developing a lesson plan 2. Presenting sample STEM lesson plans and teaching how to develop lesson plans 3. Working in groups to develop lesson plans 4. Presenting the lesson plans The control group participants develop STEM lesson plans according to the lesson study model, where one student presents her lesson plan while others observe her. At the end of the presentation, the other teachers discuss the parts they think should be improved in their lesson plan.
6-8	Presenting sample activities related to STEM education to the control group participants. Making STEM education practices and discussions the integration of STEM education practices into classroom environments. Images of the application Activity: Parachute activity and friction force  The control group participants learned about the air resistance and parachutes and how to implement the activity in class. Picture of making the parachutes together with the participants during the lesson Activity 2: Earthquakes and seismography

Table 5 (continued)

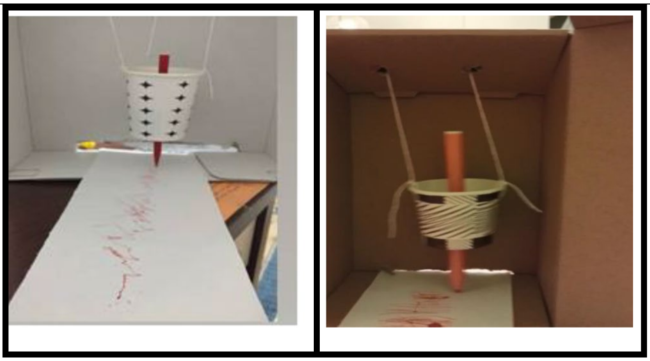
 The control group participants learned about the topic of earthquakes and how to implement it in their lessons. Picture of making the seismograph together with the participants during the lesson The control group participants worked in groups to implement the activities. At the end, they tested the materials and redesigned them. Afterward, they discussed how to implement these activities in their lessons. They also utilized TRIZ to develop their designs.
Administering posttests and conducting interviews

Table 6 Pretest and posttest PSI scores and effect sizes

	N	Mean	sd	df	*t*	*p*	Effect size
Experimental Group	33	120.45	18.66	55	2.225	0.030	0.59
Control Group	24	109.12	19.40				

*Lower scores indicate more problem-solving capability (Şahin et al., 1993)

Table 7 Pretest and posttest PSI scores (Experimental Group)

	N	Mean	sd	df	*t*	*p*	Effect Size
Pretest	33	151.48	18.46	32	8.728	0.000	0.83
Posttest	33	120.45	18.66				

Table 8 Pretest and posttest PSI scores (Control Group)

	N	Mean	sd	df	*t*	*p*	Effect Size
Pretest	24	142.13	16.31	23	6.696	0.00	0.81
Posttest	24	109.12	19.40				

The control group participants had a significantly lower mean posttest PSI score than the pretest score ($p < 0.05$), suggesting that face-to-face TRIZ-STEM education positively affected their problem-solving skills.

3.2 Findings on creative thinking dispositions

There was no significant difference in MCTDS scores between the experimental and control group ($p > 0.05$). These results indicated that the experimental and control group participants had similar creative thinking dispositions. In other words, there was no difference between online TRIZ-STEM flipped learning and face-to-face TRIZ-STEM education (Tables 9, 10, and 11).

The experimental group participants had a significantly higher mean posttest MCTDS score than the pretest score ($p < 0.05$). This result suggested that online flipped learning TRIZ-STEM education helped the experimental group participants develop creative thinking skills.

The control group participants had a significantly higher mean posttest MCTDS score than the pretest score ($p < 0.05$). This result suggested that face-to-face TRIZ-STEM education helped the control group participants develop creative thinking skills.

3.3 Findings on the Nature of Engineering

The experimental group had a significantly higher mean NoES score than the control group ($p < 0.05$). The effect sizes also pointed to a significant difference. These results indicated that online flipped learning TRIZ-STEM education was more effective than face-to-face TRIZ-STEM education (Tables 12, 13, and 14).

Table 9 Mann Whitney u-test results on creative thinking dispositions

Group	*N*	Mean rank	Sum of ranks	*U*	*p*	Effect size
Experimental	33	27.48	907.0	326	0.418	0.12
Control	24	31.08	746.0			

Table 10 Pretest and posttest MCTDS scores (Experimental Group)

Scales	Posttest-pretest	N	Mean rank	Sum of ranks	z	p	Effect size (Cohen's d)
MCTDS	Negative ranks	4	7.38	29.50	−3.446	0.001	0.60
	Positive ranks	20	13.53	270.50			
	Ties	9					

Table 11 Pretest and posttest MCTDS scores (Control Group)

Scales	Posttest-pretest	*N*	Mean rank	Sum of ranks	z	*p*	Effect size (Cohen's d)
MCTDS	Negative ranks	4	11.06	99.50	-1.444	0.149	0.29
	Positive ranks	20	13.37	200.50			
	Ties	0					

Table 12 Pretest and posttest NoES scores and effect sizes

	N	Mean	sd	df	*t*	*p*	Effect size
Experimental group	33	13.61	3.83	55	2.239	0.029	0.61
Control group	24	11.50	2.99				

Table 13 Pretest and posttest NoES scores (Experimental Group)

	N	Mean	sd	df	*t*	*p*	Effect size
Posttest	33	13.61	3.82	32	7.635	0.000	0.80
Pretest	33	9.36	3.53				

Table 14 Pretest and posttest NoES scores (Control Group)

	N	Mean	sd	df	*t*	*p*	Effect Size
Pretest	24	9.87	2.59	23	4.64	0.00	0.69
Posttest	24	11.50	2.99				

The experimental group had a significantly higher mean posttest NoES score than the pretest score ($p < 0.05$). This result indicated that online flipped learning TRIZ-STEM education helped the experimental group participants develop positive views about the nature of engineering.

The control group had a significantly higher mean posttest NoES score than the pretest score ($p < 0.05$). This result indicated that face-to-face TRIZ-STEM education helped the control group participants develop positive views about the nature of engineering.

3.4 Findings related to views on the nature of engineering

Participants' views on the nature of engineering were discussed under three main categories: (1) views on the definition of engineering, (2) views on design processes, and (3) views on skills and culture. These categories were formulated based on the data derived from the experimental group. Consequently, the results were presented in terms of both pre- and post-implementation data, facilitating clear comprehension for readers.

3.5 Findings related to the definition of engineering

Participants' views on the definition of engineering before the application were grouped under seven codes: (1) creating products for human needs, (2) making life easier, (3) Covering science and mathematics, (4) conducting data-driven studies, (5) improving the quality of life, (6) doing research, and (7) working on technical issues. Most participants focused on the codes of "creating products for human needs" and "making life easier." The following are some quotes:

> T1: "Engineering is designing products to make life easier." **Making life easier and designing products**
> T2: "Engineering is a vocation centered around technical studies and the creation of technical products." **Working on technical issues**
> T10: "Engineering involves the creation of products designed to fulfill the needs of people." **Designing products for human needs**
> T12: "Engineering is the process of making mathematics and science useful and beneficial for human beings." **Covering science and mathematics**

Participants' views on the definition of engineering after the application were grouped under 12 codes: (1) creating products for human needs, (2) developing products in the light of theoretical knowledge, (3) using different disciplines simultaneously, (4) solving problems, (5) using higher-order thinking skills, (6) working in different fields, (7) making life easier, (8) covering science and mathematics, (9) conducting data-driven studies, (10) improving the quality of life, (11) doing research, and (12) working on technical issues. Most participants focused on the codes of "creating products for human needs" and "developing products in the light of theoretical knowledge." The following are some quotes:

> T11: "Engineers design things and implement them to make life easier." **Making life easier**
> T17: "Engineers specialize in various domains, encompassing urban and rural areas such as roads, bridges, buildings, landscaping, and environmental considerations. They also extend their expertise to areas like agriculture and nutrition, as well as various scientific disciplines including physics, chemistry, biology, electricity, and electronics. Additionally, engineers contribute to the development of sectors such as aviation, maritime, automobiles, engines, construction machinery, and various technical and social fields." **Working in different fields**
> T27: "Engineers solve problems through creative ideas, develop concrete products, and design new and unusual products. They use math and science concepts while designing these products or solving problems." **Solving problems, designing products, covering science and mathematics**
> T33: "To transform the theoretical knowledge into practice by utilizing the existing knowledge in other disciplines and to produce products …" **developing products in the light of theoretical knowledge**

3.6 Findings related to the design process

When we look at participants' views on the design process before the application, we see that almost all participants defined the design process, but four participants did not express any opinion about it. In addition, the majority of the participants did not include all stages of engineering design processes when defining the design process. Five participants gave examples of all engineering design processes, while the remaining four participants gave examples of all engineering design processes but did not explain them with examples. While most participants stated that products could change after they were developed, four teachers did not express an opinion. Most of the teachers who stated that the design process could change could not provide any examples to explain the process. The following are some quotes:

> T5: "The design process is a process that engineers follow when developing a design. For example, when engineers from a white goods company are asked to design a washing machine, they first identify problems and needs. Then, they develop solutions and choose the most suitable one. They then develop prototypes and run tests."
> T13: "A project idea is found, research is done, and a product is designed."
> T15: "Recognizing problems, finding and test solutions, developing a product, and evaluating how to improve it."
> T19: "Constantly, new technologies and applications are emerging, propelling the rapid evolution of various fields. This ongoing progress and transformation serve to address the limitations of current solutions, driving changes in design. Notably, designs are being crafted to enhance efficiency and comfort, particularly concerning the aerodynamics and comfort attributes of automobiles. Looking ahead, the focus intensifies on the creation of autonomous vehicles boasting advanced safety measures, signaling a competitive race in the near future."
> T21: "When a design fails to meet expectations—either by not effectively solving a problem or due to emerging developments—it can be modified accordingly."
> T23: "It can change because there is always something better, faster, and there is always room for improvement in designs."

When we look at participants' views on the design process after the application, we see that most participants used examples to define the design process. However, some participants only design the process. Most participants included all stages of engineering design processes when defining the design process. Moreover, most participants used examples to indicate that a product could be modified after it was developed. On the other hand, some participants did not provide any examples when explaining that a product could be modified after it was developed. The following are some quotes:

> T4: "Engineering design phases are as follows: Problem situation-gathering information-developing ideas-developing prototypes-testing-product development-sharing and presenting. For example, when students are asked to design a mountaineering suit, they follow all these stages…"
> T7: "For engineering design, we first identify a problem, find solutions for it and choose the best solution. Then we move on to the implementation phase and create a product. Then we test whether the product works or not. Then, we decide on the best design."

> T11: “Yes, it changes. As people have more needs, products may not meet them. In this case, we invent innovations or new products. For example, blackboards used to be blackboards, and now they are smartboards.”
> T16: “It certainly changes and evolves... For example, today’s seat belt is the result of a 100-year history of experimentation.”
> T22: “Engineering designs remain adaptable due to the ever-evolving nature of technology and shifting requirements. A prime example lies in the realm of space shuttles: in the past, the feasibility of returning and reusing them was limited. However, in response to escalating expenses and leveraging technological progress, contemporary space shuttles have been engineered for reusability, exemplifying the responsive evolution of design.”

3.7 Findings related to skills and culture

Participants’ views on skills and culture before the intervention were examined. Only three participants gave examples to describe their views on skills and culture. On the other hand, most participants stated that creativity and engineering were used to design products, solve problems, and run tests. The other participants noted that creativity and imagination were used throughout the entire engineering design process. Most participants who emphasized that engineering is universal did not give examples in this regard. The following are some quotes:

> T4: Engineers use their creativity and imagination to improve their designs. **Creativity and imagination**
> T7: Engineering is universal because it serves similar human purposes. For example, TOGG is open to the whole world. **Universal**
> T11: Engineering serves as a reflection of societal and cultural ideals. It encompasses the architecture of communities, the array of products individuals opt to integrate into their domestic lives, and the tools and equipment pivotal to their daily existence. These elements collectively encapsulate cultural values. **National**
> T15: Creativity is used at all stages. Most of all, I think, in the refinement of the design. **Creativity and imagination**
> T21: Engineering is universal. But it carries social and cultural values and has subjective aspects. **Universal**

Participants’ views on skills and culture after the intervention were examined. All participants stated that engineers used creativity and imagination in engineering design processes. After the intervention, most participants gave examples to explain how engineers use creativity and imagination. In addition, after the intervention, half of the participants stated that creativity and imagination were used for design development, problem-solving, and testing. Other participants stated that creativity and imagination were used in all engineering design processes. After the intervention, most participants gave examples to express that engineering is influenced by social-cultural factors. More participants emphasized that engineering is universal after the intervention than before the intervention. However, most participants who emphasized that engineering is universal could not give examples to explain this. The following are some quotes:

> T3: Yes. Engineers can use their imagination to identify problems, design things, and build them.. **Creativity and imagination**
>
> T5: Yes, I think it is affected. For example, washing machines, dishwashers, or robot vacuum cleaners. But in underdeveloped countries, because of male dominance, more men become engineers and design things that are more useful for men, like guns or cars. **Universal**
>
> T7: I believe that engineering is influenced by sociocultural values. For example, our mosques are a reflection of our cultural values. **National**
>
> T9: Yes, it is used. It is used in terms of being sustainable in terms of its aesthetic appearance and being useful in terms of attracting the attention of consumers. For example, phones now have more features. **Creativity and imagination**
>
> T17: They can create original products by using their creativity at every stage. **Creativity and imagination**
>
> T23: It should be universal because this is necessary for the perspective to be developed. **Universal**

3.8 Findings on STEM teaching

There was no significant difference in STEM teaching results between the experimental and control groups, with a small effect size ($p > 0.05$). The result indicated that online flipped learning TRIZ-STEM education and face-to-face TRIZ-STEM education had similar effects on participants' STEM teaching (Tables 15, 16, and 17.

The experimental group had a significantly higher mean posttest STEM teaching score than the pretest score ($p < 0.05$), indicating that online flipped learning

Table 15 STEM teaching results and effect sizes

	N	Mean	sd	df	*t*	*p*	Effect size
Experimental group	33	7.58	1.39	55	0.191	0.849	0.055
Control group	24	7.50	1.50				

Table 16 Pretest and posttest STEM teaching results (Experimental Group)

	N	Mean	sd	df	*t*	*p*	Effect size
Pretest	33	6.18	1.48	32	6.68	0.00	0.76
Posttest	33	7.58	1.39				

Table 17 Pretest and posttest STEM teaching results (Control Group)

	N	Mean	sd	df	*t*	*p*	Effect size
Pretest	24	6.37	1.38	23	5.32	0.00	0.74
Posttest	24	7.50	1.50				

TRIZ-STEM education positively affected the experimental group participants' STEM teaching.

The control group had a significantly higher mean posttest STEM teaching score than the pretest score ($p < 0.05$), indicating that face-to-face TRIZ-STEM education positively affected the control group participants' STEM teaching.

3.9 Findings related to descriptive analysis of lesson plans related to STEM teaching

When we look at the lesson plans prepared by participants, we see that they had difficulty ensuring interdisciplinary integration, determining TRIZ process steps, integrating math, engineering, and technology, and identifying problems. Moreover, some participants did not pay attention to students' levels and skills when preparing lesson plans (Table 18).

3.10 Participants' views on STEM lesson plan preparation

The qualitative data were analyzed using content analysis. The results yielded three themes: "things to consider when preparing lesson plans," "problems encountered during lesson planning," and "points that the participants lacked when preparing lesson plans".

The theme "things to consider when preparing lesson plans" consisted of eleven codes: (1) student level appropriateness, (2) fit for purpose, (3) relevance to STEM fields, (4) relevance to design, (5) relevance to learning outcomes, (6) relevance to daily life, (7) topic selection, (8) skill development, (9) time, (10) engineering design processes, and (11) material suitability. The following are some quotes:

Table 18 Descriptive statistics for lesson plan scores

Evaluation criteria	Number of lessons that met the criterion among 12	*M*	SD
ILO	103	0.90	0.297
TS	82	0.72	0.451
SI-FS	81	0.71	0.456
SI-FM	57	0.50	0.502
SI-FE	40	0.35	0.479
SI-FT	51	0.45	0.499
IPS	62	0.54	0.500
TIRZ-PS	17	0.15	0.358
EII	22	0.19	0.396
SSL	79	0.69	0.463
STPM	92	0.81	0.396
SAT	102	0.89	0.308

*Note: Possible range of each criterion is 1 (the criterion was met) – 0 (the criterion not met)

> T18: “I prepare a design and product-oriented plan by making connections between science, technology, mathematics, and engineering.” **Relevance to STEM fields and design**
> T21: “Through STEM education, students should acquire the proficiency to seamlessly apply their knowledge across diverse disciplines, forging connections between subject content and real-world predicaments.” **Making connections between the subject and real life**
> T25: “When preparing STEM lesson plans, the first goal I set is to find a design model that is suitable for the target outcome and that I can use the subject related to my field. I prefer that the tools needed to create this model or product are easily accessible to my students.” **Relevance to the objective, subject matter, and material**

The theme “problems encountered during lesson planning” consisted of nine codes: (1) interdisciplinary integration, (2) relevance to the subject matter, (3) physical environment, (4) design process, (5) relevance to student level, (6) integration of engineering, (7) lack of materials, (8) economic problems, and (9) problems related to lack of domain knowledge. The following are some quotes:

> T1: “…The greatest challenge of preparing STEM lesson plans is to fit multiple disciplines into one plan.” **Interdisciplinary integration**
> T17: “…As a science teacher, I have difficulty integrating engineering into my lessons..” **Integration of engineering**
> T20: “…I sometimes have difficulty establishing interdisciplinary relationships while preparing STEM lesson plans.” **Interdisciplinary integration**
> T22: “When preparing STEM lesson plans, I think that I will be indecisive when choosing a topic.” **Relevance to the subject matter**

The theme “points that the participants lacked when preparing lesson plans” consisted of seven codes: (1) engineering content knowledge, (2) Technology content knowledge, (3) Mathematics content knowledge, (4) science content knowledge, (5) interdisciplinary integration, (6) A lack of skills, (7) gaps in pedagogical knowledge. The following are some quotes:

> T3: “I think I have gaps in creative thinking while preparing STEM lesson plans.” **A lack of skills**
> T15: “We stated that STEM education is an education method consisting of Science, Mathematics, Engineering, and Technology. I think that we lack engineering and technology knowledge, and sometimes math knowledge.” **Engineering, technology, and mathematics content knowledge**
> T24: “I fail to associate it with the field of engineering because engineering is also a field of skill. It requires transferring knowledge to practice. That’s what we can’t.” **Engineering content knowledge**
> T27: “I think I have gaps in knowledge and predisposition to technological innovations in engineering design processes while planning STEM lessons.” **Technology content knowledge**

4 Discussion and conclusion

This study explored the impact of online flipped learning TRIZ-STEM education on teachers' problem-solving skills and creative thinking dispositions. Additionally, the study examined the influence of online flipped learning TRIZ-STEM education on teachers' perspectives regarding the nature of engineering and STEM teaching. This section addressed the results.

The first research question examined the impact of online flipped learning TRIZ-STEM education on teachers' problem-solving skills. The findings revealed that face-to-face TRIZ-STEM education enhanced teachers' problem-solving skills more effectively than online flipped learning TRIZ-STEM education. However, both approaches demonstrated positive effects on teachers' problem-solving skills. These findings align with previous studies conducted by Park and Han (2018) and Hussian et al. (2020), which found that flipped learning contributed to problem-solving skill development among college students. Furthermore, existing research supports the positive influence of STEM education on problem-solving skills, as evidenced by studies conducted by Alatas and Yakin (2021), Kurt and Benzer (2020), and Şahin et al. (2014). Additionally, Erol et al. (2022) reported that STEAM education benefited preschoolers in developing problem-solving skills. Hence, our findings are consistent with the existing literature.

The second research question examined whether online flipped learning TRIZ-STEM education helped teachers develop creative thinking dispositions. The results showed no significant difference regarding the effect of online flipped learning TRIZ-STEM education and face-to-face TRIZ-STEM education on teachers' creative thinking dispositions. However, both online flipped learning TRIZ-STEM education and face-to-face TRIZ-STEM education helped teachers develop creative thinking dispositions. Puspitasari et al. (2020) found that flipped learning STEM education enhanced the creativity of physics teachers. Erkan and Duran (2023) reported that flipped STEM education enhanced students' creativity. Overall, research shows that both flipped learning and STEM education have a positive effect on creativity (Aguilera & Ortiz-Recilla, 2021; Al-Zahrani, 2015; Erol et al., 2022; Ozkan & Topsakal, 2021). Moghadam and Razavi (2022) documented that flipped learning improved the creativity of primary school students. Tiryaki and Adıgüzel (2021) found that STEM education positively affected children's creativity. Kim et al. (2014) found that STEM education improved children's creativity. Our findings are consistent with the literature.

The third research question addressed the effect of online flipped learning TRIZ-STEM education on teachers' perceptions of the nature of engineering. The results showed that online flipped learning TRIZ-STEM education improved participants' views of the nature of engineering more than face-to-face TRIZ-STEM education. The results also showed that both online flipped learning TRIZ-STEM education and face-to-face TRIZ-STEM education changed participants' views of the nature of engineering for the better. Although there are no studies examining the views of online flipped learning TRIZ-STEM education and face-to-face TRIZ-STEM education on the nature of engineering, studies are showing that flipped learning STEM education alone is effective in engineering education (Karahan, 2020; Low & Hew, 2019; Mamun et al., 2022). Lin (2021) found that flipped learning in software engineering education improved students' learning performance. Gök (2022) reported that STEM education positively influenced middle school students' views about the nature of engineering.

The third research question also examined the effect of online flipped learning TRIZ-STEM education on teachers' views on the nature of engineering. Participants' views were discussed under three headings: (1) defining engineering, (2) the design process, and (3) skills and cultural reflections. The results showed that online flipped learning TRIZ-STEM education had a positive impact on participants' views on the nature of engineering.

The fourth research question investigated how online flipped learning TRIZ-STEM education affected teachers' STEM teaching. The results showed no significant difference regarding the effect of online flipped learning TRIZ-STEM education and face-to-face TRIZ-STEM education on participants' STEM teaching. However, both online flipped learning TRIZ-STEM education and face-to-face TRIZ-STEM education improved participants' STEM teaching. Moreover, the lesson plans showed that participants had gaps in their knowledge of engineering and interdisciplinary integration. Some researchers have investigated the effect of flipped learning TRIZ-STEM education and face-to-face TRIZ-STEM education on teachers' STEM teaching. Research shows that flipped learning and STEM education positively affect teachers' STEM teaching (Kim et al., 2015; Weinhandl et al., 2020; Yıldırım et al., 2022). Teachers' sense of competence in STEM education is effective in STEM teaching. Çoşkun (2020) found that flipped learning STEM education positively affects preservice teachers' STEM teaching orientation. Yıldırım (2021) reported that preservice teachers who received STEM education wanted to provide STEM education in their classrooms. Integrating STEM fields into lesson plans makes teachers' in-class STEM education challenging because they have little knowledge and experience in STEM (Karakaş, 2017; Nadelson & Seifert, 2013). The increase in teachers' knowledge positively impacted their STEM teaching. The findings are consistent with the literature.

The fourth research question also addressed the descriptive analysis of the lesson plans. The results showed that participants had difficulty ensuring interdisciplinarity, determining TRIZ process steps, and integrating math, engineering, and technology. Moreover, some participants did not pay attention to students' levels and skill development in their lesson plans. Participants' statements also showed that they had gaps in their knowledge of STEM fields and had difficulty ensuring interdisciplinarity because they were inexperienced and uninformed about STEM education. Research also shows that teachers have similar problems when they develop lesson plans (Karakaya et al., 2018; Kim et al., 2015; Sarıoğlu et al., 2022; Stohlmann et al., 2012; Wan et al., 2020). For example, Park et al. (2017) highlight that insufficient STEM content knowledge among teachers leads to challenges in effectively conducting STEM instruction. Yıldırım (2023) also maintains that teachers have difficulty developing lessons plans because they have gaps in their knowledge of STEM fields.

4.1 Limitations

This study had two limitations. First, this study was conducted with teachers of different branches working in Türkiye. Second, the results are sample-specific and cannot be generalized to all teachers.

4.2 Recommendations for future studies

Based on the results, suggestions were made for future studies. There was no statistical difference between online flipped learning TRIZ-STEM education and face-to-face TRIZ-STEM education regarding their effects on teachers' STEM teaching and creative thinking. Moreover, face-to-face TRIZ-STEM education was better at helping teachers develop problem-solving skills than online flipped learning TRIZ-STEM education. On the other hand, online TRIZ-STEM education had a more positive impact on teachers' perspectives on engineering nature than face-to-face TRIZ-STEM education. In addition, pre- and post-intervention results showed that online flipped learning and face-to-face learning had positive effects on these variables. Derived from these findings, educators are recommended to utilize the online flipped learning model as a means of furnishing professional development for teachers across various domains, with a particular emphasis on STEM education.

Another result is related to the effects of TRIZ-STEM education. This is the first study to use TRIZ-STEM education for teacher training purposes. Therefore, our results will contribute to the literature and pave the way for further research. Hence, researchers should also examine the effects of TRIZ-STEM education on different variables.

Acknowledgements This article has been derived from the " BİLTEMM STEM Teacher Institutes Project," which is carried out by Hacettepe University Teknokent. I would also like to thank the Assoc. Prof. Dr. Ayça Kartal and the Assist. Prof. Ahmet Aykan for their assistance in analyzing the qualitative data.

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

Declarations

Conflict of interest None.

References

Abeysekera, L., & Dawson, P. (2015). Motivation and cognitive load in the flipped classroom: Definition, rationale and a call for research. *Higher Education Research & Development, 34*(1), 1–14. https://doi.org/10.1080/07294360.2014.934336

Aguilera, D., & Ortiz-Recilla, J. (2021). STEM vs. STEAM education and student creativity: A systematic literature revie. *Education Sciences, 11*(7), 331. https://doi.org/10.3390/educsci11070331

Alatas, F., & Yakin, N. A. (2021). The effect of science, technology, engineering, and mathematics (STEM) learning on students' problem solving skill. *Jurnal Ilmu Pendıdıkan Fısıka, 6*(1), 1–9.

Alkasem, B., & Tilfarlioğlu, F. Y. (2023). TRIZ as innovative method in english language teaching. *Journal of Education and Training Studies, 11*(1), 37–45. https://doi.org/10.11114/jets.v11i1.5823

Al-Zahrani, A. M. (2015). From passive to active: The impact of the flipped classroom through social learning platforms on higher education students' creative thinking. *British Journal of Educational Technology, 46*(5), 1133–1148. https://doi.org/10.1111/bjet.12353

Baker, J. W. (2000). The "Classroom Flip": Using web course management tools to become the guide by the side. In J. A. Chambers (Ed.), *Proceedings of the 11th International Conference on College Teaching and Learning* (pp. 9–17). Florida Community College at Jacksonville.

Balcı, A. (2016). *Research methods, techniques and principles in social sciences*. Pegem.

Bergmann, J., & Sams, A. (2014). Flipping for mastery. *Educational Leadership, 71*(4), 24–29. Retrieved from http://www.ascd.org/el/articles/flipping-for-mastery. Accessed 18 Mar 2023.

Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day* (pp. 120–190). International Society for Technology in Education.

Bozhik, S., Bagrova, E., & Osipova, E. (2023). International students' creative thinking development via the triz method in a multilingual audience. In: D. Bylieva & A. Nordmann (Eds.), *Technologies in a Multilingual Environment*. PCSF 2022. Lecture Notes in Networks and Systems, vol 636. Springer. https://doi.org/10.1007/978-3-031-26783-3_38

Cerit, G. K. (2014). TRIZ: Theory of inventive problem solving and comparison of TRIZ with the other problem-solving techniques. *Balkan Journal of Electrical & Computer Engineering, 2*(2), 66–74.

Chang, Y. S., Chien, Y. H., Yu, K. C., Chu, Y. H., & Chen, M. Y. C. (2016). Efect of TRIZ on the creativity of engineering students. *Thinking Skills and Creativity, 19*, 112–122. https://doi.org/10.1016/j.tsc.2015.10.003

Cohen, J. (1988). Statistical power analysis for the behavioral science. Hillsdale: Lawrence Erlbaum Associates.

Çoşkun, G. (2020). *The effect of STEM activities with flipped learning model onself-efficacy beliefs and STEM education approaches of prospective science teachers.* (Unpublished masters thesis). Akdeniz University.

Deniz, H., Kaya, E., Yesilyurt, E., & Trabia, M. (2020). The influence of an engineering design experience on elementary teachers' nature of engineering views. *International Journal of Technology and Design Education, 30*, 635–656.

Ejiwale, J. (2013). Barriers to successful implementation of STEM education. *Journal of Education and Learning, 7*(2), 63–74. https://doi.org/10.11591/edulearn.v7i2.220

Enfield, J. (2013). Looking at the impact of the flipped classroom model of instruction on undergraduate multimedia students at CSUN. *TechTrends, 57*(6), 14–27.

Erkan, H., & Duran, M. (2023). The effects of STEM activities conducted with the flipped learning model on primary school students' scien-tific creativity, attitudes and perceptions towards STEM. *Science Insights Education Frontiers, 15*(1), 2175–2225. https://doi.org/10.15354/sief.23.or115

Erol, A., Erol, M., & Başaran, M. (2022). The effect of STEAM education with tales on problem solving and creativity skills. *European Early Chıldhood Educatıon Research Journal*. https://doi.org/10.1080/1350293X.2022.2081347

Fey, V., & Rivin, E. (2005). *Innovation on demand: New product development using TRIZ.* Cambridge University Press.

Fung, C. H. (2020). How does flipping classroom foster the STEM education: A case study of the FPD model. *Technology, Knowledge and Learning, 25*, 479–507. https://doi.org/10.1007/s10758-020-09443-9

Fung, C. H., Poon, K. K., & Ng, S. P. (2022). Fostering student teachers' 21st century skills by using flipped learning by teaching in STEM education. *EURASIA Journal of Mathematics, Science and Technology Education, 18*(12), 1–26. https://doi.org/10.29333/ejmste/12728

Gök, N. (2022). *Middle school students' attitudes towards STEM and their views on the nature of engineering*. (Unpublished master's thesis). Alanya Alaaddin Keykubat University.

Heppner, P. P., & Petersen, C. H. (1982). The development and implications of a personal problem-solving inventory. *Journal of Counseling Psychology, 29*(1), 66–75. https://doi.org/10.1037/0022-0167.29.1.66

Hibpshman, T. L. (2007). Analysis of transcript data for mathematics and science teachers. Frankfort, Kentucky: Education Professional Standards Board.

Honeycutt, B., & Garrett, J. (2014). Expanding the definition of a flipped learning environment. *Faculty Focus.* Retrieved from https://www.facultyfocus.com/articles/blended-flipped-learning/expanding-definition-flipped-learning-environment/. Accessed 20 Mar 2023.

Hussian, S., Janwal, P. K., Munir, M. T., & Zuyeva, A. (2020). A quasi-qualitative analysis of flipped classroom implementation in an engineering course: From theory to practice. *International Journal of Educational Technology in Higher Education, 17*(43), 1–19. https://doi.org/10.1186/s41239-020-00222-1

Jung, Y. K., & Hong, H. (2020). A theoretical need for applying flipped learning to STEAM education. *Problem-Based Learning, 7*(1), 42–49. https://doi.org/10.24313/jpbl.2020.00213

Karahan, E. (2020). Investigating STEM-focused instructional module designs of engineering students. *Boğaziçi Üniversitesi Eğitim Dergisi*, *37*, 73–91. Retreved from https://dergipark.org.tr/tr/download/article-file/1453827. Accessed 1 Apr 2023.

Karakaş, A. (2017). *Reflections of science, technology, engineering, mathematics (STEM) implementation on science teaching* [Unpublished doktoral thesis]. Pamukkale University, Denizli.

Karakaya, F., Ünal, A., Çimen, O., & Yilmaz, M. (2018). STEM awareness levels of science teachers. *Eğitim ve Toplum Araştırmaları Dergisi, 5*(1), 124–138.

Kim, C., Kim, D., Yuan, J., Hill, R. B., Doshi, P., & Thai, C. N. (2015). Robotics to promote elementary education pre-service teachers' STEM engagement, learning, and teaching. *Computers & Education, 91*, 14–31. https://doi.org/10.1016/j.compedu.2015.08.005

Kim, D. H., Ko, D. G., Han, M. J., & Hong, S. H. (2014). The effects of science lessons applying STEAM education program on the creativity and interest levels of elementary students. *Journal of the Korean Association for Science Education, 34*(1), 43–54. https://doi.org/10.14697/JKASE.2014.34.1.1.00043

Kiong, T. T., Saien, S., Heong, Y. M., & Mohamad, M. M. (2017). TRIZ: An alternate way to solve problem for student. *International Journal of Academic Research in Business and Social Sciences, 7*(2), 486–492.

Kozikoğlu, İ, Erbenzer, E., & Ateş, G. (2021). The relationship between teachers' flipped learning selfefficacy perceptions and behaviors of supporting learner autonomy. *Journal of Kazım Karabekir Educational Faculty, 42*, 344–366. https://doi.org/10.33418/ataunikkefd.796531

Kurt, M., & Benzer, S. (2020). An investigation on the effect of STEM practices on sixth grade students' academic achievement, problem solving skills, and attitudes towards STEM. *Journal of Science Learning, 3*(2), 79–88. https://doi.org/10.17509/jsl.v3i2.21419

Lin, Y. T. (2021). Effects of flipped learning approaches on students' learning performance in software engineering education. *Sustainability, 13*(17), 9849. https://doi.org/10.3390/su13179849

Low, C. K., & Hew, K. F. (2019). The impact of flipped classrooms on student achievement in engineering education: A meta-analysis of 10 years of research. *Journal of Engineering Education, 108*, 523–546. https://doi.org/10.1002/jee.20293

Lu, S. Y., Lo, C. C., & Syu, J. Y. (2022). Project-based learning oriented STEAM: The case of micro–bit paper-cutting lamp. *International Journal of Technology and Design Education, 32*(5), 2553–2575. https://doi.org/10.1007/s10798-021-09714-1

Madara, D. S. (2015). Theory of inventive problem solving (TRIZ): His-story. *International Journal of Innovative Science, Engineering & Technology, 2*(7), 86–95.

MalAllah, M. B., Alshirawi, M. I., & AL-Jasim, F. A. (2022). The efect of a program based on TRIZ theory to develop the creative thinking skills among male students with mild intellectual disability. *International Journal of Systematic Innovation, 7*(2), 1–21. https://doi.org/10.6977/IJoSI.202206_7(2).0001

Mamun, M. A. A., Azad, M. A. K., Mamun, M. A. A., & Boyle, M. (2022). Review of flipped learning in engineering education: Scientific mapping and research horizon. *Education and Information Technologies, 27*, 1261–1286. https://doi.org/10.1007/s10639-021-10630-z

Merrill, J. (2015). *The flipped classroom: An examination of veteran teacher' practices when flipping their classrooms for the first time.* (Unpublished doctoral dissertation). Texas A&M University.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis* (2nd ed.). SAGE.

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). Sage.

Moghadam, S. N., & Razavi, M. R. (2022). The effect of the flipped learning method on academic performance and creativity of primary school students. *European Review of Applied Psychology, 72*(5), 1–8. https://doi.org/10.1016/j.erap.2022.100811

Nadelson, L. S., & Seifert, A. (2013). Perceptions, engagement, and practices of teachers seeking professional development in place-based integrated STEM. *Teacher Education & Practice, 26*(2), 242–266.

Nederveld, A., & Berge, Z. L. (2015). Flipped learning in the workplace. *Journal of Workplace Learning, 27*(2), 162–172. https://doi.org/10.1108/JWL-06-2014-0044

Özgenel, M., & Çetin, M. (2017). Development of the Marmara creative thinking dispositions scale: Validity and reliability analysis. *Marmara Üniversitesi Atatürk Eğitim Fakültesi Eğitim Bilimleri Dergisi, 46*(46), 113–132. https://doi.org/10.15285/maruaebd.335087

Ozkan, G., & Topsakal, U. U. (2021). Exploring the efectiveness of STEAM design processes on middle school students' creativity. *International Journal of Technology and Design Education, 31*, 95–116. https://doi.org/10.1007/s10798-019-09547-z

Park, M. H., Dimitrov, D. M., Patterson, L. G., & Park, D. Y. (2017). Early childhood teachers' beliefs about readiness for teaching science, technology, engineering, and mathematics. *Journal of Early Childhood Research, 15*(3), 275–291. https://doi.org/10.1177/1476718X15614040

Park, J. H., & Han, T. I. (2018). The effect of flipped learning on problem-solving capability in software education. *International Journal of Information and Education Technology, 8*(4), 304–307. Retrieved from http://www.ijiet.org/vol8/1052-DE008.pdf. Accessed 12 Apr 2023.

Park, S. J. (2023). Testing the effects of a TRIZ invention instruction program on creativity beliefs, creativity, and invention teaching self-efficacy. *Education and Information Technologies*. https://doi.org/10.1007/s10639-023-11614-x

Patton, M. (2002). *Qualitative evaluation and research methods*. SAGE.

Patton, Q. M. (1987). *How to use Qualitative Methods in evaluation*. SAGE.

Puspitasari, R. D., Herlina, K., & Suyatna, A. (2020). A need analysis of STEM-integrated flipped classroom e-module to improve critical thinking skills. *Indonesian Journal of Science and Mathematics Education, 3*(2), 178–184.

Şahin, A., Ayar, M. C., & Adıgüzel, T. (2014). STEM related afterschool program activities and associated outcomes on student learning. *Educational Sciences: Theory and Practice, 14*(1), 309–322.

Şahin, N., Şahin, N. H., & Heppner, P. P. (1993). The psychometric properties of the problem solving inventory. *Cognitive Therapy and Research, 17*(4), 379–396.

Sarıoğlu, S., Kıryak, Z., Ormancı, Ü., & Çepni, S. (2022). Views of STEM-trained teachers on STEM education in türkiye. *Journal of STEM Teacher Institutes, 2*(2), 39–54.

Savranksy, S. D. (2000). *Engineering of creativity - Introduction to TRIZ methodology of inventive problem solving*. CRC Press.

Shih, B. Y., Chen, C. Y., & Li, C. E. (2013). The exploration of the mobile mandarin learning system by the application of TRIZ theory. *Computer Applications in Engineering Education, 21*(2), 343–348. https://doi.org/10.1002/cae.20478

Staker, H., & Horn, M. B. (2012). *Classifying K-12 blended learning. Mountain view.* Innosight Institute. http://www.christenseninstitute.org/wp-content/uploads/2013/04/Classifying-K-12-blended-learning.pdf. Accessed 1 Apr 2023.

Stohlmann, M., Tamara, J. M., & Roehring, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research (J-PEER), 2*(1), 28–34.

Strayer, J. F. (2012). How learning in an inverted classroom influences cooperation, innovation and task orientation. *Learning Environments Research, 15*, 171–193. https://doi.org/10.1007/s10984-012-9108-4

Talley, C. P., & Scherer, S. (2013). The enhanced flipped classroom: Increasing academic performance with student-recorded lectures and practice testing in a "flipped" STEM course. *The Journal of Negro Education, 82*(3), 339–347.

The President's Council of Advisors on Science and Technology. (2010). *Prepare and inspire: K–12 education in science, technology, engineering, and math (STEM) for America's future*. Author.

Thoms, C. L. V. (2012). *Enhancing the blended learning curriculum by using the "flipped classroom" approach to produce a dynamic learning environment*. Paper presented at the 5th International Conference of Education, Research and Innovation (ICERI), Madrid, Spain.

Tiryaki, A., & Adıgüzel, S. (2021). The Effect of STEM-based robotic applications on the creativity and attitude of students. *Journal of Science Learning, 4*(3), 288–297. https://files.eric.ed.gov/fulltext/EJ1307654.pdf. Accessed 26 Mar 2023.

Tucker, B. (2012). The flipped classroom. *Education Next, 12*(1), 82. Retrieved from https://educationnext.org/the-flipped-classroom/. Accessed 20 Feb 2023.

Twining, P., Heller, R. S., Nussbaum, M., & Tsai, C. C. (2017). Some guidance on conducting and reporting qualitative studies. *Computers & Education, 106*, 1–9. https://doi.org/10.1016/j.compedu.2016.12.002

U.S. Department of Education. (2010). *A blueprint for reform: The reauthorization of the elementary and secondary education act*. Retreve from https://www2.ed.gov/policy/elsec/leg/blueprint/blueprint.pdf. Accessed 18 Feb 2023.

Wan, Z. H., Jiang, Y., & Zhan, Y. (2021). STEM education in early childhood: A review of empirical studies. *Early Education and Development, 32*(7), 940–962. https://doi.org/10.1080/10409289.2020.1814986

Wang, T., & Cheng, E. C. K. (2023). Towards effective teacher professional development for stem education in hong kong k-12: A case study. In: E. C. K. Cheng, T. Wang, T., Schlippe, & G. N. Beligiannis (Eds.), *Artificial intelligence in education technologies: new development and innovative practices.* AIET 2022. Lecture Notes on Data Engineering and Communications Technologies, vol 154. Springer. https://doi.org/10.1007/978-981-19-8040-4_1

Wang, H. H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of PreCollege Engineering Education Research, 1*(2), 1–13. https://doi.org/10.5703/1288284314636

Weinhandl, R., Lavicza, Z., & Houghton, T. (2020). Mathematics and STEM teacher development for flipped education. *Journal of Research in Innovative Teaching & Learning, 13*(1), 3–25. https://doi.org/10.1108/JRIT-01-2020-0006

Williams, B. (2013). How I flipped my classroom. NNNC Conference, Norfolk, NE.

Yao, K. C., Li, K. Y., Xu, J. R., Ho, W. S., & Shen, Y. H. (2022). Application of TRIZ innovative system method in rapid assembly of folding chairs. *Sustainability, 14*(22), 15482. https://doi.org/10.3390/su142215482

Yıldırım, B. (2021). Preschool STEM activities: Preschool teachers' preparation and views. *Early Childhood Education Journal, 49*(2), 149–162. https://doi.org/10.1007/s10643-020-01056-2

Yıldırım, B. (2023). Preparation of preschool teachers during the COVID-19 pandemic: An online professional development program in STEM education. *Research in Science & Technological Education*. https://doi.org/10.1080/02635143.2023.2209855

Yıldırım, B., Akcan, A. T., & Öcal, E. (2022). Teachers' perceptions and STEM teaching activities: Online teacher professional development and employment. *Journal of Baltic Science Education, 21*(1), 84–107. https://doi.org/10.33225/jbse/22.21

Yoo, I., & Yi, C. G. (2022). Economic innovation caused by digital transformation and impact on social systems. *Sustainability, 14*(5), 2600. https://doi.org/10.3390/su14052600

Yorgancı, S. (2020). A flipped learning approach to improving students' learning performance in mathematics courses. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 14*(1), 348–371. https://doi.org/10.17522/balikesirnef.657197