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# An examination of the effect of technology-based STEM education training in the framework of technology acceptance model

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## Abstract
The aim of this study is threefold: (1) to present a valid and reliable scale in the framework of the Technology Acceptance Model; (2) to reveal factors affecting pre-service science teachers' intentions to use technology-based STEM; (3) to examine the effect of technology-based STEM education training on pre-service science teachers' perceived ease of use, perceived usefulness, attitude, and intention. This study has two sections. Study 1 defined the reliability and validity of the Technology Based-STEM Intention Scale (TB-STEMIS) in the framework of the Technology Acceptance Model (TAM) with pre-service science teachers in Turkey. Study 2 examined the pre-service science teachers' intentions to use technology-based STEM and the impact of technology-based STEM education training on pre-service science teachers' intentions concerning the TAM model. The results of the study revealed that the proposed model tested after STEM training is superior to the before STEM training. Findings also indicated that technology-based STEM education training had a positive effect on pre-service science teachers' perceived ease of use, perceived usefulness, attitude, and intention to use the technology-based STEM education. Finally, implications were discussed and recommendations were found for further studies in line with the limitations.

**Keywords** Technology Acceptance Model (TAM) · Technology-based STEM education · Pre-service science teachers

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## 1 Introduction

The emergence of diverse forms of technology allows the use of new technology in STEM (Science, Technology, Engineering, and Mathematics) education to transform positively learning and teaching methods (Bell, 2016; Ng & Park, 2021). The use of educational technologies in STEM education such as augmented reality (AR), coding, and simulations should be one of the significant issues for researchers for an effective STEM education (Wu & Anderson, 2015). Undoubtedly, technology facilitates the discovery of STEM topics and encourages students to connect different disciplinary opinions (Yang & Baldwin, 2020). Technology is a cognitive tool to improve students' critical thinking skills, communicate, collaborate, and solve authentic problems (Ertmer & Ottenbreit-Leftwich, 2012; Nelson & Hawk, 2020). With the help of technology, lifelong learning is possible as well as teaching deeper and faster. In addition, learning with technology can take place not only in the classroom, but wherever the student can fully concentrate on the learning process (Bell, 2016; Hobbs et al., 2018). Therefore, it is important to disseminate STEM education with the help of technology. However, studies have shown that the only existence of technologies will not guarantee the quality of education; rather the quality of education depends on how they are used in teaching and learning processes (Chauhan, 2017; Stegmann, 2020; Tamim et al., 2011).

The teacher is among the key players (e.g. students, curriculum) in effectively integrating technology into STEM learning-teaching processes. A meta-analysis, conducted by Scherer and Teo (2019), concluded that teachers mostly integrated educational technology to be focused on "*word processing, presentation, and information tools*" (p. 91) rather than on the supplying of authentic and active learning (Watson & Rockinson-Szapki, 2021). Some research findings also revealed that technology is insufficiently used by pre-service and novice teachers (Dawson, 2008; Kirschner & Selinger, 2003). Huang and Liaw (2005) stated that the level of technology comprehension is strongly depended on teachers' acceptance of the technology. Various recent studies revealed the significant influence of teachers' acceptance of the technology on their intention to use technology in their future classes (e.g. Gurer, 2021; Menabò et al., 2021; Sungur-Gül & Ateş, 2021; Yeo et al., 2022). In order to effectively use technology in educational settings, teachers' positive experiences with technology use and their intentions to use technology are vital (Baek et al., 2008; Sungur-Gül & Ateş, 2021). For this reason, it is necessary to start with pre-service teacher education to effectively apply STEM education using technology in classrooms (National Academies of Sciences, Engineering, and Medicine-NASEM, 2019). Thus, it is necessary to identify factors influencing pre-service teachers' intentions to use technology-based STEM education and the impact of technology-based STEM education training on these intentions to take actions purposing to be willing to use it in their future classes. The main reason for searching pre-service teachers' intentions to use technology-based STEM education is to better predict future technology-based STEM education use in teaching.

There are some studies examining pre-service teachers' STEM teaching intentions (e.g., Adams et al., 2014; Aydogan Yenmez et al., 2021; Karisan et al., 2019; Lin & Williams, 2016; Vlasopoulou et al., 2021), intentions to use a specific technology such as augmented reality, mobile apps (Ateş & Garzón, 2022a, b), and technology use intentions in teaching (e.g., Watson & Rockinson-Szapkiw, 2021). However, to the best of our knowledge, there is no study investigating PST' acceptance of technology-based STEM education and no study conducted the empirical impact of technology-based STEM education training on PST' intentions. In addition, there was no scale developed to measure the pre-service teachers' acceptance of technology-based STEM education in the framework of the Technology Acceptance Model (TAM). Therefore, current study aims to exhibit a valid and reliable Turkish version of the multiple-component scale to detect the factors influencing pre-service science teachers' (PST) intentions with TAM. Moreover, study aims is to predict PST' intentions to use technology-based STEM education and the effect of technology-based STEM education training on their intentions in the teaching process through the extension of the Technology Acceptance Model (TAM) (Davis, 1989) as a psychological based theoretical framework. According to earlier studies, TAM is efficient in determining individuals' acceptance and use of a particular technology (Hsu & Lin, 2022; Unal & Uzun, 2021). In these studies, participants' acceptance of mobile devices and the Edmodo app, an educational technology, was examined by incorporating some research-specific variables (e.g. psychological influence factors) in the extension of the TAM model. At the same time, TAM provides individuals to explain the ease and usefulness of behavior with their statements (Davis, 1989). In this study, TAM was chosen, since it is an accepted well established technology acceptance theory that is also preferred by researchers to estimate research variables in the acceptance of new technology, for example when using mobile applications (Al-Rahmi et al., 2022; Ateş & Garzón, 2022b), augmented reality (Ateş & Garzón, 2022a). A key reason for examining pre-service teachers' intentions to use technology is to better predict future technology use in teaching (Ateş & Garzón, 2022a; Venkatesh et al., 2003).

The current study attempted to fill gaps and expand current literature with the following contributions to existing work. First, better understand which psychologically based constructs explain PST' STEM teaching intention through technology, a Turkish version of the multiple-component scale was developed in the framework of TAM. Second, to understand the constructs of TAM including perceived usefulness (PU), perceived ease of use (PEOU), and attitude (ATT) and pre-service teachers' STEM teaching intention relationship better, this study also focused on testing a robust theoretical framework using innovative educational technologies including Mobile applications, Augmented reality, QR Code, 3D Modeling, Simulations, and Coding in STEM education. In line with the aim, the study investigated how such training changes the explanation variance on the intention variable and the relationship coefficients on the variables in the TAM model. Third, considering the importance of technology in STEM education, this study aimed to conduct an implementation process assessing the effect of technology-based STEM education on PST' PU, PEOU, ATT, and Behavioral Intention (BI).

In line with these aims, the following research questions were sought to examine in line with the main research objectives:

1. Is the Technology Based-STEM Intention Scale (TB-STEMIS) in the framework of TAM reliable and valid?
2. How well does the TAM model explain PST' intentions to use technology-based STEM education in their classes?
3. What is the impact of technology-based STEM education training on PST' intentions with regards to the TAM model?

## 2 Literature review and theoretical framework

### 2.1 Technology in STEM education

Covering the disciplines of science, technology, engineering, and mathematics, STEM is applied in educational settings by conducting different activities that enable students to ask questions, become persons who solve problems related to the real world, improve 21st-century skills, and make productive students (Adams et al., 2014), increase interdisciplinary understanding and also improve students' interest in STEM careers (Roehrig et al., 2012). Therefore, creating an appropriate STEM learning environment is important to enabling students to acquire STEM learning outcomes. However, designing such an environment is difficult because of removing the traditional boundaries of disciplines, the requirement for teachers to be proficient in all STEM disciplines, and students need to apply and learn simultaneously knowledge of all disciplines in solving a problem (Yang & Baldwin, 2020). Moreover, students may entirely focus on hands-on activities, namely constructing prototypes and designing activities, and thus they do not naturally make connections to relevant concepts from STEM disciplines (Penner et al., 1997).

Educators and researchers progressively emphasized the potential benefits of using educational technology to increase STEM learning outcomes with the rapid development of information and communication technologies (Wu & Anderson, 2015). Using immersive and interactive technologies (e.g., simulations, Augmented reality-AR) can promote the learning of STEM subjects, support for students to connect different disciplinary ideas, and also allow students to arrange mathematical and scientific ideas in a new path (e.g., constructing robots or creating content) (Yang & Baldwin, 2020). Moreover, the use of technology provides students and teachers to be ability to identify and solve larger problems (Beal & Cohen, 2012). It can be concluded that the efficient use of technology may facilitate to implementation of STEM education and its related innovative practices. In the current study, we used interactive educational technologies including mobile apps, augmented reality, QR codes, 3D modeling, simulation, and coding in STEM education. The relationship between each educational technology and STEM education is explained and why they are preferred is below.

Mobile learning provides access to learning and assessment tools anywhere and anytime (Criollo-C et al., 2018). Accordingly, many studies have reported that mobile learning can be used to reduce the challenges of STEM education (Almaiah et al., 2016; Criollo-C et al., 2018; Kong, 2018; Yeop et al., 2019). Mobile learning can offer subject content more engagingly for effective STEM learning and this motivates learners to spare their time for learning (Mutambara & Bayaga, 2020). Because of the potential benefits of mobile learning to STEM education, it is important to use mobile apps in STEM education.

Augmented reality is a 3D technology that combines the physical and virtual worlds in real time. Studies have emphasized that AR offers many educational affordances when used in STEM fields including conceptual understanding, scientific inquiry learning, spatial ability, and practical skills (Cheng & Tsai, 2013; Ibáñez & Delgado-Kloos, 2018; Sırakaya & Sırakaya, 2020; Wu et al., 2013). According to AR-STEM studies, various advantages such as increasing success, motivation and interest/willingness to learn, developing positive attitudes, and facilitating learning were identified by Sırakaya and Sırakaya (2020). These contributions in educational settings revealed that AR is an effective tool for STEM education. Thus, we preferred some AR technologies (Anatomy 4D, Space 4D, Quiver, Element 4D) for STEM training in the study.

QR (Quick Response) code is a two-dimensional type of matrix barcode that encodes information. Using QR codes in education provides many advantages such as being an alternative to the problem of location (Law & So, 2010), establishing the relationship between teacher, student, and technology (Aktaş & Çaycı, 2013). This is useful because of being fast, portable, and using Qr code can be used in non-school learning environments (Law & So, 2010). We used QR codes in STEM to create a digital presentation of the final product or summarize information in product design due to the above reasons in the study.

3D modeling is the process of developing a mathematical representation of the object through special software and the product that emerges at the end of this process is called a 3D model (Spallone, 2015). Studies are showing that the 3D design process develops students' spatial skills (Liao, 2017; Luh & Chen, 2013) and improve creativity (Chang, et al., 2016). Moreover, computer-aided 3D modeling technology offers the opportunity to create original designs for students (Benzer & Yildiz, 2019). With the widespread use of STEM and the Maker movement, 3D modeling tools have become important for product design. In this study, we used Tincercad which is an online 3D modeling program, a free web app, and easy to use.

In the STEM fields, it can be difficult for students to access real materials, however, simulations allow students to experience a scientific phenomenon (D'Angelo et al., 2014). Due to the potential contributions of the simulations, just as permitting people to examine a phenomenon at different physical scales and periods, many experts suggest that using simulations in the classroom can enhance student learning (NRC, 2011). Moreover, when the simulation is used, it has facilitated students to explore STEM topics and relate interdisciplinary ideas (Yang et al., 2020). In this study, the specific simulation technology used was the Algodoo software with 2D, free, and simple interface developed for physics concepts. The choice of Algodoo software is suitable for allowing students to design their simulations. Alan et al., (2021) also concluded that Algodoo is a good tool for integrating STEM disciplines according to PST' opinions. Similarly, Sungur Gül and Saylan Kırmızıgül (2022) found that although PST had some challenges using Algodoo, they were aware of the contributions of Algodoo simulations to STEM approach.

Coding is the computer language that benefits from a series of syntax rules or blocks for primary school students that informs a computer program to perform a set of functions (Miller, 2019). Educational coding may be mentioned through innovative methods in STEM education. Coding training develops 21st-century skills, especially computational thinking skills used for coding, and is critical for all STEM disciplines (Miller, 2019; Prinsley & Johnston, 2015). For this reason, we used the "Scratch" coding program, which is a blocks-based programming language developed by MIT in the study.

## 2.2 Technology acceptance model (TAM) variables

Technology Acceptance Model (TAM) is proposed to predict factors affecting individuals' behavioral intentions to use new information technology. TAM was developed by Davis (1989) and derived from Fishbein and Ajzen's (1975) Theory of Reasoned Action (TRA). TAM includes four variables as Perceived usefulness (PU), Perceived Ease of Use (PEOU), Attitude towards use (ATT), and Behavioral Intention (BI) to use technology (see Fig. 1). Two main constructs of the users' technology system adoption are PU and PEOU. PU refers to the extent to which an individual believes that using a particular system would improve his/her job performance, and PEOU refers to the extent to which an individual believes that using a special system would be free of effort (Davis, 1989). According to the original TAM, PU and PEOU directly affect the BI to use technology; furthermore, PU is directly impacted by PEOU. BI to use of technology is situated to be impacted by ATT toward using. Both PU and PEOU jointly impact ATT toward use (Davis, 1989).

Although the first version of the TAM attempted to understand individuals' computer use, over time, the use of the model for the computer field has evolved into different technologies. The model has easily adapted to various study contexts such as computer science information systems (e.g., Kimiagari & Baei, 2021), business (e.g., Cengiz & Bakırtaş, 2020), environmental sciences (e.g., Shin et al., 2022), management (e.g., Parikh et al., 2021), psychology (e.g., Sagheer et al., 2022), and educational research (e.g., Ateş & Garzón, 2022a). Among them, recently researchers have used the TAM framework in education-based studies such as mobile technology acceptance (e.g., Sungur-Gül & Ateş, 2021), augmented reality (e.g.,

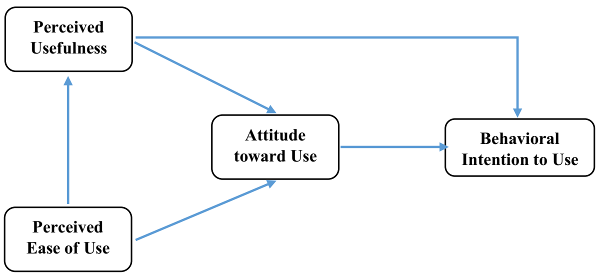


**Fig. 1** Technology acceptance model (TAM) (Davis, 1989)

Papakostas et al., 2022), iPad use (e.g., Do et al., 2022), digital learning platforms (e.g., Songkram & Osuwan, 2022), and adoption of CCtalk (e.g., Wang et al., 2022). Further, TAM is considered to be one of the most widely used theoretical frameworks in predicting and explaining teachers' intention to use technologies such as mobile learning (e.g., Ateş & Garzón, 2022b), augmented reality (e.g., Ibili et al., 2019), QR code (e.g., Lai et al., 2013), and 3D modeling (e.g., Ibili et al., 2019) and STEM teaching intentions (Aydogan Yenmez et al., 2021; Vlasopoulou et al., 2021). For example,in a study from Teo et al., (2017), a video stimulus containing innovative (making new models, the evolution of group projects in a wiki environment) and traditional technologies (teaching with ready-to-use presentations, teaching with ready-to-use models, knowledge testing with ready-to-use tests) was developed. The reason for this was explained as the perceived difficulties of teachers regarding the use of technology. In a recent study, Jang et al., (2021) examined the determinants of Korean teachers' intentions to use augmented reality and virtual reality for learning using the TAM model. The study revealed that, as expected, ATT had a significant influence on BI, and PEOU and PU had a significant influence on ATT. In another study, Ibili et al., (2019) confirmed the TAM model to examine mathematics teachers' level of acceptance and understand their intention to use the augmented reality geometry tutorial system. Among the studies examining STEM teaching intentions, in a study conducted by Vlasopoulou et al., (2021), the TAM was confirmed to understand in-service teachers' intentions regarding the integration of STEM education in primary schools in Greece. Based on above mention statements, this study tested TAM as a conceptual framework to understand PST' intentions to use technology-based STEM education, We also investigated the impact of technology-based STEM education training on PST' intentions with regards to the TAM model.

## 3 Method

We prepared this section as study 1 and study 2. TB-STEMIS was developed in the framework of TAM in study 1. Experimental research was conducted in study 2.

### 3.1 Study 1

#### 3.1.1 Sample and data collection

Data for this study were collected from universities in several cities in Turkey through a self-administered online survey with the help of Google Forms from October 2020 to January 2021. The sample of the study consisted of 159 undergraduate students (called also PST) studying in the department of science education, determined by using the convenience sampling method. In Turkey, the department of science education provides education to train science teachers who think, research, examine, are creative, scientifically literate, and can use modern education and teaching techniques. The curriculum of this department is prepared by the Turkish Council of Higher Education and the education period is four years. Graduates of this department teach basic information about physics, chemistry, and biology involved in science curriculum to middle school students. In the current science curriculum, technology is emphasized within the scope of science, engineering, and entrepreneurship practices. Moreover, it is stated that science must be associated with technology, engineering, and mathematics disciplines (Ministry of Education-MoNE, 2018). Of these participants, 136 (85.5%) were female, 23 (14.5%) were male and regarding grade levels, 42 (26.4%) were in their first year of teacher training, nine (5.7%) were in the second year of their education, 22 (13.8%) were studying in the third grade, 51 (32.1%) were in the fourth grade, only 4 (2.5%) were receiving education at the fifth or higher grade level. 31 (19.5%) postgraduate students who do not actively pursue their teaching profession and continue their master's and PhD education are also included in this research.104 (65.4%) pre-service teachers stated that they heard of the STEM concept earlier while participants' experience in STEM education (e.g. at national projects, undergraduate courses etc.) was limited (19.5%). National projects in which pre-service teachers participate are focused on the theoretical framework of STEM and designing STEM activities within the framework of the engineering design process, applied activities, robotic-coding, technology-enhanced STEM etc. Similarly, pre-service teachers stated that they were educated about the conceptual framework of STEM and prepared STEM activities in undergraduate courses such as Special Teaching Methods, Science Teaching, and Laboratory Training in Science Teaching. When we examine the Teacher Education Undergraduate Programs, it is seen that there is no direct course about technology-enhanced STEM or STEM, but there are courses such as Interdisciplinary Science Teaching, and Information Technologies (Turkish Council of Higher Education, 2018). Finally, 34% had experience in technology-based courses while participants' experience in technology-based STEM education (15.1%) was very limited.

#### 3.1.2 Data collection tool and data analysis

In order to develop the scale used in the current study, we adapted items from earlier validated instruments to the current study context (Ajzen, 2002, 2006; Davis, 1989; Davis et al., 1989; Nikou & Economides, 2017; Venkatesh, et al., 2003). Table 1 provides information from which studies the constructs and items were adapted to the current study. The initial scales and items were re-arranged with the help of experts' reviews working on the department of science education and information and communication technology (i.e., editing sentence structures and grammar, changing some words, etc.). Then, a pilot test was implemented to pre-service teachers to increase the clarity of items and test whether the scale items are suitable for the study. Based on the results of the pilot test which is a preliminary test of the final version, items were modified. The constructs and items were first prepared in English and then translated into Turkish by translation-back-translation method suggested by Esfandiar et al., (2019, 2020). The translation was made by two academics who have language competency in both Turkish and English and have who have knowledge of the literature on the subject of this study to ensure linguistic equivalence.

**Table 1** Constructs, items, factor loadings, and sources

| Construct and items | | Factor loading | Source |
|---|---|---|---|
| Attitude for use | | | |
| 1 | I think using technology based STEM education in science classes is interesting | 0.85 | Ajzen (2002, 2006) |
| 2 | I think using technology based STEM education in science classes is a good idea for students' achievements | 0.88 | |
| 3 | I think using technology based STEM education in science classes is important for effective learning | 0.92 | |
| 4 | I think using technology based STEM education in science classes is beneficial to arouse students' interests | 0.87 | |
| Perceived usefulness | | | |
| 1 | Using technology based STEM education would improve the quality of science lesson | 0.81 | Davis, 1989; Davis et al., 1989; Venkatesh et al., 2003 |
| 2 | Using technology based STEM education would improve my teaching performance | 0.86 | |
| 3 | Using technology based STEM education would enhance my effectiveness in the teaching science lesson | 0.87 | |
| 4 | Using technology based STEM education would make it easier to teach a science lesson | 0.88 | |
| 5 | I would find technology based STEM education useful to teach a science lesson | 0.84 | |
| Perceived ease of use | | | |
| 1 | Technology based STEM education is easy to use | 0.89 | Davis, 1989; Davis et al., 1989; Venkatesh et al., 2003 |
| 2 | It is easy for me to become skillful at using technology based STEM education | 0.91 | |
| 3 | It is easy to access information in technology based STEM education | 0.90 | |
| 4 | My interaction with technology based STEM education would be clear and understandable | 0.89 | |
| Behavioral Intention to Use | | | |

**Table 1** (continued)

| Construct and items | | Factor loading | Source |
|---|---|---|---|
| 1 | I intend to continue using technology based STEM education in the future | 0.85 | Ajzen, 2006; Davis, 1989; Nikou & Economides, 2017 |
| 2 | I will try to use technology based STEM education in my science lessons | 0.84 | |
| 3 | I plan to continue to use technology based STEM education | 0.81 | |

A final self-administered scale was composed of three parts. The first part includes the aim of the study, expectations from participants, ethical statements including ethical approval, statement of human rights, and statement of informed consent, and a description of educational technologies and STEM concepts. The second part of the scale was respondents' demographic information including gender, grade level, and STEM education background. The third part consisted of items and constructs (four items for ATT attitude for use), five items for PU, four items for PEOU), and three items for BI to use included in the TAM. To conclude, a total of 16 items and four constructs were measured on a five-point Likert-type scale, ranging from strongly disagree (1) to strongly agree (7).

Descriptive statistics analysis was conducted to evaluate the normality of data and sampling adequacy by using SPSS V.20. And then, we performed two phase SEM approach proposed by Anderson and Gerbing (1988) using maximum likelihood estimation in the study: Measurement model and structural model. During the testing of the measurement model, a confirmatory factor analysis (CFA) obtained in the current study was utilized to test reliability and validity among items and constructs. Then, the structural model was tested to evaluate the associations among constructs. The results are presented in Section 4.1.

## 3.2 Study 2

### 3.2.1 Research design

In this section of the study, the quantitative method was used with a one-group pretest–posttest design to determine the effect of the integration of technology-based STEM education on PST' intentions. The reason why the single-group pre-test and post-test design was used is that it is useful in the development and implementation of a new training module (Creswell, 2012). In this design, pre and post-tests were compared with each other based on several same scales to determine whether technology-based STEM education is effective.

### 3.2.2 Participants

The participants of the study were determined using convenience sampling from volunteered 37 PST who were educated in the fourth grade at the faculty of education in the autumn semester of 2020–2021 in Turkey. It is important to support PST in terms of utilizing new technologies in STEM education (Ng & Park, 2021), offering their students a learning environment based on STEM, and using technology more effectively (NASEM, 2019). Among the participants, 78.4% (29) were female, and 21.6% (8) were male. A great majority of them (83.8%) stated that although they heard of the concept of STEM, 73% of the participants didn't take any STEM course (e.g., at national projects, undergraduate courses, etc.) and almost half of the participants (48.6%) had not a course on the using of technological applications previously. Further, their experience with technology based STEM education was very limited (16.2%).

#### 3.2.3 Data collection tool

In study 2, we used TB-STEMIS, whose reliability and validity were studied using CFA in study 1. Cronbach's alpha reliability coefficient of the scale was found as 0.929. The reliability values of each construct ranged 0.864 from to 0.894.

#### 3.2.4 Experimental process

An intervention was implemented to examine the impact of technology-based STEM activities on the Technology Acceptance Model (TAM) on PST. All the implementation process was carried out by researchers working as faculty members in the science education department of universities. During the process, the participants received credits determined by the Turkish higher education institution and no extra time was set. All the experimental process was conducted in accordance with ethical principles determined by the declaration of Helsinki (The World Medical Association, 2018) and the American Psychological Association (2017).

The researchers prepared a course content related to technology-based STEM education for participants who take course 'Special Teaching Methods-II' conducted by the first researcher. The course includes the following subjects: Teaching strategies and practices commonly used in science teaching; (scientific process, engineering, and design skills, inquiry-based teaching strategy, argumentation, concept cartoons, predict-observe-explain, and learning cycle (5E and 7E); problem-based teaching method, project-based teaching method, case-based teaching method, role-playing, drama, context (life) based learning in science teaching, etc.); preparing and implementing a lesson plan based on the use of teaching methods and techniques; examination of science teacher competencies, and current teaching approaches in science teaching (Turkish Council of Higher Education, 2018). The reason for choosing this course is that it is the most appropriate course for integrating educational technologies and STEM education in the teacher education undergraduate program and allowing to integration of content-specific methods and techniques with content knowledge.

The study group consisted of 37 PST divided into several heterogeneous groups. Thus, PST experienced technology-based STEM education through collaborative study groups for 14 weeks. Table 2 contains detailed information about the course content. The researchers consulted the opinions of two experts from science and STEM education in terms of criteria such as being suitable for STEM education, widespread use, suitable for the content of the course, and low cost, and thus they decided on the educational technologies and apps given in Table 2.

PST were informed the about the implementation of the technology-based STEM course contents and what is expected from them in the first week. In particular, they were asked to attend the course with a mobile device or laptop required by the app/program every week and to prepare a STEM lesson plan in the 5E teaching model as suggested by researchers (Bybee, 1997; Ünlü & Dökme, 2022) according to that week's topic. The groups experienced teaching performance in a real classroom environment, and after the lesson process was completed, the other groups were expected to prepare a STEM activity plan for that week's subject (apps/program) to be delivered the

**Table 2** Course contents

| Weeks | Used educational technologies | Used applications/technological programs | Apps/grade level/unit/activity name in PST' STEM lesson plan |
|---|---|---|---|
| 1 | Introducing Course and Syllabus | – | – |
| 2 | Introducing STEM education | – | – |
| 3–4 | Mobile applications and STEM | Anatomy 4D, Space 4D, Plickers, Sky map, etc | Space 4D/7th grade/ The Solar System and Beyond: Space studies/Space exploration vehicle |
| 5 | Augmented reality and STEM | Anatomy 4D, Space 4D, Quiver, Element 4D, SkyView® Lite, etc | SkyView® Lite/7th grade/ The Solar System and Beyond: Celestial Bodies/ Street lamp |
| 6 | QR codes and STEM | Web page: "Qr code generator" Application: "Qr code reader" | Qr code generator/ 7th grade Domestic Waste and Recycling/ Recycle bin |
| 7–8 | 3D Modelling and STEM | Web page: "Bilgeiş", Course: "Introduction to 3D modelling", Program: Tinkercad | Tinkercad/8$^{th}$ grade/Pressure/Removing tables with Pascal principle |
| 9–10 | Simulations and STEM | Algodoo | Algodoo/6th grade/Matter and heat: intensity/Submarine design |
| 11–14 | Coding and STEM | Scratch | Scratch/The Solar System and Beyond: Space studies/7th grade/Space pollution cleanup vehicle |

following week. Then, participants were asked to fill in the PEOU, PU, ATT, and BI questionnaires as a technology based STEM education pre-test. STEM education was deeply and theoretically explained in the second week with the active participation of the participants.

Mobile learning methods in STEM education, mobile tools, and various mobile apps were introduced, and some apps (Anatomy 4D, Space 4D, Plickers, Sky map, etc.) were experienced by PST in the third week. A group of PST showed the spacecraft from the Space 4D app and implemented a Space exploration vehicle activity as if they are in a real classroom environment in the fourth week.

The relationship between STEM education and augmented reality were theoretically established with the active participation of the participants in the fifth week. In addition, some apps/technological programs were introduced to the participants and they experienced in using them with the support of the instructor. Then, a group of PST introduced SkyView® Lite app to examine the stars in a daytime and night and presented a STEM activity that prevents light pollution.

In the 6th week, the relationship between QR codes and STEM education was discussed and sample apps were shown to PST. They experienced a QR code generator app and a group of PST prepared a recycling bin activity that contains QR codes. Thus, PST performed a STEM teaching process to their colleagues using QR codes.

The theoretical framework of 3D modeling in STEM was mentioned to the PST and the pre-service teachers learned the use of the Tinkercad program, which is an effective app in 3D modeling, from the corporate website called "Bilgeiş", by experiencing the "Introduction to 3D modeling" courses in the seventh week. Then, they designed sample practices for the use of the Tinkercad program in STEM. In the eighth week, a group of PST designed an activity called "Removing tables with pascal principle" in the Tincercad program with the focus on the Pressure subject.

In the ninth week, the theoretical framework and importance of using simulations in STEM education were mentioned, and Algodoo, a current program in the use of simulation, was introduced to them. PST gained knowledge and skills about the use of Algodoo by preparing simulations for the contents of STEM education. In the tenth week, a group of PST used the Algodoo program to design a submarine.

Between 11 and 13 weeks, the importance of coding in STEM education and how it should be were discussed with pre-service teachers. Scratch, an app where individuals from all age groups can easily produce projects in coding, was introduced and a detailed education was provided for its use. Finally, in the 14th week, a group of PST designed a Space pollution cleanup vehicle in the Scratch app, focusing on The Solar system and beyond: Space studies unit.

Some examples of technology-based STEM activities of PST are presented in Fig. 2. Finally, the PST were asked to complete post-tests again to identify a possible change in their PU, PEOU, ATT, and BI.

### 3.3 Data analysis

Firstly, testing the goodness of fit of the structured model, model comparison, and path analysis were conducted in the second phase of SEM proposed by Anderson

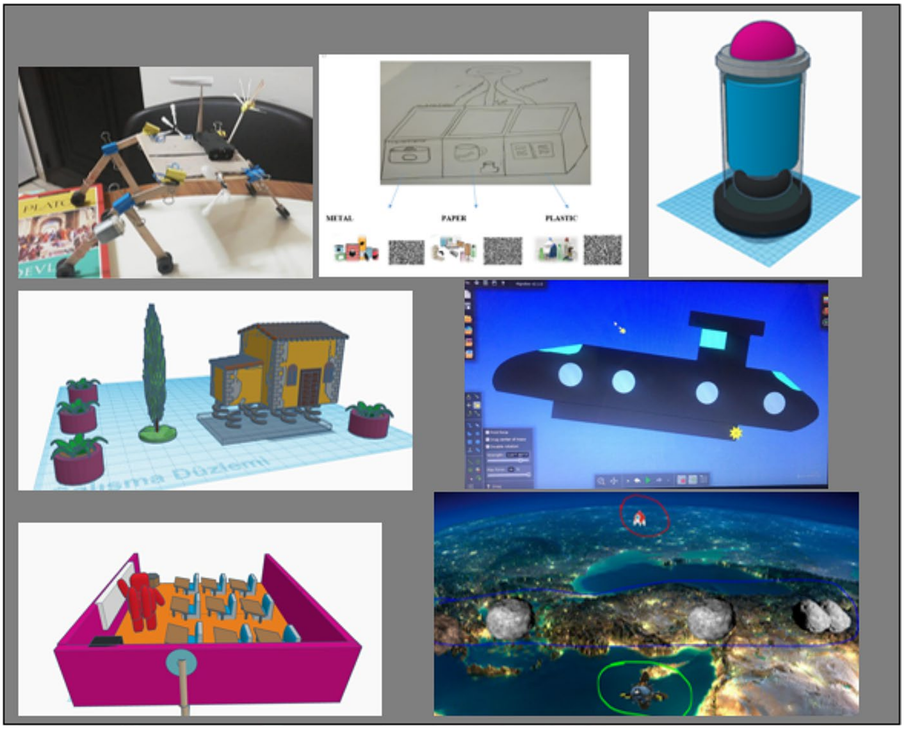


**Fig. 2** Some examples of technology based STEM activities

and Gerbing (1988) with AMOS. Secondly, reliability analysis, descriptive statistics including mean and standard deviation, and inferential analyzes including t-test were performed with SPSS. Finally, the paired sample t-test was conducted to analyze the effect of technology-based STEM education on PST' intentions to use technology based STEM education.

## 4 Findings

The findings include the results of study 1 and study 2. Firstly, the reliability and validity of the TB-STEMIS were tested by using CFA. Then, model comparison and path analysis based on the TAM model were conducted to evaluate the effectiveness of the technology-based STEM training. Finally, the impact of the experimental process on PST' ATT, PU, PEOU, and BI were examined using paired sample t-test.

### 4.1 Testing reliability and validity of the scale

So as to evaluate the reliability and validity of the TB-STEMIS, CFA was conducted using a maximum likelihood estimation method (Anderson & Gerbing, 1988). In this process, as seen in Table 3, the validity (convergent and discriminant validity) and reliability (Cronbach Alpha and composite reliability) of the constructs were examined (Fornell & Larcker, 1981). According to the results of the goodness-of-fit statistics showed an adequate fit to the data ($\chi 2 = 1614.241$, $df = 588$, $\chi^2/\mathrm{df} < 0.001$, Comparative Fit Index [CFI] = 0.92, Incremental Fit Index [IFI] = 0.92, Tucker-Lewis Index [TLI] = 0.91, Normed Fit Index [NFI] = 0.91, Root Mean Square Error of Approximation [RMSEA] = 0.06). All the factor loadings and the average variance extracted (AVE) exceeded 0.50 and the coefficient alpha was greater than the recommended value of 0.70 (Hair et al., 2017; Kline, 2015). The values of composite reliability were between 0.87 and 0.94 which were more than the suggested value of 0.60 (Bagozzi & Yi, 1988). Finally, all of the AVE values were above the square of correlations between constructs as Fornell and Larcker (1981) suggested. These findings showed that both reliability and validity are provided.

### 4.2 Model comparison

In the current study, there were two different model testing processes. The TAM model was tested before and after STEM training. The Structural Equation Modeling (SEM) was performed to evaluate the proposed models at two different times. The structural conceptual model adequately fits the data in the STEM education context before ($\chi 2 = 402.312$, df = 161, $p < 0.001$, GFI = 0.91, CFI = 0.931, IFI = 0.930, TLI = 0.922, IFI = NFI = 0.90, [SRMR = 0.058, RMSEA = 0.055) and after STEM implications ($\chi 2 = 402.213$, df = 169, $p < 0.001$, $\chi 2$ /df = 2.613, GFI = 0.93, CFI = 0.943, IFI = 0.939, TLI = 0.938, IFI = NFI = 0.092, [SRMR = 0.051, RMSEA = 0.050). The findings of the study showed that the proposed model tested after STEM training ($\chi 2$ /df = 2.38) is superior to the before STEM training ($\chi 2$ /df = 2.50). Further, the conceptual model after STEM training ($R^2 = 0.62$) had greater power in predicting PST' intentions to use technology-based STEM education in their classes than before the STEM training ($R^2 = 0.49$). These results imply that interventions involving STEM based educational technologies including mobile applications, augmented reality, QR codes, 3D modeling, simulations, and coding is more effective in explaining PST' intentions to use technology-based STEM education in their classes than before the intervention process.

**Table 3** Results related to the measurement model

| Constructs | 1 | 2 | 3 | 4 | α | AVE | $\sqrt{AVE}$ | CR |
|---|---|---|---|---|---|---|---|---|
| 1. ATT | – | | | | 0.88 | 0.78 | 0.88 | 0.93 |
| 2. PU | 0.808 | – | | | 0.87 | 0.73 | 0.85 | 0.93 |
| 3. PEOU | 0.467 | 0.511 | – | | 0.86 | 0.81 | 0.90 | 0.94 |
| 4. INT | 0.534 | 0.647 | 0.549 | – | 0.85 | 0.69 | 0.83 | 0.87 |
| Mean | 4.45 | 4.44 | 3.80 | 4.18 | – | – | – | – |
| SD | 0.66 | 0.62 | 0.70 | 0.78 | – | – | – | – |

*ATT* Attitude, *PU* Perceived Usefulness, *PEOU* Perceived Ease of Use, *INT* Intention, *α* Cronbach's Alpha, *AVE* Average Variance Extracted, *CR* Composite Reliability, *SD* Standard Deviation

### 4.3 Path analysis

Path analysis was performed to test the role of constructs of the TAM model on PST' intentions to use technology-based STEM education in their classes. SEM results revealed that variables of the model were significantly related to intentions to use technology-based STEM education in both time intervals. In particular, importance of high ATT ($\beta_{before\ experiment}=0.27$, $\beta_{after\ experiment}=0.39$, $p<0.01$) and PU ($\beta_{before\ experiment}=0.29$, $\beta_{after\ experiment}=0.42$, $p<0.01$) significantly strengthen PST' BI to use technology-based STEM education. In addition, PEOU ($\beta_{before\ experiment}=0.31$, $\beta_{after\ experiment}=0.43$, $p<0.01$), and PU ($\beta_{before\ experiment}=0.33$, $\beta_{after\ experiment}=0.44$, $p<0.01$) had a significant direct effect on ATT. The hypothesized association between PEOU and PU was significant ($\beta_{before\ experiment}=0.23$, $\beta_{after\ experiment}=0.30$, $p<0.01$). Finally, considering explanation power, PEOU and PU explained 41% and 46% of the variance in ATT before and after the experiment, respectively. In addition, 21% of the total variance in PU was accounted for by PEOU before the experimental process, while the ratio was found as 29% when the implementation process was completed. Lastly, 42% of the variance in BI was explained by PU and ATT, while this explanation was found as 49% after the implementations. The findings obtained from the structural model are indicated in Fig. 3 and Table 4.

### 4.4 Experimental results

One of the purposes of the current study was to examine the effectiveness of technology-based STEM education in improving PST' PEOU, PU, ATT, and INT. The mean values and standard deviations (SD) of the pre-test ratings were 3.88 and 0.67 for the PEOU, 4.52 and 0.56 for the PU, 4.51 and 0.70 for the ATT, and 4.29 and 0.66 for the BI. Regarding post-test results, mean values and standard deviations were found as 4.25 and 0.72 for the PEOU, 4.79 and 0.65 for the PU, 4.72 and 0.62 for ATT, and 4.61 and 0.88 for the BI. In addition, a paired-samples t-test was performed to examine the effect of technology-based STEM education on the constructs involved in the proposed model. There was a statistically important increase in scores from pre-test to post-test for four constructs including PEOU ($t(36)=0.58$, $p=0.029$), PU ($t(36)=0.46$, $p=0.036$), attitude ($t(36)=0.54$, $p=0.041$), and BI ($t(36)=0.70$, $p=0.020$). These results suggest that the PST' PEOU, PU, ATT, and BI in the postquestionnaire were significantly above than their prequestionnaire ratings, indicating that the technology-based STEM approach seems to have positively affected the acceptance of technology based STEM activities by them. Overall, this study experimentally shows that when an intervention was made on the constructs in the TAM model, it changed the relationship between the constructs and intention as well as the explained variance on intention. Tables 5 and 6 present the results of descriptive statistics and the paired-sample t-test.

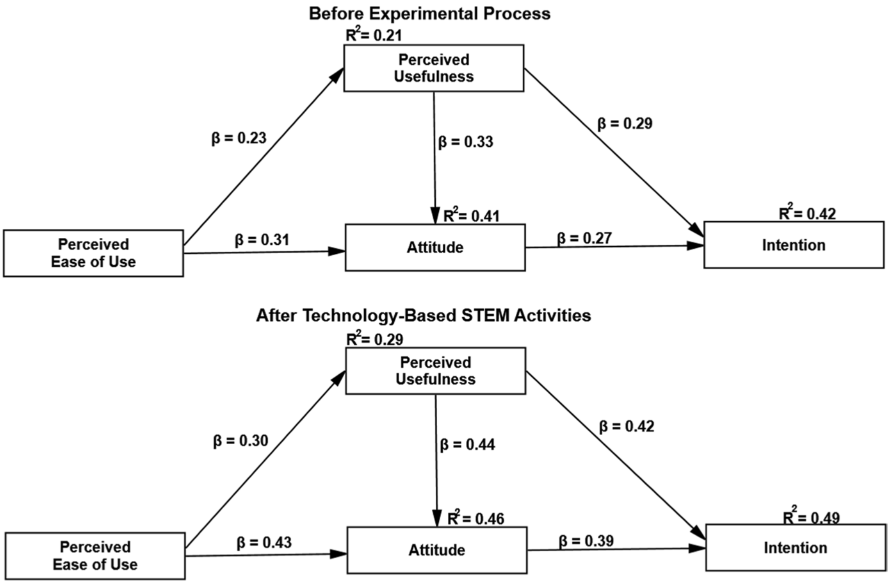


**Fig. 3** The structural model results

**Table 4** SEM results of the structural model assessment

| Pathway | No experimental interventions | | Technology-based STEM course contents | |
|---|---|---|---|---|
| | Path coefficient (β) | t-value | Path coefficient (β) | t-value |
| *PEOU → PU* | 0.23 | 5.59 | 0.30 | 6.66 |
| *PEOU → ATT* | 0.31 | 7.42 | 0.43 | 10.12 |
| *PU → ATT* | 0.33 | 7.77 | 0.44 | 10.39 |
| *PU → INT* | 0.29 | 7.01 | 0.42 | 9.78 |
| *ATT → INT* | 0.27 | 6.33 | 0.39 | 8.83 |

**Table 5** Descriptive statistics for pre and post test scores toward perceived ease of use, perceived usefulness, attitude, and intention

| Construct | Pre-test | | Post-test | |
|---|---|---|---|---|
| | Mean | Standard deviation | Mean | Standard deviation |
| Perceived Ease of Use | 3.88 | 0.67 | 4.25 | 0.72 |
| Perceived Usefulness | 4.52 | 0.56 | 4.79 | 0.65 |
| Attitude | 4.51 | 0.70 | 4.72 | 0.62 |
| Intention | 4.29 | 0.66 | 4.61 | 0.88 |

**Table 6** The paired sample t-test result of learning attitude

| Pairs and constructs | | t | p |
|---|---|---|---|
| Pair 1 | Pre-Test (PEOU) – Post-Test (PEOU) | 0.58 | 0.029 |
| Pair 2 | Pre-Test (PU) – Post-Test (PU) | 0.46 | 0.036 |
| Pair 3 | Pre-Test (ATT) – Post-Test (ATT) | 0.54 | 0.041 |
| Pair 4 | Pre-Test (BI) – Post-Test (BI) | 0.70 | 0.020 |

## 5 Discussion

In this paper, researchers wanted to carry out the reliability and validity of the Technology Based-STEM Intention Scale (TB-STEMIS). In addition, the study examined the TAM model to explain PST' intentions to use technology-based STEM education in their classes. Furthermore, the study investigated the impact of technology-based STEM education training on PST' PEOU, PU, ATT, and BI. Many previous studies investigated PST' intention to use technology (e.g., Ateş & Garzón, 2022b; Baydas & Goktas, 2017; Gurer, 2021; Scherer & Teo, 2019). However, no study empirically examine pre-service teachers' intentions for technology-based STEM education. The study presented three important results.

First, the results emerged that the TB-STEMIS indicates a high internal consistency. A four-factor structures including PEOU, PU, ATT, and BI was confirmed. Correlations between the four dimensions were found as expected. In conclusion, the TB-STEMIS is a valid and reliable scale measuring PST' intentions to use technology-based STEM education in their future classes. In the past studies, the validity of the TAM model has been tested with many current technologies such as augmented reality, 3D modeling, and iPad use (Akçayır et al., 2016; Do et al., 2022; Ibili et al., 2019).

Second, the study aimed to examine how the TAM model explains PST' intentions to use technology-based STEM education in future classes. According to the results of the SEM analysis conducted to test the proposed models at two different times, the structural conceptual model well provided a goodness-of-fit to the collected data. This finding is consistent with past research on different kinds of technologies, for several samples (Edmunds et al., 2012; Teo et al., 2015; Teo & Milutinovic, 2015). All fit values revealed that the proposed model tested after STEM training is higher than before STEM training. This mean when PST consider technology-based STEM education as useful and easy to use, they are more positive towards using it, and these positive feelings toward the use of technology-based STEM education foster to adopt it. Moreover, the model after STEM training was more capable of explaining more than half of the variance ($R^2=0.62$), exhibiting a bigger explained variance than in former reports (Eksail & Afari, 2020; Teo et al., 2012), than before STEM training ($R^2=0.49$) concerning PST' intentions to use technology-based STEM education in future classes. In other words, technology (e.g. mobile applications, 3D modeling, simulations) enhanced STEM training is more powerful in explaining PST' intentions to use technology-based STEM education in their classes than before the intervention process. Although the explanation variance is not low at the beginning, the increase after the training is remarkable. This result means that, a training about the use of these technologies in STEM education is necessary in order to positively affect their intentions. The results of the path analysis showed that variables of the TAM model were significant in affecting PST' intentions to use technology-based STEM education in their classes before and after the experiment. It is important to note that, all values obtained after the experiment had stronger effects than before the experiment. In detailed, PST' intentions to use technology-based STEM education were significantly impacted by ATT and PU which is similar to previous research findings (Teo et al., 2012; Yuen & Ma, 2008). PU had the most powerful effect on the BI in agreement with the literature (Buchanan et al., 2013; Teo & Noyes, 2014). This finding indicates that PST' PU of technology to support the learning-teaching process determines their intention to use it (Baydas & Goktas, 2017; Scherer & Teo, 2019). For these reasons, although there was no direct relationship between PU and BI (Davis, 1986), it seems that this relationship is necessary (Lee et al., 2003). The results also showed that PEOU and PU were directly associated with ATT as in past studies (Ateş & Garzón, 2022b; Jang et al., 2021; Teo & Milutinovic, 2015). This conclusion means that when pre-service teachers perceive technology to be free of effort or useful, they have a positive attitude toward computer use. PEOU significantly influenced PU which is consistent with previous research (Joo et al., 2018; Papakostas et al., 2022; Wang et al., 2022). That is, if PST believes that technology-based STEM education will be free of effort, they can also believe that technology-based STEM education will enhance their performance. In terms of explanation power, ATT towards use was explained by PEOU and PU with a 41% and 46% before and after the experiment, respectively. In addition, PEOU explained 21% of the variance in PU before, the explanation accounted for 29% after the experiment. Finally, PU and ATT accounted for 42% of the variance in BI, while the ratio was computed as 49% after the implementations. In both measures, we can see that the largest variances occurred for the PU and ATT in explaining the BI as stated in the study conducted by Scherer and Teo (2019).

Third, the current study explored the impact of technology-based STEM education on increasing PST' PEOU, PU, ATT, and BI. The data analysis revealed that there were positive findings in the development of the PST' PEOU, PU, ATT, and BI to use technology-based STEM education. A raise in the post-test mean scores of these variables was found in the study. Moreover, the results of the paired-samples t-test indicated a statistically significant difference among the pre-test and post-test for all variables involving PEOU, PU, ATT, and BI. The researchers interpret this conclusion in the fact that technology-based STEM education training presented the opportunity for PST to use various technological programs/apps practically and to benefit from them in the planning of STEM projects and lessons. The ease of use of these programs provides a positive attitude toward technology-based STEM education. Thus, this situation allows us to evaluation the effectiveness of such programs in STEM education and the intention to use them, this is consistent with the studies (Al-Hariri & Al-Hattami, 2017; Guzey et al., 2014; Incedayi, 2018). Unlike these findings, Teo et al., (2017) found that pre-service teachers' intention to use technology to teach mathematics in a traditional method was critically higher than their intention to use technology to teach mathematics in an innovative method.

Consequently, a valid and reliable scale was obtained to verify the technology-based STEM education intentions of PST in the TAM framework. The results of the study revealed that the proposed model tested after STEM training is superior to the before STEM training. Findings also indicated that technology-based STEM education training had a positive effect on PST' PEOU, PU, ATT, and BI use technology-based STEM education. The results obtained from the research are extremely important for curriculum developers, education politicians, teacher educators, researchers, and in-service and pre-service teachers. In this direction, besides the experimental research, this research showed which psychological factors are effective in the technology acceptance of pre-service teachers. Interventions on these psychological variables are effective in their behavior and technology acceptance. The study showed that PU, PEOU, and ATT variables play an important role in determining the intentions of PST to use technology-based STEM education in the future. For this reason, teacher educators and curriculum developers must pay attention to the critical role of these constructs on PST. Activities might be organized to help PST appreciate the possibilities that will facilitate the use of educational technologies for STEM education in the courses and moreover, courses related to STEM and educational technologies might be added to the program.

## 6 Limitations and recommendations for future research

Although the results of the current study had theoretically and practically many contributions to the literature, there were some limitations as follows. First, we examined four constructs in the TAM, namely PEOU, PU, ATT, and BI. Future studies could extend the TAM with other variables such as external variables (e.g. technological complexity, facilitating conditions), and also demographic characteristics (e.g. gender). Second, since the research was restricted to only PST from different universities in Turkey, our study did not provide evidence on the generalizability of the findings. This situation may lead to misinterpretation and decrease external validity, and thus may induce sample bias. Third, data were collected with the use of a self-reported scale which might lead participants to overestimate their real views. Hence, collecting qualitative data to provide a detailed perspective into the findings is suggested. Fourth, pre-service teachers were trained in STEM education enriched with some technologies such as mobile applications, augmented reality, QR codes, 3D Modeling, simulations, and coding. Future studies could focus on different types of technology in STEM education. Finally, due to the small sample size, a one-group pre-test post-test experimental design was preferred instead of the control group experimental design.

## 7 Conclusion

While pre-service teachers' technology use intentions and STEM teaching intentions are previously examined topics, the underlying variables that urge teachers to teach STEM disciplines while using some technologies including mobile apps, augmented reality, QR code, 3D modeling, simulations, and coding are insufficiently documented. In this study, we successfully developed a reliable and valid Turkish version of a multiple-component scale consisting of four constructs: PEOU, PU, ATT, and BI. The study also revealed that constructs of the TAM had a positive influence on PST' intentions to use technology-based STEM education. Our findings inform that PST' intentions to use technology during STEM education are built through their beliefs (i.e., using technology in STEM education is free of effort and enhance their teaching performance) and positive or negative evaluations when they use the technology in STEM education. Further, the current study is the first to reveal the relative importance of the experimental process (14 weeks) aimed to understand how well technology-based STEM course content including mobile apps, augmented reality, QR code, 3D modeling, simulations, and coding influences on pre-service teachers' PEOU, PU, ATT, and BI. This empirical research shows that in addition to testing the theoretical model proposed by the TAM model, the technology-based educational activities to be implemented to strengthen PEOU, PU, and ATT of PST will have a positive effect on their STEM teaching intentions. Building on the existing literature in educational technology and STEM education, our study enriches researchers' and practitioners' understanding of PST' STEM teaching intentions to implement effective technology-based education processes.

**Data availability** The datasets are available from the corresponding author on reasonable request.

## Declarations

**Conflict of interest** No conflict of interest has been declared by the authors.

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