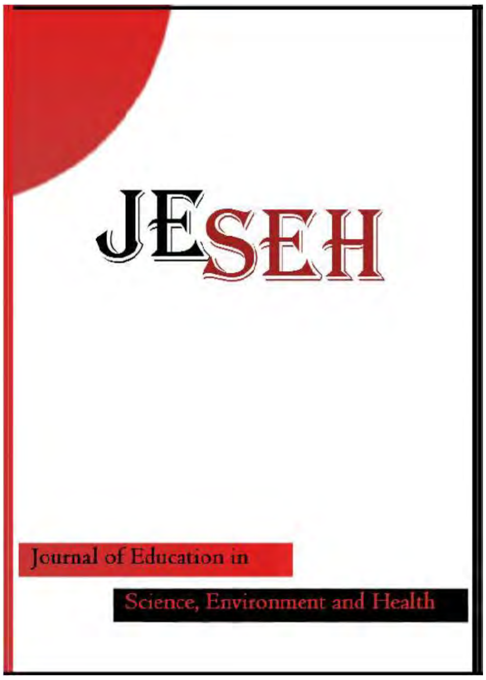

ISSN: 2149-214X

Journal of Education in Science, Environment and Health

www.jeseh.net

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To cite this article:

Kartal, T., Kiziltepe, I. S., & Kartal, B. (2022). Extending technology acceptance model with scientific epistemological and science teaching efficacy beliefs: A study with preservice teachers. *Journal of Education in Science, Environment and Health (JESEH), 8*(1), 1-16. https://doi.org/10.21891/jeseh.1055590

Journal of Education in Science, Environment and Health
Volume 8, Issue 1, 2022 https://doi.org/10.21891/jeseh.1055590

Extending Technology Acceptance Model with Scientific Epistemological and Science Teaching Efficacy Beliefs: A Study with Preservice Teachers

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Article Info

Article History

Published:
01 January 2022

Received:
07 March 2021

Accepted:
18 October 2021

Keywords

Technology acceptance model
Science teaching efficacy beliefs
Epistemological beliefs
Preservice teachers

Abstract

The technology acceptance model (TAM) is a widely used framework to investigate factors influencing technology use in education. TAM refers to a person's technology-related attitudes and beliefs influencing intention to use and actual use of technology and seeks predictors of behaviors whether to accept or reject using technology. There are various external variables extended to TAM to increase the predictivity of the model and the generalizability of findings. However, what is not yet clear is the impact of teacher-related variables such as teaching efficacy and epistemological beliefs on teachers' technology acceptance and behavioral intention. This study examined 710 preservice teachers' technology acceptance using an extended-TAM with scientific epistemological and science teaching efficacy beliefs. Data were collected through a self-reported measurement tool. Structural equation modeling was used to analyze data. Results revealed that the research model explained 59% of the variance in behavioral intention, and perceived usefulness is the most prominent determinant of behavioral intention. The subdimension of scientific epistemological beliefs, justification, is the strongest determinant in influencing TAM constructs among the external variables (epistemological and science teaching efficacy beliefs). Science teaching efficacy beliefs had small effects on technology acceptance constructs. Recommendations were made based on the findings.

Introduction

Technology has fast become a key instrument in teaching and learning as it has the potential of improving knowledge acquisition and transfer (Eksail & Afari, 2020). Incorporating new technologies in teaching and learning is a continuing concern within educational research (Granić & Marangunić, 2019; Teo et al., 2015). Teachers are the agents of effective technology integration (Siyam, 2019; Teo, 2009; Wong et al., 2012). Therefore, many researchers are interested in factors influencing teachers' technology use (Akar, 2019; Scherer, Siddiq, & Tondeur, 2019). Perceptions of technology integration, beliefs regarding teaching and learning, and efficacy beliefs are examples of the factors influencing teachers' technology use in education (Siyam, 2019). Teachers' decision to use technology in their teaching is closely related to their technology acceptance, which refers to the teachers' willingness to use technologies to accomplish their teaching-related tasks (Akar, 2019; Avcı Yucel & Gulbahar, 2013).

Among the frameworks investigating users' technology acceptance, the most commonly used is Technology Acceptance Model (TAM). The factors determining the success or failure of technology integration have been studied by many researchers using TAM (Avcı Yucel & Gulbahar, 2013; Scherer et al., 2019). TAM refers to a person's technology-related attitudes and beliefs influencing intention to use and actual use of technology (Davis, 1985) and seeks predictors of behaviors whether to accept or reject using technology (Granić & Marangunić, 2019). Among the studies regarding TAM, education studies exist extensively (Avcı Yucel & Gulbahar, 2013; Granić & Marangunić, 2019).

A large body of TAM studies has investigated preservice teachers' technology acceptance (Bardakcı & Alkan, 2019; Teo et al., 2015; Wong et al., 2012). These studies focused on different technologies such as mobile applications (Al-Azawei, & Alowayr, 2020; Bano et al., 2018), interactive whiteboards (Bardakcı & Alkan, 2019). However, various samples and contexts might lead to diverse findings regarding the relations among the constructs (Scherer & Teo, 2019). It is essential to consider several external variables to understand better the factors influencing technology acceptance (Avcı Yucel & Gulbahar, 2013). There are various external variables extended to TAM to increase the predictivity of the model and generalizability of findings, such as TPACK (Bardakcı & Alkan, 2019), individual innovativeness (Akar, 2019), and teacher efficacy (Joo et al., 2018). It is suggested to replicate TAM studies with different modeling approaches and larger samples (Scherer et al., 2019). What is not yet clear is the impact of teacher-related variables such as teaching efficacy and epistemological beliefs on teachers' technology acceptance and behavioral intention.

Turkey is among the countries that conducted large national projects to incorporate digital technologies into teaching and learning processes (Bardakcı & Alkan, 2019), and the project of Movement of Enhancing Opportunities and Improving Technology, called FATIH was developed in 2010. FATIH project aims to ensure equality in terms of technological resources among students all around the country. To achieve the project goals, most schools and classrooms have been re-designed to increase the availability of technological resources through interactive whiteboards, internet access, tablets, and specific portals. Keeping up with the developing technologies is considered a competence for the teaching profession in Turkey (Akar, 2019). Therefore, teachers' technology acceptance is crucial within the context of the Turkish teacher education programs to avoid wasting these investments. Considering the importance of adding various external variables to TAM, we investigated the impact of science teaching efficacy beliefs and scientific epistemological beliefs on 710 preservice teachers' technology acceptance. Therefore, this study is supposed to make a major contribution to research on TAM by demonstrating the effect of external variables that were not examined previously in TAM studies.

Theoretical Framework

Technology Acceptance Model

Since the inclusion of technology in business and education, the reasons for accepting or rejecting technology have sparked the attraction of researchers growingly (Granić & Marangunić, 2019). TAM is the most commonly used model to explain teachers' intention to use technology in education by examining users' beliefs and attitudes because of its simplicity and understandability (Eksail & Afari, 2020; Scherer et al., 2019; Siyam, 2019). TAM adopts the idea that individuals tend to use new technology if they believe it would improve their performance and be free of effort (Akar, 2019). Recent review studies concluded that TAM is a relevant model in examining factors influencing technology use (Granić & Marangunić, 2019; Scherer et al., 2019).

Davis (1989) adapted TAM from the Theory of Reasoned Action developed by Fishbein and Ajzen (1975) to investigate the determinants influencing behavioral intention that leads to actual usage. TAM deals with the relationship between attitude, intention, and behavior. The main factors determining the level of acceptance of technology are perceived ease of use (PEU) and perceived usefulness (PU) (Granić & Marangunić, 2019; Wong et al., 2012; Scherer et al., 2019). TAM posits that PEU and PU significantly influence attitude toward using (ATU) and, in turn, behavioral intention (BI). The relations between PEU, PU, and ATU and the predictive role of PU and ATU on BI are the particular concerns of the original TAM (Siyam, 2019). Figure 1 presents the constructs and relationships among these constructs in TAM.

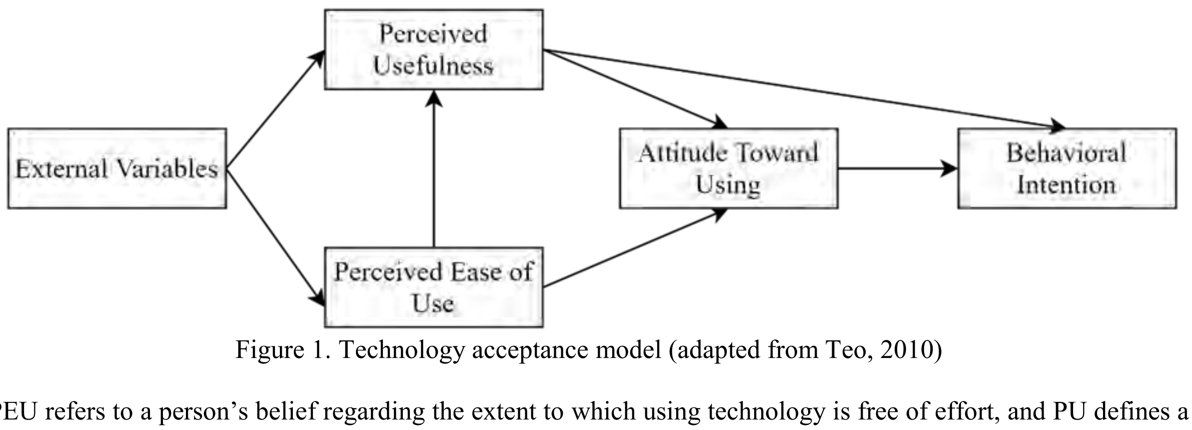

Figure 1. Technology acceptance model (adapted from Teo, 2010)

PEU refers to a person's belief regarding the extent to which using technology is free of effort, and PU defines a person's belief regarding the degree to which using technology would improve the person's performance (Avcı Yucel & Gulbahar, 2013). PEU also proposes that regarding technology as easy to use and believing in their ability to manage technology make people use technology (Teo et al., 2015). PEU significantly impacts PU, and both have influences on ATU. In other words, a person with positive attitudes toward using technology also perceives that using technology is effortless and improves her/his performance. PU was found to be the most significant determinant in a review study by Avcı Yucel and Gulbahar (2013). Similarly, most research concluded that PU had the strongest effect on BI (Akar, 2019; Granić & Marangunić, 2019). Besides, Bardakcı and Alkan (2019) proposed that believing the impact of interactive whiteboards on teaching performance promoted preservice teachers' intentions to use, consistent with given findings.

Attitude toward using technology consists of feelings about technology use (Eksail & Afari, 2020; Kartal, 2019) and determines how teachers respond to technologies and the extent to which technology integration would be successful (Teo et al., 2015). TAM adapts the idea that attitude is the major determinant in accepting or rejecting technology (Davis, 1989) and is influenced by PEU and PU. BI influenced by PU and ATU is closely related to teachers' intrinsic motivations to use technology (Anderson, Groulx, & Maninger, 2011; Kartal, 2019) and the actual use of technology (Teo, 2010; Teo et al., 2015). Researchers attempted to achieve higher percentages of explained variance in BI as the behavioral intention is a key instrument to predict actual technology usage behavior in preservice teachers' future classrooms.

Science Teaching Efficacy Beliefs

Bandura (1977) regarded self-efficacy as a belief in a person's capability for performing a specific task. According to Bandura (1977), if a person feels confident in performing a specific task and believes in the favorable result, he/she feels efficacious in performing the given task. Teaching efficacy is a teacher's belief regarding his/her capacity to promote student learning (Gagnier, Holochwost, & Fisher, 2021). Gibson and Dembo (1984) mentioned two distinct dimensions of teaching efficacy based on Bandura's social cognitive theory: self-efficacy beliefs and outcome expectations. The former is teacher confidence in own teaching abilities. The latter assumes that effective teaching influences student learning.

Teachers with a high level of science teaching efficacy are supposed to be open and willing to innovations, new teaching methods, and new ideas such as using instructional technologies (Blonder et al., 2013; Gagnier et al., 2021; Kartal & Dilek, 2021; Woolfolk-Hoy & Spero, 2005). Teachers' efficacy levels determine the effort they put on and the time they spent to achieve their teaching-related goals (Tschannen-Moran & Woolfolk-Hoy, 2001). Teaching efficacy beliefs impact teachers' in-class behaviors and teaching methods. Teachers with high teaching efficacy might be resistant to deal with challenges in the classroom and insist on promoting all students' learning (Ekici, 2016; Kartal, 2020). To achieve these teaching objectives, teachers' use of technology has undoubtedly great benefits. Therefore, it is supposed that teachers with high science teaching efficacy beliefs are supposed to tend to use technology in their teaching.

The implementation and success of reforms promoting technology use are influenced by teacher beliefs (Gagnier et al., 2021; Kartal & Çınar, 2018). Blonder and colleagues (2013) reported that opportunities to develop teaching efficacy promoted teachers' tendency to use new technologies. Teachers improving their science education with technologies also promote students' learning motivation (Al-Azawei & Alowayr, 2020; Huang et al., 2020), collaborative learning (Kartal & Dilek, 2021), and cognitive gains (Becker et al., 2020). Some teachers might consider technology an essential component in effective science teaching. Kartal and Dilek (2021) found that a technology-supported teaching method course and microteaching promoted preservice teachers' science teaching efficacy beliefs. Similarly, preservice teachers reported that using technology promoted students' learning, and technology was a crucial constituent of effective science teaching (Min et al., 2020).

Scientific Epistemological Beliefs

Epistemological beliefs are beliefs about knowledge and knowing (Conley et al., 2004; Hofer & Pintrich, 1997). Beliefs about knowledge consist of the source of knowledge and justification for knowing. On the other hand, beliefs about knowing include certainty and simplicity of knowledge (Lee et al., 2021). Strong epistemological beliefs might be considered sophisticated as well as weak beliefs might be considered naïve. Someone who perceives himself/herself as being able to think and act like a scientist has sophisticated beliefs, and someone who believes scientists constructed nearly all almost of actual knowledge has naïve beliefs (Demirbag & Bahcivan, 2021; Kızıltepe & Kartal, 2021).

Epistemological beliefs are related to teaching and learning beliefs (Bahcivan, 2014; Cheng et al., 2009; Deng et al., 2014; Kızıltepe & Kartal, 2021). Sophisticated beliefs that assume knowledge evolves in nature with constructions by self or anyone are more likely to lead teachers to teach in a constructivist way (Deng et al., 2014). Teachers' epistemological beliefs have a crucial role in teaching effectiveness (Bondy et al., 2007) and teaching-related behaviors (Schommer-Aikins, 2004). Besides, research also showed the interrelatedness of epistemological beliefs with digital literacy (Demirbag & Bahcivan, 2021; Güneş & Bahçivan, 2018), attitude toward computer use (Teo, 2008), and type of technology use such as traditional or constructivist (Deng et al., 2014). Nevertheless, it is still underresearched the effect of epistemological beliefs on technology acceptance.

Literature Review

This section highlights the preservice teachers' technology acceptance studies, mainly focusing on their external variables. Avcı Yucel and Gulbahar (2013) reviewed TAM studies based on variables used in the study, working areas, measurement items, and results. They found that PU was the most effective variable, followed by PEU. A vast majority of research investigated the structural relationships between TAM constructs and technological complexity, social norms, computer self-efficacy, and facilitation conditions (Baydas & Goktas, 2017; Huang & Teo, 2019; Aypay et al., 2012; Kabakçı-Yurdakul et al., 2014; Lee et al., 2010; Teo, 2009). Granić and Marangunić (2019) addressed the gap of incorporating new external variables into the TAM and studying with larger samples in their review study.

Different from the mentioned studies, Wong and colleagues (2012) explored the effect of computer teaching efficacy and gender on student teachers' technology acceptance and concluded that computer teaching efficacy was the strongest determinant of ATU. Joo and colleagues (2018) added teacher efficacy as an external variable to TAM. Siyam (2019) extended TAM by adding job relevance, time, self-efficacy, and access to technology as external variables to investigate special education teachers' technology acceptance. Individual innovativeness and the social norm were the external variables in the study of Akar (2019), regarding primary and secondary teachers' technology acceptance. Bardakcı and Alkan (2019) investigated student teachers' intentions to use interactive whiteboards, investigating the effect of traditional and constructive teaching beliefs, individual innovativeness, pedagogical, technological, and technological pedagogical knowledge, interactive whiteboard self-efficacy, and effort and performance expectancy. The result revealed that performance expectancy is the one variable that significantly influences respondents' intention to use interactive whiteboards.

Teacher beliefs and attitudes play a major role in determining the extent to which technology would be used in education, with a more significant influence on technology use than first-order barriers such as access and availability (Kartal, 2019; 2020; Siyam, 2019). Teachers' pedagogical beliefs are amongst the most frequently investigated teacher beliefs in TAM (Gurer & Akkaya, 2021; Gyamfi, 2016; Huang & Teo, 2021; Li et al., 2019; Teo & Zhou, 2017; Teo et al., 2008). To our knowledge, the external variables in this study, scientific epistemological beliefs and science teaching efficacy beliefs, are not investigated in a TAM study.

Research Model and Hypotheses

Understanding student teachers' technology acceptance is crucial as their level of acceptance would provide insight into the effective and efficient use of technology in future classrooms (Wong et al., 2012). It is essential to test various research models to increase the predictive validity of TAM in educational settings (Parkman, Litz, & Gromik, 2018; Siyam, 2019). Examining the effect of external variables is crucial since the patterns in the impacts of teacher-related factors might promote the design of teacher preparation programs (Siyam, 2019). Most of the research highlighted the structural relationships among the external variables and PEU and PU (Gurer & Akkaya, 2021; Gyamfi, 2016; Siyam, 2019; Wong et al., 2012), but the direct effects of external variables on BI are still underresearched.

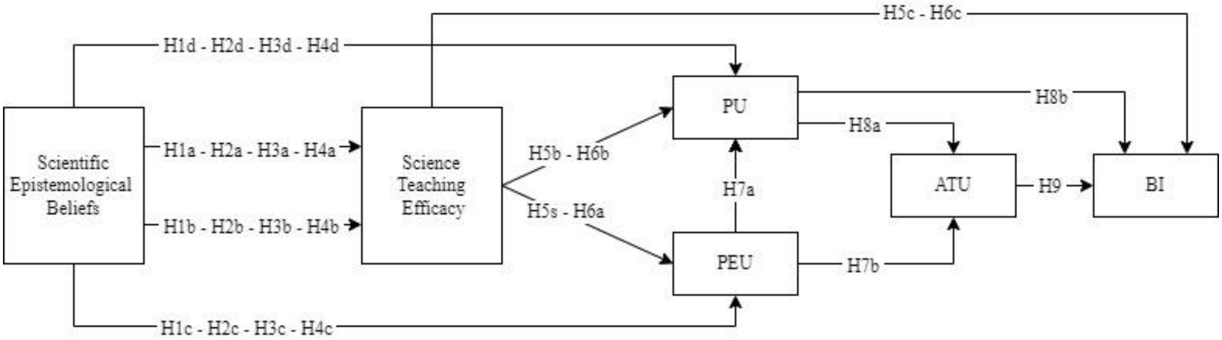

Figure 2. The research model

To reveal the chain of the influence of external variables on BI, researchers need to incorporate various external variables into TAM (Joo et al., 2018; Huang & Teo, 2021; Sang, Valcke, Van Braak, & Tondeur, 2010). We incorporated two interrelated constructs to reveal preservice teachers' technology acceptance: scientific epistemological beliefs and science teaching efficacy beliefs. Therefore, this study makes a major contribution to research on TAM by demonstrating the effect of scientific epistemological and science teaching efficacy beliefs on preservice teachers' technology acceptance. Figure 2 represents the hypothesized research model.

The hypotheses generated based on the literature review are as follows:

H1a: Source will significantly influence personal science teaching efficacy.
H1b: Source will significantly influence science teaching outcome expectancy.
H1c: Source will significantly influence PEU.
H1d: Source will significantly influence PU.
H2a: Certainty will significantly influence personal science teaching efficacy.
H2b: Certainty will significantly influence science teaching outcome expectancy.
H2c: Certainty will significantly influence PEU.
H2d: Certainty will significantly influence PU.
H3a: Justification will significantly influence personal science teaching efficacy.
H3b: Justification will significantly influence science teaching outcome expectancy.
H3c: Justification will significantly influence PEU.
H3d: Justification will significantly influence PU.
H4a: Development will significantly influence personal science teaching efficacy.
H4b: Development will significantly influence science teaching outcome expectancy.
H4c: Development will significantly influence PEU.
H4d: Development will significantly influence PU.
H5a: Personal science teaching efficacy beliefs will significantly influence PEU.
H5b: Personal science teaching efficacy beliefs will significantly influence PU.
H5c: Personal science teaching efficacy beliefs will significantly influence BI.
H6a: Science teaching outcome expectancy beliefs will significantly influence PEU.
H6b: Science teaching outcome expectancy beliefs will significantly influence PU.
H6c: Science teaching outcome expectancy beliefs will significantly influence BI.
H7a: PEU will significantly influence PU.
H7b: PEU will significantly influence ATU.
H8a: PU will significantly influence ATU.
H8b: PU will significantly influence BI.
H9: ATU will significantly influence BI.

Method

Research Design

This study uses a structural equation modeling (SEM) to reveal the structural relationships between preservice teachers' scientific epistemological beliefs, science teaching efficacy beliefs, and technology acceptance. SEM allows researchers to see the extent to which data is consistent with the hypothesized model, employing a simultaneous analysis of the entire system of the variables (Byrne, 2016). This study tested an extended-TAM, including preservice teachers' science teaching efficacy beliefs and epistemological beliefs as external variables, through model fit indices, path analysis, and hypothesis testing.

Participants

The participants were 710 preservice teachers whose major programs were science, elementary, and early childhood teaching. One of the external variables was science teaching efficacy beliefs; therefore, we invited preservice teachers trained for science teaching in their teacher preparation programs and supposed to teach science when they begin teaching. The respondents were informed about the purpose of the study and their rights to withdraw from the administration whenever they wished. The instrument was administered to 738 preservice teachers, and 710 of them were entirely completed. The return rate was 96%, demonstrating a higher rate than the suggested rate range of 70%-80% by Cresswell (2015) to make valid interpretations. Table 1 demostrates that just over half of the sample (56.2%) was fourth-grade, and over three-quarters of the sample

(83.8%) was female. In terms of technical proficiency and opportunity, more than half of the respondents reported that they used technology daily, and almost 90% of them perceived their competency either at the intermediate level (56.3%) or at the advanced level (31.4%).

Table 1. Demographic information of participants

Variable	Number	%
Grade level		
3.Grade	311	43.8
4.Grade	399	56.2
Gender		
Female	595	83.8
Male	115	16.2
Major programs		
Science Education	333	46.9
Elementary Education	182	25.6
Early Childhood Education	195	27.5
Computer ownership		
Yes	495	69.7
No	215	30.3
Hours of computer usage		
Less than an hour a day	210	29.6
1-3 hours a day	120	16.9
More than three hours a day	75	10.6
Less than an hour a week	118	16.6
1-3 hours per week	134	18.9
More than three hours a week	53	7.5
Computer competency		
Basic level	54	7.6
Intermediate level	400	56.3
Advanced level	223	31.4
Proficient	33	4.6
Age	M=21.997 (SD=1.734)	

Instruments

A survey questionnaire was distributed to respondents in a paper-pencil environment, and it took approximately 30 minutes for respondents to complete the instrument. Participants were asked to provide demographic information and rate their level of agreement to statements on the ten constructs in the research model; personal science teaching efficacy (PSTE), science teaching outcome expectancy (STOE), source, certainty, development, justification, perceived ease of use (PEU), perceived usefulness (PU), attitude toward using (ATU), and behavioral intention (BI). The instrument has three sections in addition to the demographic information, which are (i) Science Teaching Efficacy Beliefs Instrument (STEBI-B), (ii) Scientific Epistemological Beliefs Scale (SEBs), and (iii) Technology Acceptance Scale.

STEB-I was developed by Enochs and Riggs in 1990 and adapted into Turkish by Tekkaya, Cakiroglu, and Ozkan in 2004. The instrument has two factors, namely PSTE and STOE, with 13 and 10 items, respectively. On the other hand, Conley and colleagues (2004) developed SEBs in 2004, and Bahcivan (2014) adapted the scale into Turkish. The scale has four factors; source (5 items), certainty (6 items), development (6 items), and justification (9 items). The high scores obtained from these scales demonstrate that respondents have a high level of science teaching efficacy beliefs and sophisticated epistemological beliefs.

Lastly, the technology acceptance scale was designed to measure the following fundamental TAM constructs; PEU, PU, ATU, and BI. Most of the items were derived from the study of Ursavaş and colleagues (2014), which has adapted items into Turkish. It may be challenging for studies to result in similar findings related to intention to use technology as the target behavior might have overly broad definitions. Ajzen (2006) proposed that it would be better to identify the behavior at an appropriate level of specificity because individuals focus on these specific definitions, and more valuable results would be yielded. Besides, Sang and colleagues (2010) argued that measuring constructs such as BI by two items might hinder understanding the constructs clearly. Therefore, we added items to the PU, ATU, and BI from the existing research (Sang et al., 2010; Teo, 2009). The added items were prepared by using appropriate translation-back-translation procedures. All statements were measured on a 5-point Likert scale, ranging from “strongly disagree” (1) to “strongly agree” (5). The reliability coefficients were calculated for this study with the obtained data. Table 2 includes the sample items, number of items, sources of the items, and the reliability coefficients for each factor.

Table 2. Number of items, sample items, and Cronbach’s alpha for each construct

Variables	Items	Sample item
PSTE (α=.868)	13	I will continually find better ways to teach science.
STOE(α=.779)	10	The teacher is generally responsible for the achievement of students in science.
Source(α=.841)	5	Only scientists know for sure what is true in science.
Certainty(α=.834)	6	Scientists always agree about what is true in science.
Development(α=.794)	6	New discoveries can change what scientists think is true.
Justification(α=.849)	9	A good way to know if something is true is to do an experiment.
Perceived usefulness(α=.831)	7	Using computers will increase my productivity.
Perceived ease of use(α=.768)	3	I find computers easy to use.
Attitudes towards using(α=.795)	8	I like using computers.
Behavioral intention(α=.875)	10	I plan to use computers in the future.

Data Analysis

Data were examined in terms of missing data and outliers before data analysis, and the negatively-worded items were reverse-coded. Descriptive data were generated for all variables, including mean, standard deviation, and minimum and maximum scores. Normality was ensured by checking to what extent the skewness and kurtosis values are in the recommended range (|3| and |10|, respectively). The next step was to assess convergent and discriminant validity and the goodness of the model fit. Lastly, SEM was carried out using AMOS, version 21, to test the hypotheses in the research model. Path coefficients, direct, indirect, and total effects were investigated.

Results and Discussion

This section comprised the descriptive statistics, convergent and discriminant validity of data, path analysis, and hypothesis testing.

Descriptive Statistics

The means, minimum and maximum values, standard deviations, and skewness and kurtosis values were generated for all variables to confirm the normal distribution (Table 3). The mean scores were above the midpoint of 3.00, ranging from 3.46 to 4.03 in all factors. The standard deviations ranged between .478-.708, indicating a narrow spread around the mean.

Table 3. Descriptive statistics, skewness, and kurtosis values for all constructs

	N	Min	Max	Mean	Std. Deviation	Skewness	Kurtosis
Source	710	1.40	5.00	3.74	.686	-.422	.076
Certainty	710	1.00	5.00	3.58	.708	-.475	.162
Development	710	1.17	5.00	3.90	.573	-.721	1.184
Justification	710	1.22	5.00	4.03	.573	-1.071	1.243
PSTE	710	2.00	5.00	3.65	.569	.061	-.486
STOE	710	1.80	5.00	3.46	.478	-,125	.673
PEU	710	1.67	5.00	3.67	.667	-.165	.073
PU	710	2.00	5.00	3.84	.556	-.378	.511
ATU	710	2.00	5.00	3.71	.587	-.013	-.159
BI	710	1.10	5.00	3.86	.553	-.529	1.089

The descriptive statistics imply that respondents had sophisticated epistemological beliefs and a high level of science teaching efficacy beliefs. Besides, they reported positive perceptions regarding the ease of use and usefulness of technology, positive attitudes towards and responses to using technology in education. The skewness (ranging from |.013| to |1.071|) and kurtosis (ranging from |.073| to |1.243|) values were within the recommended value range (|3| and |10|, respectively) by Kline (2011). The results demonstrated that the normality of data was confirmed.

Convergent validity

There is three procedures to assess convergent validity: (1) item reliability, (2) composite reliability index (CRI), and (3) the average variance extracted (AVE) (Fornell & Larcker, 1981). Convergent validity deals with the extent to which different items measure the same construct. Item reliability is associated with the factor loadings, and it is recommended that the correlations between observed and latent variables (factor loadings) be .50 and above (Hair et al., 2019; Kline, 2011). The factor loadings of items ranged between .50-.82, indicating the reliability of items (Table 4). The composite reliability index should be .70 and above to be adequate, and Table 4 demonstrates that all values are above the threshold. The benchmark for AVE to be acceptable is .50 and above. It is worth noting that the adequate levels of CRI might be adequate for convergent validity if AVE values are not within the recommended range (Fornell & Larcker, 1981). It was found that a few of the AVE values were higher than the benchmark of .50. As anticipated by Fornell and Larcker (1981), the factor loadings and CRI values confirm the convergent validity of the research model.

Table 4. Results of convergent validity for the measurement model

Latent Variable	No. of items	Range of the factor loadings	CRI	AVE	Cronbach's α
Source	5	.56-.74	.78	.44	.84
Certainty	6	.53-.66	.77	.39	.83
Development	6	.52-.74	.78	.37	.79
Justification	9	.51-.71	.84	.37	.85
PSTE	13	.58-.82	.93	.51	.87
STOE	10	.53-.64	.81	.30	.78
PEU	3	.56-.69	.67	.40	.77
PU	7	.62-.76	.88	.51	.83
ATU	8	.52-.76	.85	.54	.80
BI	10	.51-.66	.85	.56	.88

Note. $CR=(\sum\lambda)^2/(((\sum\lambda)^2+(\sum(1-\lambda^2)))$
Note. $AVE= (\sum\lambda^2)/(\sum\lambda^2+\sum(1-\lambda^2))$

Discriminant validity

Kline (2011) stated that "a set of variables presumed to measure different constructs show discriminant validity if their intercorrelations are not too high" (p.72.). The intercorrelations ranged between .022-.728, smaller than the benchmark of .90 (Kline, 2011). To assess discriminant validity, the square root of the average variance extracted of each construct is compared to inter-construct correlations of the given construct. The evidence of the discriminant validity is that the square roots of the average variance extracted of the constructs are higher than the intercorrelation coefficients between the given construct and other constructs (Fornell & Larcker, 1981; Kline, 2011). The bold diagonal elements are the square roots of the AVEs, and it is seen that the diagonal elements (the square roots of the AVEs) are higher than the off-diagonal elements (inter-construct correlations), confirming the discriminant validity of the research model for further analysis.

Table 5. Intercorrelation matrix

		1	2	3	4	5	6	7	8	9	10
1. Source	r	**.660**									
2. Certainty	r	.607**	**.624**								
3.Development	r	.226**	.267**	**.608**							
4.Justification	r	.252**	.308**	.593**	**.608**						
5.PSTE	r	.296**	.311**	.320**	.451**	**.714**					
6. STOE	r	.022	.085*	.325**	.359**	.330**	**.547**				
7. PEU	r	.060	.030	.232**	.270**	.214**	.144**	**.632**			
8. PU	r	.196**	.216**	.421**	.523**	.396**	.336**	.387**	**.714**		
9. ATU	r	.204**	.212**	.387**	.436**	.395**	.297**	.372**	.703*	**.734**	
10. BI	r	.120**	.146**	.412**	.467**	.329**	.258**	.425**	.710*	.728**	**.748**

*p<.05, **p<.01

Model fit

The fit between the research model and obtained data were assessed before examining the structural model, employing a maximum likelihood estimation procedure in AMOS, version 21. The most commonly used indices to evaluate the goodness-of-fit were the ratio of the minimum fit function to its degree of freedom (χ^2/df), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Standardized Root Mean Residual (SRMR), and Root Mean Square Error of Approximation (RMSEA). The desirable values of acceptable fit for these indices are lower than 5.0 for χ^2/df, greater than .90 for CFI and TLI, and less than .08 for SRMR and RMSEA, respectively. The results of the research model (χ^2/df= 3.187, CFI=.935, TLI=.907, RMSEA=.056, and SRMR=.734) indicate that the measurement model satisfied that recommended thresholds and has an acceptable level of fit (Hair et al., 2019; Kline, 2011).

Hypothesis testing and path analysis

Twenty-seven hypotheses were generated, and 15 of them were supported. Table 6 reveals the path coefficients between constructs and the results of the hypothesis testing. Preservice teachers' beliefs regarding that the source of knowledge is not always authority significantly influenced personal science teaching efficacy beliefs (β=.163, p<.01). The sophisticated epistemological beliefs assuming that there is more than one answer (certainty) had a positive influence on PSTE (β=.180, p<.001). Additionally, the justification dimension has positive influences on PSTE (β=.377, p<.001), STOE (β=.417, p<.001), PEU (β=.4117, p<.05) and PU (β=.252, p<.001). Lastly, there is a significant positive relationship between the development dimension and STOE (β=.232, p<.001).

Table 6. Hypothesis testing results

Hypotheses	Path	Path coefficient	Results
H1a	Source→PSTE	.163**	Supported
H1b	Source→STOE	-.077	Not supported
H1c	Source→PEU	.067	Not supported
H1d	Source→PU	.022	Not supported
H2a	Certainty→PSTE	.180***	Supported
H2b	Certainty→STOE	-.004	Not supported
H2c	Certainty→PEU	-.085	Not supported
H2d	Certainty→PU	.027	Not supported
H3a	Justification→PSTE	.377***	Supported
H3b	Justification→STOE	.417***	Supported
H3c	Justification→PEU	.117*	Supported
H3d	Justification→PU	.252***	Supported
H4a	Development→PSTE	-.038	Not supported
H4b	Development→STOE	.232***	Supported
H4c	Development→PEU	.083	Not supported
H4d	Development→PU	.022	Not supported
H5a	PSTE→PEU	.083	Not supported
H5b	PSTE→PU	.102*	Supported
H5c	PSTE→BI	-.136**	Supported
H6a	STOE→PEU	.104	Not supported
H6b	STOE→PU	.235***	Supported
H6c	STOE→BI	.033	Not supported
H7a	PEU→PU	.234***	Supported
H7b	PEU→ATU	.426***	Supported
H8a	PU→ATU	.651***	Supported
H8b	PU→BI	.670***	Supported
H9	ATU→BI	.361***	Supported

*p<.05, **p<.01, ***p<.001

There were significant relationships between PSTE and PU (β=.102, p<.05). Interestingly, the significant relationship between PSTE and BI was negative (β=-.136, p<.05). Hypotheses testing revealed that STOE significantly influenced PU (β=.235, p<.001). TAM hypotheses were also supported with medium to large effects.

Figure 3 provides the relationships among the latent variables and the explained total variance in each endogenous variable. As Figure 3 shows, STOE and ATU were significant positive predictors of BI. The research model accounts for approximately 59% of the variance in BI, indicating a high level of explained variance. The predictors significantly determined PSTE, STOE, PEU, PU, and ATU by the percentages of 29%, 35%, 9%, 40%, and 46%, respectively.

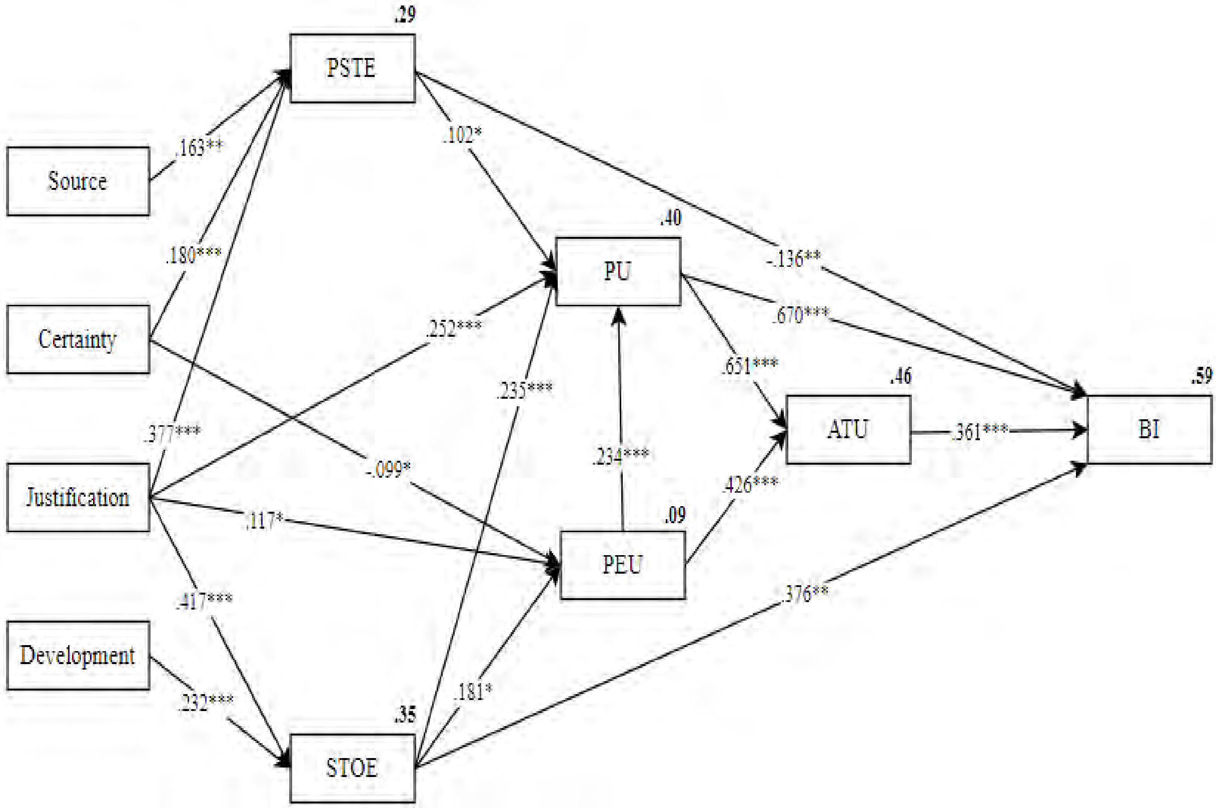

Figure 3. The results of the structural model

Table 7 presents the results of the direct, indirect, and total effects on each endogenous variable. The benchmarks proposed by Cohen (1988) (<.1 as small, <.3 as medium, and <.5 as large) were used in evaluating the size of the effect of a determinant on an outcome. The strongest determinant of BI is PU, with a total effect size of .898, and PEU follows PU with a total effect size of .363, which is entirely an indirect effect. Justification is also the most prominent determinant of BI among the external variables to TAM. The nine determinants in the research model accounted for approximately 59% of the variance in BI.

Similarly, the determinants explained 46% of the variance of ATU. The most vital determinant of ATU was PU, with a total effect size of .632, which is a large effect. PEU and justification were the other strong determinants of ATU, with total effect sizes of .574 and .355, respectively. Lastly, justification was also the strongest determinant of PU and PEU, with total effect sizes of .433 and .192, respectively. The justification was the most dominant determinant of TAM constructs among the variables external to TAM.

Conclusion and Discussion

The present study was designed to test an extended TAM including scientific epistemological beliefs and science teaching efficacy beliefs as external variables. After ensuring the convergent and discriminant validity of the measurement tools, the goodness of the model fit was assessed, and the model-fit analysis has shown that the research model has an acceptable level of fit to the obtained data. Respondents had the highest mean score in the justification dimension and the lowest mean score in science teaching outcome expectancy beliefs. The mean scores in each dimension were above the midpoint of 3, indicating that respondents had sophisticated epistemological beliefs, high levels of science teaching efficacy, positive perceptions regarding the use of technology in education.

Table 7. Direct, indirect, and total effects of the model

Outcome	Determinant	Standard estimates		
		Direct effect	Indirect effect	Total effect
PSTE (R^2=.29)	Source	.163	-	.163
	Certainty	.180	-	.180
	Justification	.377	-	.377
	Development	-.038	-	-.038
STOE (R^2=.35)	Source	-.077	-	-.077
	Certainty	-.004	-	-.004
	Justification	.417	-	.417
	Development	.232	-	.232
PEU (R^2=.09)	Source	.067	.005	.072
	Certainty	-.085	.015	-.070
	Justification	.117	.075	.192
	Development	.083	.021	.104
	PSTE	.083	-	.083
	STOE	.104	-	.104
PU (R^2=.40)	Source	.022	.015	.037
	Certainty	.027	.001	.028
	Justification	.252	.181	.433
	Development	.022	.075	.097
	PSTE	.102	.019	.121
	STOE	.235	.024	.259
	PEU	.234	-	.234
ATU (R^2=.46)	Source	-	.054	.054
	Certainty	-	-.012	-.012
	Justification	-	.355	.355
	Development	-	.105	.105
	PSTE	-	.112	.112
	STOE	-	.208	.208
	PEU	.426	.148	.574
	PU	.632	-	.632
BI (R^2=.59)	Source	-	.020	.020
	Certainty	-	-.010	-.010
	Justification	-	.381	.381
	Development	-	.116	.116
	PSTE	-.136	.121	-.015
	STOE	.033	.248	.281
	PEU	-	.363	.363
	PU	.670	.228	.898
	ATU	.361	-	.361

The structural model consisted of 27 hypotheses, and the results of the path analysis showed that data supported 15 of them. Path analysis demonstrated that beliefs about the source and certainty of the knowledge were significantly related to PSTE. The justification dimension significantly influenced PSTE, STOE, PEU, PU. In other words, respondents who believed knowledge should be justified by experiments and multiple sources, also feel efficacious in science teaching and have positive perceptions of the technology's ease of use and usefulness. Beliefs about the nature of knowing (source and justification) are found to be positively related to students' efficacy beliefs in learning in science (Kapucu & Bahçivan, 2015). The results consistently showed that preservice teachers' sophisticated beliefs regarding the nature of knowing are positively related to their personal science teaching efficacy beliefs. Surprisingly, respondents' epistemological beliefs, except for justification, did not have significant relationships with PEU and PU. Contrary to this finding, Demirbag and Bahcivan (2021) found that certainty and development dimensions were positively related to digital literacy.

The second belief system added to TAM was science teaching efficacy beliefs, which have two distinct dimensions regarding teaching efficacy and the impact of effective science teaching on students' learning. These distinct dimensions (PSTE and STOE) significantly influenced the PU. Preservice teachers who felt efficacious in science teaching and believed effective teaching would promote students' learning perceived technology as an effective and productive tool in their teaching practices. Additionally, all TAM hypotheses were supported with medium to large effect sizes. This finding supports the existing research addressing the positive relationship between PEU, PU, ATU, and BI (Baydas & Göktas, 2017; Gurer & Akkaya, 2021; Joo et al., 2018; Siyam, 2019; Wong et al., 2012).

This study has also shown the direct, indirect, and total effects of determinants on each endogenous variable. The determinants in the research model explained 59 % of the variance in BI, indicating a greater explained variance than in other studies (Eksail & Afari, 2020; Wong et al., 2012; Sang et al., 2010; Siyam, 2019; Teo, Ursavaş, & Bahçekapılı, 2012). The strongest determinant of BI was PU, with a total effect size of .898. PU has a large direct effect on BI, and ATU also moderated its effect. This finding implies that it is more likely for preservice teachers to use technology in education when they perceive using it would improve their teaching and feel positive emotions regarding its use. The justification dimension had the largest effect on BI among the external variables, and STOE followed it. The effect of justification was entirely indirect. The moderating effect of PSTE, STOE, PEU, and PU promoted the effect of justification. Only believing in knowledge should be justified does not ensure to intend using technology; instead, these beliefs should be supported with science teaching efficacy beliefs and positive perceptions regarding technology use. Interestingly, the direct effect of the PSTE on BI was negative and smaller than the indirect effect. It is possible to imply that the combined effect of PSTE, PEU, PU, and ATU on PSTE leads to positive responses to BI.

The determinants of ATU accounted for approximately 46% of its variance. The most prominent determinants were PU, PEU, and justification, respectively. This finding supports the idea of Venkatesh (2000), indicating that PEU and PU are fundamental constructs in TAM. When it comes to determinants of PU and PEU, justification was the strongest determinant of both. It is also worth noting that science teaching efficacy beliefs and scientific epistemological beliefs explained 9% of PEU variance, leaving 91% unexplained. PEU might be considered a sort of competence to use technology (Wong et al., 2012). Therefore, respondents might not have perceived teaching efficacy and epistemological beliefs as related to PEU. Justification had the largest total effects on PEU, PU, ATU, and BI among the external variables. An implication of this is the possibility that technology is a productive and valuable tool in justifying knowledge, providing multiple opportunities.

To sum up, this study extends our knowledge of TAM and shows that incorporating teaching efficacy and scientific epistemological beliefs into TAM explained more than half of the variance in BI. Preservice teachers' beliefs about justifying knowledge were significant determinants of their technology acceptance and behavioral intention. Teaching efficacy beliefs had small effects on technology acceptance. This finding has important implications for developing preservice teachers' understanding of the relatedness of teaching efficacy and technology and needs to be further examined to reveal the underlying reasons. Besides, an unexpected finding was that PSTE has a negative direct and positive indirect effect on BI. It is difficult to explain this result, but it might be implied that beliefs regarding effective science teaching should be supported with positive perceptions of and attitudes toward technology use to increase preservice teachers' willingness to teach with technology. Further work is required the establish the reasons for the negative effect.

Finally, a number of important limitations need to be considered. Data was collected through self-reported measures, which might lead respondents to overestimate their beliefs, perceptions, and attitudes and give responses to meet the desired outcome. Therefore, it is crucial to collect qualitative data further to give a detailed insight into the findings. Secondly, the current study has only examined the technology acceptance of preservice teachers. To reveal how science teaching and scientific epistemological beliefs impact technology acceptance and behavioral intention, studies with larger samples and in-service teachers might allow to compare and establish the relationships among the observed constructs. Lastly, the research model explained 59% of the variance in BI, and 41% of the variance remained unexplained. Further research should include various external variables to increase the predictivity of the model.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

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