Journal of Mathematics Teacher Education (2022) 25:479–495
https://doi.org/10.1007/s10857-021-09504-5

# The influence of pedagogical beliefs on technology acceptance: a structural equation modeling study of pre-service mathematics teachers

Melih Derya Gurer[1] · Recai Akkaya[2]

Accepted: 27 June 2021 / Published online: 5 July 2021


**Abstract**
Pedagogical beliefs are a critical factor in terms of integrating technology into teaching, but very few technology acceptance models (TAMs) have considered them. Hence, this study aims to extend the TAM by incorporating pre-service teachers' conception of teaching and learning. The revised model examined the influence of pre-service mathematics teachers' constructivist and traditional pedagogical beliefs on their technology acceptance through perceived ease of use, perceived usefulness, attitude toward technology, and behavioral intention to use. Survey data were collected from 714 pre-service mathematics teachers in Turkey and analyzed through path analysis. The results showed that pre-service mathematics teachers' pedagogical beliefs were more constructivist-oriented than traditional-oriented, and constructivist beliefs had a significant influence on the components of the TAM. On the other hand, pre-service teachers' traditional-oriented beliefs did not influence their perceived usefulness of and attitudes toward technology but had positive effects on perceived ease of use. Implications for pre-service mathematics teacher education were discussed.

**Keywords** Constructivist pedagogical beliefs · Traditional pedagogical beliefs · Technology acceptance model · Pre-service mathematics teachers · Structural equation modeling

✉ Melih Derya Gurer
mdgurer@gmail.com

Recai Akkaya
recaiakkaya@gmail.com

1 Department of Computer Education and Instructional Technology, Faculty of Education, Bolu Abant Izzet Baysal University, 14030 Bolu, Turkey

2 Department of Mathematics and Science Education, Faculty of Education, Bolu Abant Izzet Baysal University, 14030 Bolu, Turkey

## Introduction

Technology has become popular at all levels of education and has been used in many learning environments. In mathematics education, technology supports students' visualization, active-knowledge construction, and higher-order thinking (Barak, 2014; Wenglinsky, 1998). Information and communication technologies (ICT) can extend students' efficacy in mathematical investigations and provide authentic environments to learn mathematics. Simulations, calculators, Web applications, mathematical software such as GeoGebra or Sketchpad, and other technologies support students in collecting, recording, organizing, and analyzing data. These tools provide new opportunities for communication and development of mathematical understanding (Ball et al., 2019) by enabling multiple representations of mathematics concepts (Thurm & Barzel, 2020). Through modeling, visualization, manipulation, and the introduction of more complex scenarios, the use of digital tools supports exploratory tasks, realistic problem-solving, and collaborative approaches in mathematics (Cayton et al., 2017; ter Vrugte et al., 2015). Additionally, Tan and Hew (2019) indicated that students' use of technology at home, especially its use for learning, is a strong predictor of their math performance. Furthermore, Bray and Tangney's (2017) systematic review of research on technology-enhanced mathematics education indicated that digital tools have the potential to address some of the issues commonly associated with mathematics education and enrich students' mathematical learning experiences. The National Council of Teachers of Mathematics (NCTM) also advocated the use of technology for teaching mathematics by stating "Effective teachers optimize the potential of technology to develop students' understanding, stimulate their interest, and increase their proficiency in mathematics" (NCTM, 2015).

With the importance of technology in education, governments and organizations have made a considerable investment to build technological infrastructure in schools, train teachers, and provide digital materials to teachers (Ertmer & Ottenbreit-Leftwich, 2013). As a result, access to technology in schools has increased. Nevertheless, research indicated that technology in mathematics classrooms is underused, and the results of its use do not meet the expected outcomes (Barak, 2014). Joubert (2013) suggested that the challenges within the use of technology in mathematics education are teachers' beliefs, their understanding of the landscape, and changes in mathematics education due to the new technologies. Among teachers' beliefs, pedagogical beliefs (Ertmer et al., 2012) and technology acceptance (Teo, 2010) play a significant role in the effective integration of technology into teaching. Although researchers have applied technology acceptance models to investigate why teachers accept technology in their teaching, few studies have incorporated teachers' pedagogical beliefs into technology acceptance. Furthermore, studies on technology acceptance of teachers have often been implemented without regarding teachers' academic discipline.

This study aims to investigate the influence of pedagogical beliefs on technology acceptance in the context of pre-service mathematics teachers. To address this, pedagogical beliefs were incorporated into Davis's (1989) Technology Acceptance Model (TAM), and the proposed model was tested. A key reason to address pre-service teachers' technology acceptance is to better understand the future use of technology in teaching mathematics and to guide teacher educators to foster positive experiences and attitudes to their students. This study's findings will help researchers and stakeholders understand the role of pedagogical beliefs in technology acceptance.

## Literature review

### Pedagogical beliefs and technology integration

Individuals hold beliefs that help them define and understand themselves and the world around them (Pajares, 1992). Rokeach (1968) thought that one's beliefs about oneself and the physical and social world exist within a comprehensive belief system. As emphasized by Pajares (1992), "All teachers hold beliefs … about their work, their students, their subject matter, and their roles and responsibilities…" (p. 314). Teachers' pedagogical beliefs, specifically, refers to the complex beliefs of teachers on teaching and learning (Chan & Elliot, 2004).

In a broad sense, pedagogical beliefs are portrayed as either constructivist or traditional (Alburo, 2019; Deng et al., 2014). Traditional beliefs are derived from the behavioral roots of learning. The behaviorist approach focuses on the creation of behaviors or behavior patterns through reinforcement or punishment. A mechanical construction of associations between different units of information is considered as learning. Moreover, traditional pedagogy emphasizes the transmission of knowledge from teacher to student (Driscoll, 2014). On the other hand, the constructivist conception emphasizes the importance of experience and active participation of the individual in the learning process. Knowledge is not received passively; rather the individual is involved in the creation of knowledge actively. Students' participation in meaningful instructional activities increases students' capacity to understand a subject. In addition, a child's interaction with his/her peers or adults promotes the construction of knowledge (Woolfolk, 2016).

Research studies have shown that pre-service teachers' conceptions of learning are consistent with their conceptions of teaching (Tsai, 2002). The teachers having traditional pedagogical beliefs tend to be the source of knowledge and authority in the classroom to emphasize discipline and moral standards. Students are passive recipients of knowledge gained from teachers and textbooks. Teacher-centered activities take precedence to transmit knowledge in a highly structured and directed learning environment (Chan & Elliot, 2004). In contrast, teachers holding constructivist pedagogical beliefs help students understand their world, construct knowledge, and reflect their understanding through scaffolding. To organize student-centered activities, individual needs and characteristics are focused, and critical thinking and collaboration are emphasized. In addition, unstructured and open-ended learning environments are created by teachers to help students in the knowledge-creation process (Mayer, 2003). Although traditional and constructivist pedagogical beliefs might be considered opposites, this polarization was criticized by Kerlinger and Kaya (1959). It was hypothesized that many teachers might hold both beliefs and may change between student- and teacher-centered teaching activities (Alburo, 2019).

Several studies indicated that there is a relationship between teachers' pedagogical beliefs and classroom practices, specifically technology integration practices (Ertmer et al., 2012; Teo & Zhou, 2017; Tondeur et al., 2016). Teachers holding constructivist beliefs tend to use technology actively and use digital tools in more student-centered ways, whereas teachers holding traditional pedagogical beliefs tend to use technology to foster teacher-centered curriculum activities (Kim et al., 2013). In their survey of 32,256 secondary school students from 16 OECD economies, Tan and Hew (2019) reported that students whose mathematics teachers believed in student-centered teaching reported their teachers' higher levels of technology integration. On the other hand, students who teachers utilized a more teacher-centered teaching approach reported that their teachers integrated technology into classroom practices at a lower level.

Pedagogical beliefs are also associated with the perception of technology in teaching. Teachers having traditional pedagogical beliefs do not perceive technology as useful and essential for teaching. On the other hand, teachers holding constructivist beliefs perceive technology as a more useful and supportive learning tool (Tondeur et al., 2016). Liu et al. (2017) reported that while constructivist-teaching beliefs had a significant positive influence on perceived ease of use, the usefulness of and attitude toward technology, traditional beliefs had negative effects only on the perceived ease of use. Moreover, Teo and Zhou (2017) surveyed 592 teachers in a South-East Asian country and concluded that teachers' pedagogical beliefs had significant influences on their intention to use technology, attitude, facilitating conditions, perceived usefulness, and perceived ease of use.

Previous studies with pre-service teachers have produced similar results. Bahcivan et al. (2019) found that pre-service teachers' pedagogical beliefs significantly predicted their perceived technology integration competencies. Yang and Leung, (2015) indicated that pre-service teachers' constructivist beliefs about mathematics learning and teaching, and attitudes toward technology are positively correlated. Anderson et al. (2011) reported that pre-service teachers' constructivist teaching beliefs positively related to their self-efficacy in technology and their intention to use it. Moreover, pre-service teachers holding constructivist pedagogical beliefs exhibited a greater intention to use technology in future classrooms than those with traditional beliefs.

## Technology acceptance model

The factors related to the effective integration of technology into teaching has been investigated with an extensive body of research. Several frameworks such as Theory of Planned Behavior (TPB), Theory of Reasoned Action (TRA), Unified Theory of Acceptance and Use of Technology (UTAUT) and Technology Acceptance Model (TAM) have been used to predict individuals' perception and use of specific technologies. However, the UTAUT and TAM have been extensively used and have proven to have good exploratory powers in education research. Although UTAUT has more predictive power than TAM in information system studies, it has lower predictive power in education contexts (Birch & Irvine, 2009). On the other hand, the TAM is the most widely applied framework and has been found to be a more powerful and robust predictive model in 42 studies (Šumak et al., 2011).

The (TAM), proposed by Davis (1989), examined why users accept and use specific information technology. The TAM hypothesizes that behavioral intention is related to individuals' behaviors and predicted by users' beliefs and attitudes. Within TAM, the causal relationships between behavioral intention to use technology (BIU), attitude toward technology (ATT), perceived ease of use (PEU), and perceived usefulness (PU) is investigated (see Fig. 1). The TAM hypothesizes that PEU directly influences PU. Together, PEU and PU directly affect ATT, which, in turn, directly influences BIU. PEU and PU also affect BIU indirectly. Finally, BIU determines the actual use of technology.

Previous studies have validated the TAM with both in- and pre-service teachers and indicated that TAM was an effective model for determining teachers' acceptance of technology (e.g., Teo, 2015). Teo and Milutinović (2015) indicated that mathematics teachers holding positive attitudes toward technology are more ready to use technology. PU (Teo, 2010; Teo et al., 2012) and PEU (Teo & Milutinović, 2015; Wong, 2015) together are significant predictors of ATT. Furthermore, ATT influences BIU technology in the classroom

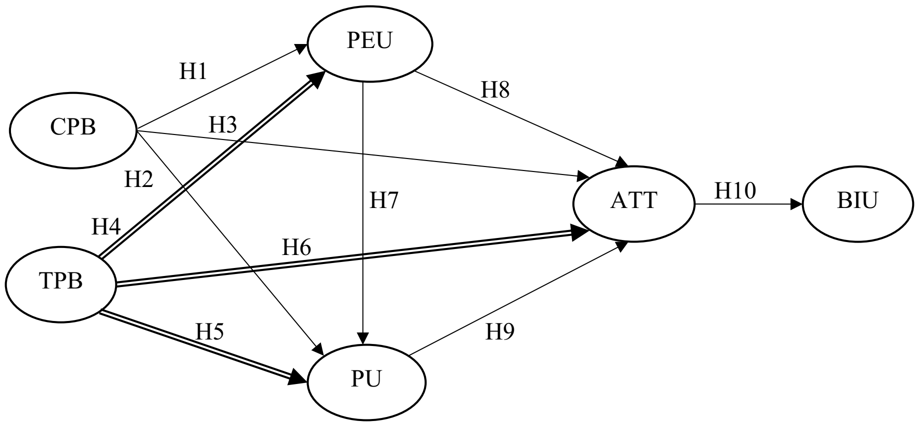


**Fig. 1** The proposed model with standardized path coefficients (Note: CPB: constructivist pedagogical beliefs; TPB: traditional pedagogical beliefs; PEU: perceived ease of use; PU: perceived usefulness; ATT: attitude toward technology; BIU: behavioral intention to use; single-line arrow: positive influence; double-line arrow: negative influence)

(Han et al., 2017; Teo et al., 2012). In a recent and comprehensive study, Ibili et al. (2019) investigated mathematics teachers' acceptance of augmented reality (AR) application. They found that mathematics teachers in Turkey had a high intention to use the AR application for teaching. Mathematics teachers' attitudes toward AR significantly influenced their intention of using AR in teaching mathematics. Moreover, the perceived usefulness of AR and satisfaction predicted their attitudes toward AR.

Despite its validity, the TAM has also been criticized for being too deterministic and for disregarding important factors like subject content and pedagogical beliefs (Bagozzi, 2007). Hence, to extend the TAM and explain teachers' acceptance of technology comprehensively, different factors such as technological complexity, social norms, and facilitating conditions were added to the model. In this study, pedagogical beliefs, which is a crucial factor influencing intention to perform technology in teaching (Davis, 1989), was included in the model to test its influence on pre-service teachers' acceptance of technology.

## Mathematics teachers' technology adoption

There are controversial results to-date to support or refute that ICT enhances students' achievement in mathematics classrooms. A meta-analysis of 74 studies by Cheung and Slavin (2013) indicated that technology applications for teaching produced a positive and modest effect on mathematics achievement. In another meta-analysis study, Chauhan (2017) also investigated the findings of 122 papers that measured the effect of technology on learning outcomes and concluded that the use of technology has a medium effect size on the learning effectiveness of students in mathematics. On the other side, analyzing the 2012 Programme for International Student Assessment (PISA) data, Bulut and Cutumisu (2018) reported that the use of technology at school was negatively associated with mathematics achievement.

Instead of asking whether technology brings achievement into mathematics classrooms, it might be more fruitful to study why and how to use these resources for teaching effectively in the first place. Given the ways of using technology for teaching, researchers have shifted their attention to the complexity of the technology integration process and the factors that predict effective technology integration. For example, Tan and Hew (2019) reported that the availability of technological resources and mathematics teachers' pedagogical beliefs are beyond the other school, teacher, and student-related factors. McCulloch et al. (2018) interviewed with early career secondary school mathematics teachers and concluded that the alignment of technology with the goals of the lesson and ease of use of technology tools for both teachers and their students led to the integration of technology into mathematics teaching. Pierce and Ball (2009) indicated that mathematics teachers' perceptions of technology, perceived potential benefits of technology, and their school leaders' expectations to use technology for teaching mathematics had considerable effects on the incorporation of technology with teaching. In addition, Psycharis and Kalogeria (2018) interrelated teachers' epistemologies of teaching and learning mathematics with their perception of technological pedagogical content knowledge. Similarly, mathematics teachers' knowledge and epistemological beliefs and pedagogical beliefs (Thurm & Barzel, 2020) also play a decisive role.

## Research questions and hypotheses

This study aims to explore the influence of pedagogical beliefs on technology acceptance in the context of pre-service mathematics teachers. Specifically, this study focuses on pre-service mathematics teachers' pedagogical beliefs, perceptions on easy use and usefulness of technology, attitudes toward technology, behavioral intentions to use technology, and, finally, the causal relationships among them. According to the proposed model presented in Fig. 1, there are two research questions and ten hypotheses.

> RQ1: How do the pedagogical beliefs of pre-service mathematics teachers affect their acceptance of technology?

**H1:** Constructivist pedagogical beliefs have a positive influence on perceived ease of use.

**H2:** Constructivist pedagogical beliefs have a positive influence on perceived usefulness.

**H3:** Constructivist pedagogical beliefs have a positive influence on attitude toward technology.

**H4:** Traditional pedagogical beliefs have a negative influence on perceived ease of use.

**H5:** Traditional pedagogical beliefs have a negative influence on perceived usefulness.

**H6:** Traditional pedagogical beliefs have a negative influence on attitude toward technology.

> RQ2: What factors best predict pre-service mathematics teachers' intention to use technology in their future classrooms?

**H7:** Perceived ease of use has a positive influence on perceived usefulness.

**H8:** Perceived ease of use has a positive influence on attitude toward technology.

**H9:** Perceived usefulness have a positive influence on attitude toward technology.

**H10:** Attitude toward technology have a positive influence on behavioral intention to use technology.

## Method

### Participants

The participants were 714 pre-service mathematics teachers in four large-size public universities in Turkey. The pre-service mathematics teachers in Turkey attend to a four-years of study at a faculty of education. With core mathematics courses such as algebra and geometry, they take pedagogy courses and specific courses related to the teaching of mathematics. Of the participants, 78.4% were female, and 21.6% were male. Among the participants, 75.8% and 24.2% were trained to be primary and secondary school mathematics teachers, respectively. Their ages were between 18 and 31. A paper-based questionnaire was distributed to the pre-service teachers. The participants were briefed about the purpose of the study and the privacy and security of the data with a statement on the first page of the questionnaire. They were also told that they had the right to withdraw from the study at any time. The pre-service teachers responded to the questionnaire voluntarily. The questionnaire took around 20 min to complete.

### Measures

The questionnaire, titled "Pre-service teachers' technology acceptance and pedagogical beliefs," used in this study included two parts. Part 1 asked the pre-service teachers about their technology acceptance in four constructs: PEU (four items), PU (five items), ATT (three items), and BIU (five items). The items were adapted from the studies of Teo and Milutinovic (2015) and Ursavaş et al. (2014), which were based on Davis's (1989) TAM. Part 2 included 30 items to measure pre-service mathematics teachers' pedagogical beliefs. They focused on constructivist pedagogical beliefs (CPB) (12 items) and traditional pedagogical beliefs (TPB) (18 items). These were developed by Chan and Elliot (2004) and adapted into Turkish by Aypay (2011). All items in Part 1 and Part 2 were presented on a 5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. Additionally, the Cronbach's alpha coefficients were found as 0.80 for PEU, 0.90 for PU, 0.80 for ATT, 0.86 for BIU, 0.91 for TPB, and 0.82 for CPB.

### Data analysis

Prior to data analysis, all negative items were reversed. For data analysis, descriptive statistics were first examined. Structural equation modeling (SEM) was then used to establish the reliability of the measurement items and to investigate the relationships between pedagogical beliefs and the TAM constructs. As a multivariate statistical analysis technique, SEM is used to study relationships among variables. It analyses the relationships between measured variables and latent constructs (Kline, 2005). In this study, the SEM measured both direct, indirect, and total effects of variables among them. The offered model was tested via SPSS AMOS 24.0. The normality of data for SEM was satisfied through skewness and kurtosis (Kline, 2005).

## Results

### Descriptive statistics

As indicated in Table 1, the pre-service mathematics teachers' mean score for CPB was 4.362, indicating that they had positive responses to constructivist teaching, while the pre-service mathematics teachers' mean score for TPB was 2.795, indicating that the pre-service mathematics teachers were undecided about the traditional conceptions of teaching and learning in classroom settings. The pre-service teachers' pedagogical beliefs were more constructivist-oriented. Moreover, the pre-service teachers generally had positive perceptions of technology in education. They had moderately high perceptions of usefulness and easy use of technology with mean scores of 4.159 and 3.997, respectively. The pre-service teachers also had moderately high attitudes toward technology with a mean score of 4.155. In addition, they indicated strong intentions to use technology in their future classrooms with a mean score of 4.076. The standard deviations ranged between 0.365 and 0.648, reflecting narrow spreads around the mean scores. Finally, the skewness and kurtosis ranged between −0.916 and 0.328, indicating the univariate normality of data for SEM (Kline, 2005).

### Correlations

Pearson correlation analysis was conducted to investigate the correlations between the TAM variables and pedagogical beliefs. As shown in Table 2, there were positive and significant correlations between the TAM constructs (PU, PEU, ATT, and BIU) ($p<0.01$). Additionally, CPB positively and significantly correlated with TAM constructs ($p<0.01$). On the other hand, TPB negatively correlated with BIU, PU, ATT, and CPB ($p<0.01$, and $p<0.05$). Furthermore, a significant correlation between TPB and PEU was not computed ($p>0.05$).

**Table 1** Descriptive statistics and normality estimates

| Variables | CPB | TPB | PU | PEU | ATT | BIU |
|---|---|---|---|---|---|---|
| Mean | 4.362 | 2.795 | 4.159 | 3.997 | 4.155 | 4.076 |
| SD | .365 | .648 | .485 | .569 | .540 | .491 |
| Skewness | −.011 | .328 | .191 | −.121 | .057 | .000 |
| Kurtosis | − .916 | −.432 | −.363 | −.438 | −.557 | −.152 |

CPB: constructivist pedagogical beliefs; TPB: traditional pedagogical beliefs; PU: perceived usefulness; PEU: perceived ease of use; ATT: attitude toward technology; BIU: behavioral intention to use

**Table 2** Bivariate correlations among the variables

| | BIU | PU | PEU | ATT | CPB | TPB |
|---|---|---|---|---|---|---|
| BIU | 1 | | | | | |
| PU | .555** | 1 | | | | |
| PEU | .367** | .338** | 1 | | | |
| ATT | .547** | .500** | .254** | 1 | | |
| CPB | .320** | .267** | .199** | .293** | 1 | |
| TPB | −.109** | −.082* | .015 | −.079* | −.302** | 1 |

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

## Test of the model

Within the two-step process of SEM (Anderson & Gerbing, 1988), first, the model was assessed on how well the questionnaire items measure the latent variables. Both the composite reliability (CR) and average variance extracted (AVE) were used to measure item reliability and construct validity. Hair et al. (2010) stated that the value of CR and AVE equal to or exceed 0.50 is adequate for CR and AVE. Moreover, a standardized estimate greater than 0.50 explains its latent variable. The results indicated that CR, AVE, and standardized estimates were satisfied. Table 3 indicates the standardized estimate, t-value, CR, and AVE.

As the second step, to test the suggested model, using different goodness of fit indices is recommended. The most commonly used fit indices offered by researchers (Hair et al., 2010; Kline, 2005) are the ratio of chi-square to its degree of freedom ($\chi^2$/df), the standardized root mean square residual (SRMR), the root mean square error of approximation (RMSEA), the goodness of fit index (GFI), and the comparative fit index (CFI). The model results were computed as $\chi^2/\text{df} = 2.548$, RMSEA = 0.047, SRMR = 0.046, GFI = 0.933, and CFI = 0.908. The conceptual model proposed in this study met the criteria offered by Hair et al. (2010) and Kline (2005). The results suggested that the model showed a reasonably good fit with the sample of the study.

## Hypothesis testing

The results of the significance testing and path coefficient estimates are presented in Table 4. Of the ten hypotheses, seven were supported. CPB had a significant positive effect on PEU, PU, and ATT ($\beta = 0.276$, $p < 0.001$; $\beta = 0.222$, $p < 0.001$; $\beta = 0.192$, $p < 0.001$, respectively), supporting H1, H2, and H3. On the other hand, although TPB had a negative influence on PU ($\beta = -0.011$) and ATT ($\beta = -0.019$), this influence was not significant ($p > 0.05$). Thus, H5 and H6 were not supported. Moreover, H4 was not supported, because the effect of TPB on PEU was positive and significant ($\beta = 0.122$, $p < 0.05$), although a negative effect was expected. Lastly, all the hypotheses regarding TAM variables (H7, H8, H9, and H10) were supported. PEU had a positive significant effect on PU ($\beta = 0.326$), both PEU and PU had positive significant influences on ATT ($\beta = 0.150$ and $\beta = 0.616$, respectively), and BIU was predicted by ATT positively and significantly ($\beta = 0.825$).

**Table 3** Results of item reliability and construct validity

| Construct | Item | Standardized estimate | t-value* | CR** | AVE*** |
|---|---|---|---|---|---|
| Constructivist pedagogical beliefs | CPB1 | 0.898 | – | 0.969 | 0.722 |
| | CPB2 | 0.787 | 9.275 | | |
| | CPB3 | 0.791 | 9.343 | | |
| | CPB4 | 0.876 | 10.638 | | |
| | CPB5 | 0.691 | 7.588 | | |
| | CPB6 | 0.644 | 6.662 | | |
| | CPB7 | 0.857 | 10.363 | | |
| | CPB8 | 0.929 | 11.349 | | |
| | CPB9 | 0.954 | 11.660 | | |
| | CPB10 | 0.954 | 11.664 | | |
| | CPB11 | 0.912 | 11.129 | | |
| | CPB12 | 0.842 | 10.141 | | |
| Traditional pedagogical beliefs | TPB1 | 0.789 | – | 0.967 | 0.619 |
| | TPB2 | 0.627 | 5.636 | | |
| | TPB3 | 0.826 | 13.626 | | |
| | TPB4 | 0.705 | 11.542 | | |
| | TPB5 | 0.852 | 14.029 | | |
| | TPB6 | 0.783 | 12.924 | | |
| | TPB7 | 0.689 | 9.255 | | |
| | TPB8 | 0.913 | 14.936 | | |
| | TPB9 | 0.835 | 13.776 | | |
| | TPB10 | 0.842 | 13.879 | | |
| | TPB11 | 0.764 | 12.594 | | |
| | TPB12 | 0.695 | 9.395 | | |
| | TPB13 | 0.683 | 9.130 | | |
| | TPB14 | 0.897 | 14.699 | | |
| | TPB15 | 0.871 | 14.322 | | |
| | TPB16 | 0.900 | 14.742 | | |
| | TPB17 | 0.742 | 12.220 | | |
| | TPB18 | 0.667 | 10.831 | | |
| Perceived ease of use | PEU1 | 0.642 | – | 0.902 | 0.701 |
| | PEU2 | 0.932 | 10.751 | | |
| | PEU3 | 0.917 | 10.488 | | |
| | PEU4 | 0.826 | 9.965 | | |
| Perceived usefulness | PU1 | 0.862 | - | 0.960 | 0.829 |
| | PU2 | 0.859 | 15.277 | | |
| | PU3 | 0.933 | 16.707 | | |
| | PU4 | 0.929 | 18.304 | | |
| | PU5 | 0.964 | 17.254 | | |
| Attitude toward technology | ATT1 | 0.760 | – | 0.855 | 0.663 |
| | ATT2 | 0.844 | 12.436 | | |
| | ATT3 | 0.836 | 12.336 | | |
| Behavioral intention to use | BIU1 | 0.844 | – | 0.924 | 0.712 |
| | BIU2 | 0.903 | 17.663 | | |

**Table 3** (continued)

| Construct | Item | Standardized estimate | t-value* | CR** | AVE*** |
|---|---|---|---|---|---|
| | BIU3 | 0.919 | 17.116 | | |
| | BIU4 | 0.870 | 15.101 | | |
| | BIU5 | 0.656 | 10.834 | | |

*$p<0.01$

**CR = $(\Sigma\lambda)^2/((\Sigma\lambda)^2+(\Sigma(1-\lambda^2)))$

***AVE = $(\Sigma\lambda^2)/((\Sigma\lambda^2)+(\Sigma(1-\lambda^2)))$

**Table 4** Hypothesis testing results

| Hypothesis | Path | Path coefficient | S.E | t-value | Results |
|---|---|---|---|---|---|
| H1 | PEU ← CPB | .276** | .077 | 4.237 | Supported |
| H2 | PU ← CPB | .222** | .096 | 3.901 | Supported |
| H3 | ATT ← CPB | .192** | .077 | 3.615 | Supported |
| H4 | PEU ← TPB | .122* | .021 | 2.418 | Not supported |
| H5 | PU ← TPB | −.011 | .027 | −.233 | Not supported |
| H6 | ATT ← TPB | −.019 | .021 | −.459 | Not supported |
| H7 | PU ← PEU | .326** | .077 | 6.110 | Supported |
| H8 | ATT ← PEU | .150** | .057 | 3.284 | Supported |
| H9 | ATT ← PU | .616** | .053 | 10.115 | Supported |
| H10 | BIU ← ATT | .825** | .069 | 11.352 | Supported |

*$p<0.05$, **$p<0.001$

## Path analysis

The direct, indirect, and total influences of the variables were examined using path analysis, and the results are indicated in Table 5. Cohen (1998) proposed that an effect size with a value of less than 0.100 is small, values around 0.300 indicate a medium, and values bigger than 0.500 indicate a large effect. Namely, the larger the effect size the stronger the relationship between two variables and the stronger the effect on one variable on the other. The most dominant positive determinant of BIU is ATT ($\beta=0.825$), followed by PU ($\beta=0.508$), CPB ($\beta=0.351$), PEU ($\beta=0.289$) and TPB ($\beta=0.014$). While ATT and PU have large positive effect sizes, CPB and PEU have medium positive effect sizes, and TPB has a small positive effect size on behavioral intention. Five determinants account for 68% ($R^2=0.680$) of the variance in behavioral intention to use technology.

Within the scope of the proposed model, the most effective factor on ATT is PU, with a large positive effect size ($\beta=0.616$). This is followed by CPB, PEU, and TPB, with total positive effect sizes of 0.425, 0.351, and 0.017, respectively. While CPB and PEU have medium positive effect sizes ($\beta=0.425$ and $\beta=0.351$, respectively), TPB has a small positive effect size ($\beta=0.017$). These four variables account for approximately 59.8% of the variance in attitude toward technology. Regarding perceived usefulness, PEU and CPB are the prominent determinants with total positive effect sizes of 0.326 and 0.312, respectively, which are medium. TPB has a small total effect size ($\beta=0.029$) on perceived usefulness.

**Table 5** Direct, indirect and total effects in the proposed model

| Dependent variable | Independent variable | Standardized estimates | | |
|---|---|---|---|---|
| | | Direct | Indirect | Total |
| Behavioral intention ($R^2=0.680$) | TPB | – | 0.014 | 0.014 |
| | CPB | – | 0.351 | 0.351 |
| | PEU | – | 0.289 | 0.289 |
| | PU | – | 0.508 | 0.508 |
| | ATT | 0.825** | – | 0.825 |
| Attitude toward technology ($R^2=0.598$) | TPB | −0.019 | 0.036 | 0.017 |
| | CPB | 0.192** | 0.234 | 0.425 |
| | PEU | 0.150** | 0.201 | 0.351 |
| | PU | 0.616** | – | 0.616 |
| Perceived usefulness ($R^2=0.190$) | TPB | −0.011 | 0.04 | 0.029 |
| | CPB | 0.222** | 0.09 | 0.312 |
| | PEU | 0.326** | – | 0.326 |
| Perceived ease of use ($R^2=0.062$) | TPB | 0.122* | – | 0.122 |
| | CPB | 0.276** | – | 0.276 |

*$p<0.05$, **$p<0.01$

Determinants account for approximately 19% of the variance in perceived usefulness. Lastly, CPB is the positive prominent determinant of perceived ease of use with a medium total effect size ($\beta=0.276$). Additionally, TPB has a total positive medium effect on PEU ($\beta=0.122$). TPB and CPB account for 6.2% of the variance in the perceived ease of use.

## Discussion

### Pedagogical beliefs and TAM constructs

The primary goal of this study was to examine the influence of pedagogical beliefs on PEU, PU, ATT, and BIU for pre-service teachers. The results showed that CPB has a positive direct effect on ATT, PEU, and PU. In addition, CPB has an indirect effect on BIU with high effect size, and indirect influences on ATT and PU with medium and small effect sizes, respectively. It can be inferred that pre-service teachers' CPB could predict their attitudes toward technology and intentions to use it. These results corroborate with Liu et al. (2017) who showed that pre-service teachers' CPB has a positive influence on their attitudes toward technology, perception regarding the easy use and usefulness of technology in teaching. Similarly, in the field of mathematics teaching, Lai and Lin (2018) and Marban and Mulenga (2019) indicated that teachers' student-centered pedagogical beliefs were correlated with their technology integration beliefs. The result implies that when pre-service mathematics teachers have high CPB, it reinforces their positive feelings toward the use of technology. This result is consistent with the assumptions of constructivism and the potentials of technology in education. Technology in education has the potential to foster dynamic interaction among students and teachers, support collaborative learning, and engage students in higher-order thinking skills. It can provide an authentic environment and meaningful learning tasks through extensive learning opportunities connected to the real-world (Howland et al., 2011). These potentials adequately fit within the constructivist teaching and learning of mathematics.

TPB was found to have a positive and significant influence on pre-service teachers' ease of use. In addition, TPB did not have a significant influence on PU and ATT. This result is consistent with results from previous studies (Bahcivan et al., 2019; Liu et al., 2017), which reported that TPB was positively or non-significantly correlated with beliefs in technology integration. On the other hand, Tondeur et al. (2016) found that teachers who hold TPB do not perceive technology to be useful in teaching. This confounding result can be explained in two ways. The first is that pre-service teachers hold both constructivist and traditional teaching beliefs (Alburo, 2019). In this study, the pre-service mathematics teachers' scores on constructivist items were higher than those on traditional items, indicating the pre-service teachers were much more oriented toward constructivism. Therefore, the positive correlation between traditional beliefs and perceptions of technology's ease of use could be explained by high scores in constructivist pedagogical beliefs (Bahcivan et al., 2019; Liu et al., 2017). The second is that, although teachers may have CPB, there may be a difference between their beliefs and practices. It is expected that teachers holding CPB would be more likely to use technology in the classroom than teachers who have traditional beliefs. However, teachers' pedagogical beliefs are not always compatible with their classroom practices, and they use technology in more traditional ways (Ertmer et al., 2012).

## Predictors of behavioral intention to use technology

The results indicate that four hypotheses regarding the TAM were supported. It was found that pre-service teachers' PEU had a significant effect on PU. This means, as the perceived level of ease of use increases, the perception of usefulness also increases proportionally. This result is in line with previous studies indicating that PEU is a significant indicator of PU (Liu et al., 2017; Teo et al., 2012). Given this result, pre-service mathematics teachers are likely to perceive a particular technology as more useful for teaching if they think they will require less effort to use it.

Another result derived from this study is that PU and PEU were two of the significant direct determinants of ATT. Additionally, PEU had an indirect influence on ATT through PU. Similarly, Teo et al. (2012) reported that pre-service mathematics teachers' attitudes toward technology are influenced by how useful they see it and how easy it is to use. In this study, PU was found as the strongest predictor of the ATT. The positive influences of PEU and PU on ATT suggest that when pre-service teachers perceive technology to be useful for teaching and that it would increase their productivity with little effort, they are likely to have positive feelings toward technology use.

This study showed that ATT has a direct positive effect on the BIU, implicating that pre-service teachers with positive feelings toward the technology are more likely to use it to teach mathematics. ATT was found as the most important factor in influencing pre-service teachers' intention to use technology. This finding is in line with previous studies predicting pre-service mathematics teachers' intentions to use different technologies (Ibili et al., 2019; Teo & Milutinovic, 2015; Wong, 2015). In addition, the results show that ATT had mediated the effect of CPB, PU, and PEU on BIU.

## Limitations

The current study has some limitations that should be considered. First, five variables explained approximately 68% of the variance in behavioral intention. However, 32% of the variation in behavioral intention was not explained. This study does not include other variables that can significantly influence behavioral intention to use technology such as social influence, computer anxiety, or facilitating conditions that could test the direct or indirect effects on behavioral intention. Second, the study participants were pre-service teachers rather than in-service teachers. Since pre-service teachers do not have information about the actual conditions in the schools, their perceptions and attitudes toward technology may differ from those of in-service teachers. Longitudinal studies may compare the current case and the case when they are in-service teachers. Lastly, the technologies were not specified in survey questions. Šumak et al. (2011) stated that the type of technology determines the size of the causal effects between individual factors and technology acceptance. Hence, studies with different technologies might produce different results.

## Implications

The findings of this study have some implications for teacher educators and policymakers. For pre-service mathematics teacher educators, the results indicated the importance of constructivist pedagogical beliefs in the technology integration process. If pre-service teachers are asked to integrate technology in their future classrooms, changes in teaching beliefs from traditional to constructivist are recommended (Ertmer & Ottenbreit-Leftwich, 2013). Thus, teacher educators should understand pre-service mathematics teachers' pedagogical beliefs and perceptions in course design. To shape pre-service mathematics teachers' pedagogical beliefs in constructivism, teacher educators would train their students in more constructivist ways and model how to implement constructivist teaching strategies and activities for their students (Chan & Elliot, 2004).

One of the results of the current study indicated that attitude toward technology is the most influential factor on the intention to use technology. In addition, the prior experiences of pre-service mathematics teachers with technology shape their perceptions and attitudes toward its use in teaching. As Driskell et al. (2016) stated, to transform in-service mathematics teachers' knowledge and skills of effective technology integration, appropriate professional development opportunities are required. For example, to help pre-service teachers to gain experience in using technology and teaching with it, teacher education institutions should provide courses offering technology literacy and strategies to integrate technology into teaching mathematics. Different hardware such as interactive whiteboards and calculators, and software and applications such as Omnigraph, GeoGebra, Mathematica, and The Geometer's Sketchpad have been used to teach mathematics. To increase pre-service teachers' perceptions of the ease of use and usefulness of technology, pre-service mathematics teachers would experience different software more. Moreover, mathematics teacher educators could model how to use technology in teaching and encourage them to use technology in teaching practice.

## Conclusion

From the theoretical perspective, the findings of this study contribute to the technology acceptance by suggesting a new factor, pedagogical beliefs, that determines pre-service mathematics teachers' technology acceptance. More importantly, this research indicated that the modified version of TAM could be effective in explaining pre-service teachers' intention to use technology in a more comprehensive context. In the current research, pre-service mathematics teachers were more constructivist-oriented, and their constructivist pedagogical beliefs had positive influences on the perception of the easy use and usefulness of technology for teaching mathematics, and attitudes toward technology. On the other hand, traditional pedagogical beliefs did not have negative effects on perceived ease of use and usefulness, as well as attitudes toward technology.

**Funding** This study was not funded by any organizations/institutes.

**Declarations**

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical Approval** Approval was obtained from the social studies ethics committee of Bolu Abant Izzet Baysal University, Turkey. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

## References

Alburo, F. G. (2019). Mathematics teachers' pedagogical beliefs and practices: Does being 'conventional or constructivist matter?' *The Normal Lights, 13*(1), 83–107.

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin, 103*, 411–423.

Anderson, S. E., Groulx, J. G., & Maninger, R. M. (2011). Relationships among preservice teachers' technology-related abilities, beliefs, and intentions to use technology in their future classrooms. *Journal of Educational Computing Research, 45*(3), 321–338. https://doi.org/10.2190/EC.45.3.d

Aypay, A. (2011). The adaptation of the teaching-learning conceptions questionnaire and its relationships with epistemological beliefs. *Educational Sciences: Theory & Practice, 11*(1), 7–29.

Bagozzi, R. P. (2007). The legacy of the technology acceptance model and a proposal for a paradigm shift. *Journal of the Association of Information Systems, 8*(4), 244–254.

Bahcivan, E., Gurer, M. D., Yavuzalp, N., & Akayoglu, S. (2019). Investigating the relations among pre-service teachers' teaching/learning beliefs and educational technology integration competencies: A structural equation modeling study. *Journal of Science Education and Technology, 28*, 579–588. https://doi.org/10.1007/s10857-021-09504-5

Ball, L., Drijvers, P., Ladel, S., Siller, H.-S., Tabach, M., & Vale, C. (Eds.). (2019). *Uses of technology in primary and secondary mathematics education—tools, topics and trends*. Springer.

Barak, M. (2014). Closing the gap between attitudes and perceptions about ICT-enhanced learning among pre-service STEM teachers. *Journal of Science Education and Technology, 23*, 1–14.

Birch, A., & Irvine, V. (2009). Preservice teachers' acceptance of ICT integration in the classroom: Applying the UTAUT model. *Educational Media International, 46*(4), 295–315. https://doi.org/10.1080/09523980903387506

Bray, A., & Tangney, B. (2017). Technology usage in mathematics education research: A systematic review of recent trends. *Computers & Education, 114*, 255–273. https://doi.org/10.1016/j.compedu.2017.07.004

Bulut, O., & Cutumisu, M. (2018). When technology does not add up: ICT use negatively predicts mathematics and science achievement for Finnish and Turkish students in PISA 2012. *Journal of Educational Multimedia and Hypermedia, 27*(1), 25–42.

Cayton, C., Hollebrands, K., Okumuş, S., & Boehm, E. (2017). Pivotal teaching moments in technology-intensive secondary geometry classrooms. *Journal of Mathematics Teacher Education, 20*, 75–100. https://doi.org/10.1007/s10857-015-9314-y

Chan, K. W., & Elliott, R. G. (2004). Relational analysis of personal epistemology and conceptions about teaching and learning. *Teaching and Teacher Education, 20*, 817–831.

Chauhan, S. (2017). A meta-analysis of the impact of technology on learning effectiveness of elementary students. *Computers & Education, 105*, 14–30. https://doi.org/10.1016/j.compedu.2016.11.005

Cheung, A. C. K., & Slavin, R. E. (2013). The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: A meta-analysis. *Educational Research Review, 9*, 88–113.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use and user acceptance of information technology. *MIS Quarterly, 13*, 319–340.

Deng, F., Chai, C. S., Tsai, C. C., & Lee, M. H. (2014). The relationships among Chinese practicing teachers' epistemic beliefs, pedagogical beliefs and their beliefs about the use of ICT. *Journal of Educational Technology & Society, 17*(2), 245–256.

Driscoll, M. P. (2014). *Psychology of learning for instruction* (3rd ed.). Pearson.

Driskell, S. O., Bush, S. B., Ronau, R. N., Niess, M. L., Rakes, C. R., & Pugalee, D. (2016). Mathematics education technology professional development: Changes over several decades. In M. L. Niess, S. O. Driskell, & K. F. Hollebrands (Eds.), *Handbook of research on transforming mathematics teacher education in the digital age* (pp. 107–136). IGI Global.

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2013). Removing obstacles to the pedagogical changes required by Jonassen's vision of authentic technology-enabled learning. *Computers & Education, 64*, 175–182. https://doi.org/10.1016/j.compedu.2012.10.008

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education, 59*, 423–435.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis: A global perspective* (7th ed.). Pearson-Hall International.

Han, I., Shin, W. S., & Ko, Y. (2017). The effect of student teaching experience and teacher beliefs on pre-service teachers' self-efficacy and intention to use technology in teaching. *Teachers and Teaching: Theory and Practice, 23*(7), 829–842. https://doi.org/10.1080/13540602.2017.1322057

Howland, J. L., Jonassen, D. H., & Marra, R. M. (2011). *Meaningful learning with technology*. Pearson.

Ibili, E., Resnyansky, D., & Billinghurst, M. (2019). Applying the technology acceptance model to understand maths teachers' perceptions towards an augmented reality tutoring system. *Education and Information Technologies, 24*, 2653–2675. https://doi.org/10.1007/s10639-019-09925-z

Joubert, M. (2013). Using digital technologies in mathematics teaching: Developing an understanding of the landscape using three "grand challenge" themes. *Educational Studies in Mathematics, 82*, 341–359.

Kim, C., Kim, M. K., Lee, C., Spector, J. M., & DeMeester, K. (2013). Teacher beliefs and technology integration. *Teaching and Teacher Education, 29*, 76–85.

Kerlinger, F. N., & Kaya, E. (1959). The construction and factor analytic validation of scales to measure attitudes toward education. *Educational and Psychological Measurement, 19*, 13–29.

Kline, R. B. (2005). *Principles and practice of structural equation modeling* (2nd ed.). New York, NY.

Lai, T., & Lin, H. L. (2018). An investigation of the relationship of beliefs, values and technological pedagogical content knowledge among teachers. *Technology, Pedagogy and Education, 27*(4), 445–458.

Liu, H., Lin, C. H., & Zhang, D. (2017). Pedagogical beliefs and attitudes toward information and communication technology: A survey of teachers of English as a foreign language in China. *Computer Assisted Language Learning, 30*(8), 745–765. https://doi.org/10.1080/09588221.2017.1347572

Marban, J. M., & Mulenga, E. M. (2019). Pre-service primary teachers' teaching styles and attitudes towards the use of technology in mathematics classrooms. *International Electronic Journal of Mathematics Education, 14*(2), 253–263.

Mayer, R. E. (2003). Theories of learning and their application to technology. In H. F. O'Neil Jr. & R. S. Perez (Eds.), *Technology applications in education: A learning view.* Erlbaum.

McCulloch, A. W., Hollebrands, K., Lee, H., Harrison, T., & Mutlu, A. (2018). Factors that influence secondary mathematics teachers' integration of technology in mathematics lessons. *Computers & Education, 123*, 26–40. https://doi.org/10.1016/j.compedu.2018.04.008

National Council of Teachers of Mathematics [NCTM]. (2015). *Strategic use of technology in teaching and learning mathematics*. (Reston, VA: Author).
Pajares, M. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*, 307–332.
Pierce, R., & Ball, L. (2009). Perceptions that may affect teachers' intention to use technology in secondary mathematics classes. *Educational Studies in Mathematics, 71*(3), 299–317.
Psycharis, G., & Kalogeria, E. (2018). Studying the process of becoming a teacher educator in technology-enhanced mathematics. *Journal of Mathematics Teacher Education, 21*, 631–660. https://doi.org/10.1007/s10857-017-9371-5
Rokeach, M. (1968). *Beliefs, attitudes, and values*. Jossey-Bass Pub.
Šumak, B., Heričko, M., & Pušnik, M. (2011). A meta-analysis of e-learning technology acceptance: The role of user types and e-learning technology types. *Computers in Human Behavior, 27*(1), 2067–2077.
Tan, C. Y., & Hew, K. F. (2019). The impact of digital divides on student mathematics achievement in Confucian heritage cultures: A critical examination using PISA 2012 data. *International Journal of Science and Mathematics Education, 17*, 1213–1232. https://doi.org/10.1007/s10763-018-9917-8
Teo, T. (2010). A path analysis of pre-service teachers' attitudes to computer use: Applying and extending the technology acceptance model in an educational context. *Interactive Learning Environments, 18*(1), 65–79. https://doi.org/10.1080/10494820802231327
Teo, T. (2015). Comparing pre-service and in-service teachers' acceptance of technology: Assessment of measurement invariance and latent mean differences. *Computers & Education, 83*, 22–31. https://doi.org/10.1016/j.compedu.2014.11.015
Teo, T., & Milutinovic, V. (2015). Modelling the intention to use technology for teaching mathematics among pre-service teachers in Serbia. *Australasian Journal of Educational Technology, 31*(4), 363–380.
Teo, T., & Zhou, M. (2017). The influence of teachers' conceptions of teaching and learning on their technology acceptance. *Interactive Learning Environments, 25*(4), 513–527. https://doi.org/10.1080/10494820.2016.1143844
Teo, T., Ursavaş, O. F., & Bahçekapili, E. (2012). An assessment of pre-service teachers' technology acceptance in Turkey: A structural modeling approach. *The Asia-Pacific Education Researcher, 21*(1), 191–202.
ter Vrugte, J., de Jong, T., Vandercruysse, S., Wouters, P., van Oostendorp, H., & Elen, J. (2015). How competition and heterogeneous collaboration interact in prevocational game-based mathematics education. *Computers & Education, 89*, 42–52.
Thurm, D., & Barzel, B. (2020). Effects of a professional development program for teaching mathematics with technology on teachers' beliefs, self-efficacy and practices. *ZDM Mathematics Education, 52*, 1411–1422. https://doi.org/10.1007/s11858-020-01158-6
Tondeur, J., van Braak, J., Ertmer, P. A., & Ottenbreit-Leftwich, A. (2016). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educational Technology Research & Development, 65*(3), 555–575. https://doi.org/10.1007/s11423-016-9481-2
Tsai, C. C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning, and science. *International Journal of Science Education, 24*(8), 771–783.
Ursavaş, Ö. F., Şahin, S., & McIlroy, D. (2014). Technology acceptance measure for teachers: T-TAM. *Journal of Theory and Practice in Education, 10*(4), 885–917.
Wenglinsky, H. (1998). *Does it compute? The relationship between educational technology and student achievement in mathematics*. Educational Testing Service.
Wong, G. W. (2015). Understanding technology acceptance in pre-service teachers of primary mathematics in Hong Kong. *Australasian Journal of Educational Technology, 31*(6), 713–735.
Woolfolk, A. (2016). *Educational psychology* (13th ed.). Pearson.
Yang, X., & Leung, F. K. S. (2015). The relationships among preservice mathematics teachers' beliefs about mathematics, mathematics teaching, and use of technology in China. *Eurasia Journal of Mathematics, Science & Technology Education, 11*(6), 1363–1378.