Investigating models for preservice teachers’ use of technology to support student-centered learning

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Abstract

The study addressed two limitations of previous research on factors related to teachers’ integration of technology in their teaching. It attempted to test a structural equation model (SEM) of the relationships among a set of variables influencing preservice teachers’ use of technology specifically to support student-centered learning. A review of literature led to a path model that provided the design and analysis for the study, which involved 206 preservice teachers in the United States. The results show that the proposed model had a moderate fit to the observed data, and a more parsimonious model was found to have a better fit. In addition, preservice teachers’ self-efficacy of teaching with technology had the strongest influence on technology use, which was mediated by their perceived value of teaching and learning with technology. School’s contextual factors had moderate influence on technology use. Moreover, the effect of preservice teachers’ training on student-centered technology use was mediated by both perceived value and self-efficacy of technology. The implications for teacher preparation include close collaboration between teacher education program and field experience, focusing on specific technology uses.

1. Introduction

Information and communication technology (ICT) has been a component in many recent educational reforms in many countries. In the UK, British Educational Communications (Becta) initiated the Next Generation Learning campaign to ensure the effective and innovative use of ICT in education. In the US, Cuban (1986, 2001) argues that historically American educators have pursued the use of technology in the classroom as part of an attempt to increase productivity and efficiency. Teachers are on the frontline of educational reforms. To improve the education of teachers in technology integration, both Becta (2009) and the International Society of Technology in Education (ISTE, 2008) have developed a set of technology guidelines and standards for teachers, students, and other stakeholders. These guidelines and standards have been widely adopted, adapted, or otherwise referenced in country/state’s and local educational institution’s technology plans and standards.

Thus, teachers have become expected to incorporate technology into their curricula. However, research has found that many teachers do not use technology in their teaching or use it effectively despite the availability of hardware and software (Cuban, 2001; Harrison et al., 2002; Henning, Robinson, Herring, & McDonald, 2006). Numerous studies are conducted to examine factors that are related to teachers’ use of technology in classrooms (Baek, Jung, & Kim, 2008; Norton, McRobbie, & Cooper, 2000; see more examples in the following discussion and Section 2).

There are two limitations of the “factor research.” First, teachers’ use of technology is not clearly defined. As Drent and Meelissen (2008) aptly pointed out that:

Most of the research on the implementation of ICT in schools is focusing on factors that influence the use of ICT in general. It is often assumed that the use of ICT will lead to changes in learning arrangements and teaching methods but factors influencing innovative ICT-use are not explicitly analysed (p. 188).

Here “innovative use” means to use ICT to support student-centered learning instead of teachers using technology to prepare lessons, finding information, or doing e-mail. Indeed, Becta’s survey showed that technology was used by teachers primarily for presentational purposes rather than as a means to engage students in learning activities (Smith, Rudd, & Coghlan, 2008). According to Wozney, Venkatesh,
teachers’ use of computer technology was predominantly for informative (Internet and CD-ROM), expressive (word processing), and administrative and evaluative (data keeping, lesson planning, and testing) purposes. Thus, research on teachers’ use of technology should clearly define how technology is used, especially to provide opportunities for students to learn with technology.

The second limitation is that many researchers do not attempt to distinguish the relative importance of the factors or the distinction is rudimentary. In Franklin’s study (2007), all factors were considered to significantly influence teachers’ technology use, a finding that does not shed much new light on the field of technology and teacher education. Ertmer, Ottenbreit-Leftwich, and York (2006) moved a little further and concluded that intrinsic factors (such as beliefs, confidence, and commitment) were stronger than extrinsic factors (such as access to technology, support, and time). In this study, the researchers used mean scores of the factors as indicators of importance. But comparing means does not take into account the complex correlations among the factors and thus not adequate. In short, readers of this type of research are left to wonder about the subtle ways the factors encourage or impede technology use. Does teachers’ training in technology directly related to their use of technology? Or is this influence mediated by other factors such as teachers’ beliefs about teaching and technology?

Methodologically, structural equation modeling (SEM) can help researchers answer these questions. For example, Y.-L. Chen (2008) tested a SEM model that predicted the level of Internet use by English teachers in Taiwan. Teo (2009) attempted to build a SEM model to predict preservice teachers’ level of technology acceptance. Wang, Wu, and Wang (2009) proposed a SEM model to account for adults’ intention to use mobile learning (by means of wireless Internet and mobile devices such as cell phones, PDAs, and digital audio players). In these studies, the researchers were able to specify a path model to predict or explain the determinants of people’s intention or use of technology. Although these studies address the second limitation by decomposing differentiated effects of factors on technology use, they fall short of addressing the first limitation and fail to clearly define how technology is used. For example, in Teo’s study, preservice teachers’ behavioral intention to use technology was measured by two general items on the questionnaire: “I will use computers in future” and “I plan to use the computer often” (p. 311). It is not clear how exactly technology would be used in instructional activities.

The current study attempted to address the above two limitations. It sought to build a SEM model that accounts for preservice teachers’ use of technology to support students’ learning with technology. Based on a review of literature on psychology, teacher education, and educational technology, an initial theoretical model was proposed. SEM analysis was conducted to investigate to what degree the model fitted the data collected from 206 preservice teachers. The model fitted the data well, and an alternative, more parsimonious model was found to have a better fit. Both models were formulated in accordance with previous research, and meaningful interpretation was given to every parameter of the model. In addition, the current study sought to decompose the effect of each factor into direct and mediated effects. In short, the following research questions guided the design and data analysis of the study:

1. How does the SEM model fit the data? Is there an alternative model with a better fit?
2. What is the relative importance of the variables in explaining preservice teachers’ use of technology to facilitate student-centered learning?

Answers to these questions would help to assess the usefulness of the proposed theoretical model. The investigation would also shed some light on variables that affect preservice teachers’ decision making and their acceptance of or resistance to technology in the classroom.

2. Theoretical framework that leads to the proposed model

The SEM model in the study was derived from an in-depth review of the literature pertaining to psychology theories on human behavior and preservice teachers’ learning to teach with technology. A special attention was given to identifying factors that are involved in preservice teachers’ thought process and perceptions of support as they consider using technology in their teaching.

2.1. Training in technology

2.1.1. Technology skills and experience

Various quantitative, qualitative, and mixed-methods studies have shown that, whether novice or veteran, teachers’ competency in using ICT is a strong determinant of their level of technology use in classrooms (Bauer & Kenton, 2005; Demetriadis et al., 2003; Franklin, 2007; Wozney et al., 2006). It is not surprising that preparation of technology proficient preservice teachers was an emphasis of many Preparing Tomorrow’s Teachers to Use Technology (PT3) grants in the United States (Mims, Polly, Shepherd, & Inan, 2006). These programs focused on improving preservice teachers’ skills in using various hardware and software for teaching and learning.

Preservice teachers can gain these skills and experiences from their teacher education programs as well as field practicum. Accordingly, Schrum (1999) argued that three aspects of experience are crucial for preservice teachers to learn about and integrate technology in their teaching. First, preservice teachers must be exposed to various types of technology tools in skill-based courses. Second, they need to learn how these technology tools can be integrated in subject areas in the methods courses. Finally, they need to be placed in a technology-rich field environment where they can receive on-going guidance as they implement technology-supported lessons. In other words, preservice teachers’ obtaining technology skills need to be complemented by pedagogical knowledge and extensive practice of how to use their technology skills to augment student learning.

At any rate, technology skills remain at the core of many ICT courses for preservice teachers and professional development programs for inservice teachers. However, Sandholtz and Reilly (2004) raised an interesting point by arguing that, while teachers’ technology skills are an important factor, it is not a prerequisite for successful integration of technology in curriculum. With adequate and reliable access to hardware and software, professional development program that focuses on instructional rather than technical issues, and effective technical support, teachers can move quickly to productive and creative uses of computers in classrooms.
2.1.2. Teacher education program

Sandholtz and Reilly (2004) pointed out the role of teacher education program in teachers’ learning to teach with technology. Chen and Ferneding (2003) found that preservice teachers’ perceptions about how their teacher education programs promoted the educational use of ICT were a strong factor influencing their intention and use of technology resources in their practicum. This finding is corroborated by the results of the factor analysis conducted by Franklin's (2007), who found that teacher preparation was one of a few key factors associated with classroom use of technology, implying that curriculum integration of technology into methods courses would influence novice teachers’ use of technology in their teaching. This also means that university faculty's proficiency in technology and their attitudes toward ICT in education can influence the type of experience preservice teachers receive in their programs (Mims et al., 2006). Faculty members are encouraged to learn about and then model how technology can be incorporated in content area teaching and learning.

2.2. Perceived value and self-efficacy

The expectancy–value theory (e.g., Feather, 1982; Wigfield, 1994) proposes that people’s intention to perform a particular task is a function of two variables. First, people must believe that there are benefits in performing a task; in other words, they will determine the value of performing an action, and this determination will influence their behavior intention. Second, people must believe they can succeed; in other words, they must have a high expectancy about their task performance. This notion is similar to social learning theorists’ concept of self-efficacy (Bandura, 1977), which refers to the idea that people are likely to perform a certain behavior when they believe they are capable of performing the behavior successfully.

The expectancy–value theory was used by Wozney et al. (2006) in their development of a comprehensive questionnaire to examine teachers’ personal and instructional use of technology. They found that teachers’ expectancy of success and perceived value were the most important factors accounted for their levels of computer use; teachers who believed that technology can greatly improve teaching and learning tended to be creative in technology use. Indeed, recent research demonstrates that both preservice and in-service teachers’ pedagogical beliefs about the appropriate role of ICT in education are a critical indicator for classroom use of technology (Czerniak, Lumpe, Haney, & Beck, 1999; Ertmer, 2005; Guerrero, Walker, & Dugdale, 2004; Schmidt, 1999).

2.3. School context

Teachers’ use of technology is influenced by organizational context, in addition to teachers’ beliefs and other technology-related factors (C.-H. Chen, 2008; Clausen, 2007; Hermans, Tondeur, van Braak, & Valcke, 2008; Higgins & Spithulnik, 2008; Hu, Clark, & Ma, 2003; Lim & Chai, 2008; Schrum, 1999; Tearle, 2003). Specifically, research has shown that access to technology, a supportive school culture, and adequate time for preservice teachers to explore educational technology are essential for successful technology integration. A discussion of each of these issues is provided in the following.

First of all, access does not mean only the availability of hardware and software but also the appropriate type of technology and programs that support teaching and learning (Tondeur, Valcke, & van Braak, 2008). Access to appropriate technology means that the affordances and constraints (Freidhoff, 2008) of a technological tool need to be carefully considered when the tool is incorporated in the lesson. Moreover, a distinction of access needs to be made. Typically, teachers have easier access to technology than students. For example, in Dexter and Reidel's (2003) study of preservice teachers during their student teaching, nearly twice as many preservice teachers (34.7%) indicated that computers were available for teacher use compared with being available for student use (14.4%). Clearly, a student-centered approach to technology integration calls for students’ access to quality technology resources.

A supportive culture at the school site where preservice teachers’ practicum occurs is another important factor. Necessary support from administration, cooperating teachers, and other teachers and technical staff has been shown as a key factor influencing preservice teachers’ intention and use of technology resources (Bullock, 2004; Dexter & Riedel, 2003). Particularly for preservice teachers, the practicum experience will be conducive to professional growth in ICT if they are placed in an encouraging environment in which they can feel comfortable to try and even to fail as they integrate technology in their teaching. Moreover, one-on-one technology support was considered a necessary part of many projects aimed at improving preservice teachers’ capacity to use technology in their teaching (Mims et al., 2006).

Finally, time is often cited as a key factor influencing teachers’ use of technology (e.g., Franklin, 2007), even for “tech-savvy” teachers (Bauer & Kenton, 2005). The issue of time is dire for preservice teachers in their practicum as they work very hard to learn about the school and students and prepare new lessons. Time is a deciding factor for the extent of effort preservice teachers can devote themselves in exploring new ideas and materials, organizing various technology resources for effective student learning, working with cooperating teachers, and reflecting on their teaching (Bullock, 2004; Russell, Bebell, O'Dwyer, & O'Connor, 2003).

2.4. Types and ways of preservice and new teachers’ technology use

As stated in Section 1, many studies examining factors associated with teachers’ use of technology fail to identify the types of technology in the classrooms or how it is used. In fact, “technology use” is defined very differently in research, and many studies involve a generic notion of teachers’ use of technology. The following two studies are exceptions.

Dexter and Riedel (2003) surveyed 201 preservice teachers about their use of different types of technology and the conditions facilitating or otherwise affecting that use during student teaching. Word-processing programs and Internet browsers were commonly used by these preservice teachers. Spreadsheet, presentation, and database programs were not used often. In addition, the study showed that students were not given adequate opportunities to use these technological tools. In general, students occasionally used word processors and the Internet, and they rarely used spreadsheet, presentation, or database programs in their learning.

Russell, Bebell, O’Dwyer, and O’Connor (2003) investigated the relationship between teachers’ years of teaching experience and the manners technology was used in their study of 2894 K-12 teachers in Massachusetts, United States. A special attention was given to understanding how new teachers (defined as those with less than 5 years of teaching experience) used technology in their teaching compared with matured teachers (with 6–10 years of experience) and retirement-age teachers (with more than 15 years of experience). The comparisons were organized into the following four ways of technology use: (a) teacher use of technology for preparation, (b) teacher use of e-
mail, (c) teacher use of technology for delivery of lessons, and (d) teacher-directed student use of technology. The results showed that new teachers had a higher level of preparation use than both the matured and retirement-age teachers and that new teachers used e-mail more intensively than retirement-age teachers. However, new teachers had lower level of teacher-directed student use than either mature teachers or retirement-age teachers.

Russell, Bebell, O’Dwyer, and O’Connor (2003) noted that, although new teachers had higher technology skills than veteran teachers, they did not display higher levels of technology use in the classroom, especially in the student use category. The researchers provided two reasons. First, new teachers could focus on learning about how to use technology rather than on how to integrate technology in the content areas. Second, the first few years of teaching are challenging, and new teachers typically spend most of their time and energy in getting acquainted with curriculum and classroom management instead of technology integration. The researchers discussed implications for preparation of preservice teachers and argued for a focus on specific instructional uses of technology instead of general technology skills.

Similar to the teacher-directed student use of technology in Russell et al. (2003) research, the current study focuses on preservice teachers’ instructional use of technology to facilitate student-centered learning. This refers to the degree to which participating teachers provided opportunities for students to use technology to do projects, collect information/data, and share their ideas with peers by means of classroom presentations. Therefore, the following activities are not considered: Teachers’ use of software programs to gather information, write up lesson plans, and prepare instructional materials; teachers’ use of PowerPoint, document scanner, and interactive whiteboard to present lessons; teachers’ use of e-mail, blog, and Web 2.0 applications for communication purposes.

3. Methods

The main purpose of the study was to develop a SEM model that adequately represents factors influencing preservice teachers’ use of technology resources to support student-centered learning. Based on the above review of research, these factors are: Preservice teachers’ training in teaching with technology, perceived value of technology integration, perceived self-efficacy of teaching with technology, and contextual factors at the school site of their practicum. Each of these latent constructs has two to three indicators (see Table 1). Data were collected via surveying 206 preservice teachers during their student teaching. AMOS statistics software program was used to calculate parameter estimates and analyze the model fit.

3.1. Instruments and variables

A questionnaire was developed to measure the variables in the SEM model. The questionnaire consisted of both published (Cassidy & Eachus, 2002; McGinnis et al., 2002) and researcher-developed instruments. A description of each variable is provided in Table 1 (see Section 2 for a discussion of each of these variables and indicators).

3.2. Participants and data collection methods

Two methods were used to collect data from preservice teachers in a comprehensive university in the United States. First, an e-mail invitation was sent to 115 preservice elementary teachers to complete the on-line version of the questionnaire. The participation was voluntary and anonymous. With a few reminders, 78 of them (or 68%) successfully completed the on-line survey. This process took 2 weeks near the end of the preservice teachers’ student teaching experiences. In addition, to increase the return rate, the paper-based version of the questionnaire was distributed by the researcher to 136 preservice secondary teachers during methods classes. This survey was also anonymous. Eight teachers’ responses were not complete and were excluded from the sample. Therefore, the final sample consisted of 206 preservice teachers. The overall return rate for both surveys was 82%. A convenient sample was used to include as many preservice teachers as possible on this campus because the SEM in the study required a relative large sample, preferably 150 participants and more. The participants were between 22 and 31 years old. Among them, 28 were male, and 178 were female. On average, they used the computer 14.3 hours per week. It took approximately 20 minutes for the participants to complete the questionnaire.

3.3. Statistical analysis: structural equation modeling (SEM)

According to Pedhazur (1997), growing out of multiple regression, SEM is a more powerful way for testing the tenability of causal models involving a set of independent and dependent variables. Unlike multiple regression, SEM takes into account measurement errors, correlated residuals, modeling of interactions, nonlinearities, and correlated independence. It is particularly useful in social and behavior research where many variables (e.g., motivation, anxiety, and attitudes) are not directly observable. In SEM, such a variable is called a latent variable. To capture validly and reliably of such a latent variable, more than one single indicator (observable variable) are necessary. SEM also has the ability to model mediating variables rather than be restricted to an additive model. In other words, SEM allows researchers to decompose the relationship between two variables into direct, indirect (through mediators), unanalyzed (due to correlated causes), and spurious (due to common causes) effects. The sum of direct and indirect effects is the total effect. Moreover, researchers can use SEM to compare alternative models to assess relative model fit, which is adopted in the current study.

3.3.1. Model specification and identification

Fig. 1 illustrates the proposed model that guided the design and analysis of this study. This model is based on a careful review of literature (see Section 2) and Technology Acceptance Model (TAM), proposed by David, Bagozzi, and Warshaw (1989), which is widely used to predict and explain the determinants of computer acceptance in an organization. In TAM, two particular user perceptions, perceived usefulness and perceived ease of use of the target technology system are considered to be of primary relevance for people’s attitude toward and intention to use the technology. According to TAM, perceived ease of use (which is compared to the latent variable EFFICACY in the current study) influences perceived usefulness (which is compared to the latent variable VALUE in the current study). Therefore, it is hypothesized that TRAINING affects two endogenous variables – VALUE and EFFICACY, and that EFFICACY affects VALUE. Note that TRAINING is an exog-
enous variable whose variation is assumed to be determined by causes outside the model. Another exogenous variable is CONTEXT. It is hypothesized that CONTEXT, VALUE, and EFFICACY have a direct effect on USE. Lastly, TRAINING has an indirect effect on USE via VALUE and EFFICACY.

3.3.2. Model evaluation and modification

The hypothesized model needs to be tested to see how closely the model matches the data. The $\chi^2$-test is the basis for the model fit test, which addresses the question whether the model differs significantly from one that fits the data perfectly. AMOS reports $\chi^2$ value, its degrees of freedom, and significance level that help determine model fit. However, $\chi^2$-test is sensitive to sample size and the assumption of multivariate normality of the variables. Pedhazur (1997) suggests that researchers use $\chi^2$-test as a measure of fit and that the degrees of freedom serve as a standard by which to judge whether $\chi^2$ is large or small. One common way is to calculate $\chi^2/df$, and a small ratio is considered a good fit. A popular rule of thumb is that the $\chi^2/df$ ratio is less than 3 for a good fit. However, some researchers question the validity of such a rule of thumb. Therefore, other indicators of model fit are needed. See Table 6 for a summary of a few commonly used indexes of model fit. If a proposed model does not fit the data, researchers can test alternative models for goodness-of-fit and parameter estimates. However, model modification should be based on sound theories and established research rather than merely increasing the model fit indexes.

4. Results

4.1. Descriptive statistics and correlations

The descriptive statistics of the observed variables and internal consistency (Cronbach's $\alpha$ values) are listed in Table 2. Kline (2005) posits that an $\alpha$ value of .90 and up is considered excellent, .80 very good, and .70 acceptable. Accordingly, the observed variables in this study had good internal consistency. The correlations among these variables are reported in Table 3.
4.2. Measurement model

The reliability and validity of the measurement model need to be satisfactory before proceeding to the structural model. The factor loadings for the measurement model are listed in Table 4. These factor loadings indicate the relationship between a latent variable and each of its constituent observable indicators. The results show that the majority of the factor loadings were above 0.70, which indicated an internally consistent measure. For CONTEXT, the factor loading of Access was low, at 0.28, in the initial model. This observation suggests the removal of Access from the model.

The reliability and convergent validity of the latent variables were estimated by construct reliability and average variance extracted, both can be derived from the factor loadings. Specifically, construct reliability = \( \frac{\text{R}_{\text{standardized loading}}^2}{\text{R}_{\text{standardized loading}}^2 + R_{ej}} \), where \( R_{ej} \) is the measurement error of each indicator. Average variance extracted = \( \frac{\text{R}_{\text{standardized loading}}^2}{\text{R}_{\text{standardized loading}}^2 + R_{ej}} \). The results are reported in Table 5.

To be considered adequate, construct reliability should be at least 0.70, and average variance extracted should be at least 0.50. Based on these guidelines, in the initial model, CONTEXT had inadequate reliability and validity because of the low factor loading of Access (0.28, see Table 4). The revised model did not include Access, and all latent variables in the revised model had satisfactory reliability and convergent validity.

4.3. Model fit

A test of model fit indicates the degree of alignment between the theorized model and the collected data. As stated in Section 3.3.2, various indicators should be considered to provide a broad picture of how the model matches the data. These indicators are reported in Table 6. The fit indicators showed a moderate fit of the initial model.

4.4. An alternative model

AMOS reports model modification indexes that can help increase model fit. However, any changes to the initial model should be based on previous research and sound theories instead of merely statistically significant changes. Two changes were made to the initial model. First, a correlation was established between Skill and Computer Self-efficacy. The reason was that teachers with advanced technology skills tend to have...
high self-efficacy with regard to technology integration (Ropp, 1999). Second, parsimony is another consideration for model modification. It is hoped that a model can explain a phenomenon using a small set of variables and relationships. In the initial model, the factor loading of Access to CONTEXT was low. It was removed from the initial model. Applying the above two changes to the initial model improved the model fit. The fit indicators are summarized in Table 6. It is apparent that the revised model had a better fit than the original model.

The above indexes are for overall model fit. It is also necessary to examine individual components. It is possible that the fit of some portion of the model is poor despite a good overall model fit. Inspection of the residual covariances can help to identify particular observed associations that are poorly explained by the model. For instance, the observed covariance between Program and Skill was 9.396, and the predicted covariance between these two variables was 9.527. The residual covariance was therefore $0.131 (9.396 – 9.527)$, which was $0.099$ when standardized. Since the size of residuals is affected by the units of the measures of the observed variables, standardized residuals were used. Table 7 contains the standardized residual covariances in the upper triangle and the observed covariances in the lower triangle.

Pedhazur (1997) suggests that a standardized residual is considered large if it is greater than 2.58 in absolute value. Accordingly, the standardized residual covariances in Table 7 were considered small. Therefore, each component of the model was a good fit to the observed data.

4.5. Structural equation model

The revised structural equation model is shown in Fig. 2. USE was significantly determined by CONTEXT ($\beta = 0.43, p < 0.001$), VALUE ($\beta = 0.18, p = 0.02$), and EFFICACY ($\beta = 0.45, p < 0.001$). These three factors accounted for an $R^2$ of 0.72, indicating that the exogenous variable, USE, could be strongly predicted. In addition, TRAINING significantly influenced VALUE ($\beta = 0.49, p < 0.001$) and EFFICACY ($\beta = 0.60, p < 0.001$). The correlation between the two exogenous factors, CONTEXT and TRAINING, was $0.88$ with $p < 0.001$. That is, preservice teachers’ training in teaching with technology was highly related to how they perceived the resources and support at the school site.

| Table 4 |
| Factor loadings for the measurement model. |
| Latent variable | Indicator | Standardized loading |
| | | Initial model | Revised model |
| TRAINING | Program | .72 | .74 |
| | Skill | .80 | .79 |
| VALUE | Teaching belief | .77 | .76 |
| | Learning belief | .77 | .77 |
| EFFICACY | Computer self-efficacy | .79 | .77 |
| | Teaching w/technology | .86 | .89 |
| CONTEXT | Support | .69 | .68 |
| | Time | .77 | .80 |
| | Access | .28 | – |
| USE | Info and data | .82 | .82 |
| | Presentation | .88 | .88 |
| | Project | .64 | .64 |

| Table 5 |
| Reliability and convergent validity of the latent variables. |
| Latent variable | Construct reliability | Average variance extracted |
| | | Initial model | Revised model |
| | | Initial model | Revised model |
| TRAINING | 0.733 | 0.739 | 0.579 | 0.586 |
| VALUE | 0.744 | 0.738 | 0.593 | 0.585 |
| EFFICACY | 0.811 | 0.818 | 0.682 | 0.693 |
| CONTEXT | 0.620 | 0.709 | 0.382 | 0.551 |
| USE | 0.827 | 0.827 | 0.619 | 0.619 |

| Table 6 |
| Model fit indicators of the initial and revised models. |
| Indicator | Suggested guidelines | Initial model | Revised model |
| | | | |
| $\chi^2 (p)$ | – | 81.92 (.001) | 41.41 (.246) |
| df | – | 47 | 36 |
| $\chi^2/df$ | $\leq 3$ | 1.74 | 1.15 |
| GFI | $\geq 0.9$ | 0.935 | 0.962 |
| AGFI | $\geq 0.8$ | 0.893 | 0.931 |
| CFI | $\geq 0.9$ | 0.964 | 0.994 |
| SRMR | $\leq 0.10$ | 0.047 | 0.037 |
| RMSEA | $\leq 0.05$ | 0.060 | 0.027 |

Note: df: degrees of freedom; GFI: goodness-of-fit index; AGFI: adjusted goodness-of-fit index; CFI: comparative fit index; SRMR: standardized root mean-square residual; RMSEA: root mean-square error of approximation. The suggested guidelines are based on Bollen (1989), Kline (2005), and Pedhazur (1997).
4.6. Direct and indirect effects on USE

Table 8 contains the direct and indirect effects of each of the factors on preservice teachers’ use of technology. EFFICACY had the strongest total effect on USE among the four factors. Thus, preservice teachers’ perceived confidence in using computers in general and integrating technology in their teaching in particular was a strong determinant of their decisions to use technology to facilitate students’ learning with technology. Most of the total effect of EFFICACY on USE was a direct effect; the indirect effect mediated by VALUE was very weak.

The school context was also an important determinant. CONTEXT, measured by preservice teachers’ perceived level of support and adequate time for technology use, had a moderate direct impact on preservice teachers’ providing opportunities for students to learn with technology.

TRAINING did not have a direct effect on USE but a moderate indirect effect via both VALUE and EFFICACY. Thus, preservice teacher’s levels of technology skills and their teacher education experience had a moderate impact on preservice teachers’ providing opportunities for students to learn with technology.

VALUE had a weak direct effect on USE. In other words, after accounting for the effects of other factors on USE, preservice teachers’ perceived value of using technology in the teaching and learning process had only a small influence on USE.

Table 8

<table>
<thead>
<tr>
<th>Variable</th>
<th>Direct effect</th>
<th>Indirect effect</th>
<th>Total effect</th>
</tr>
</thead>
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<tr>
<td>TRAINING</td>
<td>.43</td>
<td>.36</td>
<td>.36</td>
</tr>
<tr>
<td>CONTEXT</td>
<td>.18</td>
<td></td>
<td>.18</td>
</tr>
<tr>
<td>VALUE</td>
<td>.45</td>
<td>.03</td>
<td>.48</td>
</tr>
</tbody>
</table>

Note: Upper triangle: standardized residual covariances; lower triangle: observed covariances.

Fig. 2. SEM model of preservice teachers’ use of technology with standardized parameter estimates.
5. Discussion and conclusion

Although research abounds on factors influencing teachers’ use of technology, the current study involved SEM and contributed beyond confirming conventional wisdom developed over the years. Research indicates that the introductory step for computers in school is using them in administrative tasks and not as part of the learning process (Demetriadis et al., 2003). The current research focused on teachers’ use of technology specifically to support student-centered learning. Moreover, this study systematically analyzed a wide array of factors influencing preservice teachers’ use of the technological resources available to them. The resulting model revealed the relative importance of these factors in terms of their direct and mediated effects instead of merely providing a list of factors.

5.1. Implications for teacher education

These factors can be roughly divided into two categories, and a close relationship exists between them. First, TRAINING, VALUE, and EFFICACY are intrinsic to preservice teachers. They refer to preservice teachers’ technology skills, teacher education program experiences, and underlying (sometimes deeply ingrained) beliefs and perceived efficacy about teaching and learning with technology. Together, these three intrinsic constructs had a strong influence on preservice teachers’ use of technology. EFFICACY (effect size = 0.48) was the strongest determinant of technology use, followed by TRAINING (effect size = 0.36). VALUE’s influence was weak (effect size = 0.18).

Recall that the expectancy–value theory stipulates that people’s perceived value and self-efficacy of performing a task determine their intention to do so (see Section 2.2), but the theory does not specify the relative importance of these two factors. The current study shows that, self-efficacy had a stronger influence than perceived value in terms of technology integration. This confirms a previous research finding that although most teachers see the value and benefits of technology in education, many do not use technology in their teaching (OTA, 1995). Preservice teachers’ perceived ability to use technology effectively and produce the desired results is a deciding factor.

Previous research (e.g., Becker, 1994; Ertmer et al., 2006) addresses the influence of teachers’ training on their decisions to use technology, assuming that such influence is direct. However, the resulting model in the current study shows that the influence of TRAINING on preservice teachers’ use of technology was mediated by both VALUE and EFFICACY. This finding shows that preservice teachers’ perceptions of the benefits of ICT and their perceived efficacy of teaching with technology act as mediators that shape how preservice teachers’ training is enacted in their decisions on technology use. Indeed, the purpose of training is to help preservice teachers appreciate the value and become aware of the strengths and limitations of ICT and to boost their self-efficacy of teaching with technology, hoping to promote effective use of ICT for students’ meaningful learning.

Another category includes factors that are extrinsic to preservice teachers. The construct CONTEXT refers to preservice teachers’ perceptions about the instructional resources (technological equipment, time, and support) available at the school site. This factor had a moderate influence on preservice teachers’ use of technology (effect size = 0.43). However, it is naive to assume that as long as adequate resources and support are provided to teachers, technology integration would follow (Ertmer, 2005), as other factors can be involved. Indeed, the results of the study show that the correlation between CONTEXT and TRAINING was 0.68. This high correlation indicates that preservice teachers’ levels of technology skills and their teacher education experience are related to how they perceive the resources and support at the school site. Preservice teachers who have significant amount of training may not consider lack of adequate equipment, time, and support as deterrents; it is possible that they have skills and positive dispositions to better overcome the challenges in technology integration than teachers who have limited amount of training in technology.

The high correlation between CONTEXT and TRAINING also implies that efforts to prepare new teachers to use technology effectively should synchronize coursework with field experiences. A possible gap can exist between these two venues: preservice teachers with adequate training in ICT in coursework may not be placed in a supported student teaching site that facilitates effective use of ICT in lessons. If possible, teacher education providers should seek out field sites with ample technology resources and supports. Dexter and Riedel (2003) argued that teacher education programs should set high expectations for preservice teachers’ use of technology during student teaching and that both cooperating teachers and university supervisors need preparation to know how to facilitate student teachers’ technology integration.

Since preservice teachers work very closely with their cooperating teachers during student teaching, teacher education programs can deliberately train cooperating teachers so they can provide necessary support and facilitate technology integration. Dexter and Riedel (2003) suggested three approaches: (a) developing cooperating teachers’ expertise through workshops, (b) encouraging cooperating teachers to plan technology projects with preservice teachers, and (c) implementing field-based faculty modeling that involves concrete examples of technology integrated into curriculum. Together, these approaches can help boost preservice teachers’ beliefs and self-efficacy of integrating technology in their teaching, which are shown in this study to mediate technology use.

Moreover, Russell, Rebell, O’Dwyer, and O’Connor (2003) suggested that preparing teachers, both preservice and inservice, to use technology should focus on specific instructional uses of technology rather than on familiarizing them with technology in general. As discussed in Sections 1 and 2, commentators often treat teachers’ use of technology as one generic construct rather than a complex phenomenon. Due to the multi-dimensional nature of technology use, it will be effective if teacher education providers distinguish various types of technology uses and articulate each use. In particular, the current study investigates preservice teachers’ use of technology to support student-center learning, and thus an implication for teacher education is that effort to train preservice teachers to use technology can focus on designing and implementing technology-supported projects where students use technology in their learning. For example, this particular manner of technology use in mathematics education is the focus in the edited book by Masalski and Elliott (2005). Preservice teachers can benefit from seeing how technology can be specifically integrated and become immanent in the curriculum, not as an addition to existing lessons.

5.2. Limitations and implications for future research

A limitation of the current study is that self-report scales were used to measure the variables for analysis. The results can be biased because the participants might give socially desirable responses, especially when the researchers were course instructors. The second limitation pertains to the particular group of preservice teachers in the study. Rather than random sampling, a convenient sample was used. A
description of the characteristics of the participating teachers is provided in Section 3.2. Research involving both similar and different teacher characteristics can be conducted to exhaust this line of inquiry so that we can gain a deeper and broader understanding of the phenomenon.

Another limitation of the current study is that CONTEXT did not address the “soft” aspect of the social and contextual factors in teachers’ daily decision making regarding technology integration in their teaching. Cuban (1986, 2001) has developed a construct, “situationally constrained choice,” for understanding classroom teachers’ decisions on classroom strategies and in particular on technology use. He argues that teachers’ decision making is strongly shaped by school and classroom settings, including school schedules, curriculum, and the culture of teaching. Teachers also take a very practical stance toward what to do and how to do things in order for them to “survive” in the classroom. In fact, Cuban’s review of the history of the diffusion of technology in American schools has suggested that teachers’ practical and tacit knowledge plays a fundamental role in their decisions about adopting new instructional strategies and technology.

Thus, future research can include these considerations. Specifically, Cuban’s notion of teachers’ “situationally constrained choice” can be a latent variable, which is particular suited to a SEM analysis. It is not possible to capture validly and reliably such a complex construct with a single observable variable. Instead, this latent variable can include multiple indicators such as preservice teachers’ perceptions about the curriculum standards and pacing guides they need to address, the types of lessons they are expected to teach (see Henning et al., 2006), and their perceptions about students. Indeed, SEM allows for testing of alternative models that can adequately stipulate the relationships among variables and to what extent each variable influences or mediates the effects of other variables. Pedhazur (1997) emphasizes the importance of testing alternative models because researchers cannot exclude the explanations they have not considered. However, formulation of meaningful alternative models should be based on theories rather than assumptions.

To summarize, the study addressed two limitations of previous research. First, the study involved a SEM analysis of factors that influence preservice teachers’ adoption of ICT. It sought to unveil the relative weights of these intercorrelated factors rather than merely identifying a list of significant factors. Second, preservice teachers’ use of technology was specifically defined as facilitating a student-centered approach to teaching. However, the concealed nature of teachers’ belief systems and the complexity of classroom context bring challenges and limitations to the study. A few strategies for future research are provided to overcome these challenges and limitations and to increase our understanding of teachers’ decision making concerning the educational use of technology. Such an understanding is crucial for improving the learning experience of preservice teachers in a teacher education program.

Teachers have been blamed by technology proponents for resisting or slow adopting technology in teaching (Ferneding, 2003). Indeed, commentators of teachers’ learning to teach with technology can have a pathological tone. In particular, technology-using teachers are regarded as “normal” and “healthy.” Teachers who doubt or resist technology are seen as anomalies who need to be treated. What is missing in this pathological approach to studying teachers’ process of technology adoption is a genuine and multi-dimensional understanding of the complexity of such a process. The present study addresses this process from a specific perspective by utilizing a SEM analysis. This vision is partial and needs to be complemented by others. It is by no means sufficient to account for the complicated phenomenon under study. To integrate ICT in their teaching, some teachers will have thought through issues and reached a mature decision after due thought. Others, however, will have made the choice by clutching at recommendations ready-made by technology proponents, who may have particular political and commercial agendas in education. Such a difference in teachers’ rationality is not discernable by the SEM model in the current study. Research framed in different methodologies (such as qualitative case study, autobiography, phenomenological research, and so on) can be conducted to explore the multiplicity of the meanings of teachers’ technology adoption. Only through multiple perspectives can we forsake a narrowed way of understanding teachers’ work and life and adopt a more open-minded approach to teacher education.

References


