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Break the walls! Second-Order barriers and the acceptance of mLearning by first-year pre-service teachers

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A B S T R A C T

Despite their many advantages, teachers' adoption of mobile technologies as didactic tools is still limited. Their adoption is conditioned by first-order and second-order barriers. The former are associated with the availability of resources, and the latter refer to internal barriers as a consequence of the reflection of instructors about their own teaching practice, which are harder to overcome. Teacher training plays an important role on the formation of these barriers, but prior research mainly focuses on pre-service teachers in their last years of training, where some of those barriers have already been formed, and it mostly investigates computer-based learning. This research aims to fill that gap by analyzing the influence of second-order barriers on first-year pre-service teachers' intention to use mobile devices in their future teaching practice. The study identifies the most relevant second-order barriers and tests the proposed model using a sample of 160 first-year primary education pre-service teachers. The results of the partial least squares structural equation modeling analysis offer relevant practical, theoretical and methodological implications for mobile learning adoption: first, they provide evidence of the key role of second-order barriers, accounting for 70.8% of the variance of the intention to use these technologies; second, the importance of compatibility and enjoyment, higher than that of traditional key variables as perceived ease of use and perceived usefulness, points out tothe need to reconsider pre-service teacher training programs; third, the study compares traditional reflective modeling of subjective norm and formative modeling, suggesting the adequacy of formative formulations in technology adoption studies.

1. Introduction

The use of information technologies (IT) in education gives access to a wide selection of new teaching methods. Rapid advances in technology make new solutions available for teachers to help students to adapt to the professional needs of a constantly changing world. One of the most notable technology advances are mobile devices. The increasing storage, fast adoption and presence of mobile devices in all aspects of everyday life make it possible to talk about a post-PC era already (Wei, Valler, Madhyastha, Neamtiu, & Faloutsos, 2017).

Educational uses of mobile devices in formal education, under the name of mobile learning or mLearning, enables customization and flexibility of learning processes (Traxler, 2009). Anywhere and anytime connectivity, integration of multimedia content, personal use and communication facilitate situated and collaborative learning, adapted to the characteristics of students, and free from time and space constraints (Crompton, 2017). Due to its many advantages, mLearning has gained interest among educators and scholars and its use is increasing in varied educational settings, such as in-company training or museums, with a wide catalogue of learning activities (Liu, Han, & Li, 2010).

In formal education contexts, the number of studies on the use of mobile devices is increasing (Wingkvist & Ericsson, 2011), with examples of initiatives at all educational levels (Crompton & Burke, 2018). In compulsory education, the implementation of mLearning activities can be divided into two groups, depending on the type of technology under analysis: the use of laptops in schools, and application of different types of mobile devices in education (Sung, Chang, & Liu, 2016). The latter primarily focuses on the use of mobile phones and smartphones, with primary education being the most commonly

educational level under study (Liu et al., 2014; Sung et al., 2016). That primary education is the predominant educational context in these studies most likely owes to the more active conception of teaching in primary schools, which takes advantage of mobile devices as supporting technologies for student-centered teaching (Crompton, Burke, & Gregory, 2017).

The results of these initiatives are mostly positive, showing an overall improvement of student academic outcomes. However, from a pedagogical point of view, the implementation of mobile devices in educational settings does not necessarily entail a methodological change because the activities are designed under a traditional behaviorist paradigm in most cases (Crompton et al., 2017; Sung et al., 2016). Consequently, mobile devices are primarily used as tools to access passive content rather than to construct new knowledge.

However, and despite the positive effect on student achievement and the ubiquity of mobile devices in everyday life, the use of mobile learning in the classroom is not commonplace, and it is quite below the expected rate of adoption (Liu et al., 2010; Moreira, Ferreira, Santos, & Durão, 2017). In addition, in many occasions, either the initiatives fail, or they are one-off implementations that lack continuity (Sánchez-Prieto, Olmos-Migueláñez, & García-Peñalvo, 2016).

These signs point out to the existence of a problem with the adoption of mobile technologies in educational institutions. One of the reasons that better explain this problem is the reluctance of instructors to incorporate IT to their teaching practice (Kreijns, Vermeulen, Kirschner, Buuren, & Acker, 2013; Sanchez-Mena, Marti-Parreno, & Aldas-Manzano, 2017). Student attitudes or preferences aside, in the end the decision about whether or not using mobile devices in the classroom falls on the educators (Sang, Valcke, Braak, & Tondeur, 2010), because they choose the instructional method they consider most appropriate to teach their classes (Yang & Huang, 2008), and they have the final word on the frequency, quality and type of technology the students will be using. Consequently, teachers who do not perceive that a technology fulfills their needs, or the students' needs, will resist using these technologies (Teo, Lee, & Chai, 2008), considerably hindering adoption of mobile technologies in education. Thus, teachers' intention to incorporate mobile technologies is a critical aspect for mLearning adoption.

There are two different groups of factors that prevent instructors from incorporating a given technology in their teaching practice: first-order or external barriers, and second-order or internal barriers (Brickner, 1995). External barriers relate to availability of resources. In order to ensure a successful integration of technologies, educational institutions need to be able to provide teachers and students with the adequate equipment, training, time, technical support and content (Reid, 2014; Lucas, 2018). If instructors do not perceive that those barriers have been overcome, they can hardly initiate a process of technology integration where they have to solve every problem by themselves before even starting to use IT in the classroom (Ertmer, 1999). Consequently, external barriers have a capital relevance in the technology acceptance process (Brown, Englehardt, & Mathers, 2016; Reid, 2014; Venkatesh, Morris, Davis, & Davis, 2003).

Nonetheless, overcoming these first-order barriers is usually a matter of resources, and even when the resources are available it does not automatically imply that teachers will immediately start using a new system or technology; that is where internal barriers come into play. Second-order barriers refer to how instructors regard their own teaching practices and the specific technology (McLoughlin, Wang, & Beasley, 2008), and therefore these barriers are associated with motivational aspects, teaching styles or social influence. In this sense, the training an instructor receives during his years as pre-service teacher plays an essential role (Sang et al., 2010) because it is during these years when the individual creates his or her professional identity, leaving the role of expert student to take on the role of a novice teacher (So, Choi, Lim, & Xiong, 2012).

Given that future teachers are currently digital natives who have grown in pervasive technology environments (Baltaci-Goktalay & Ozdilek, 2010; Teo, Yurdakul, & Ursavas, 2016), they are expected to use new technologies in their practice, as they are supposed to be expert users. However, this assumption is not enough (Jones, Ramanau, Cross, & Healing, 2010; Kimmons, Clark, & Lim, 2017; So et al., 2012), because being familiar with the use of mobile devices does not directly translate to using mobile technologies in educational contexts (Corbeil & Valdés-Corbeil, 2007). Furthermore, students carry a series of preconceptions and learning with them when they begin their training as teachers, which shape their idea of good and bad teaching practices (Holt-Reynolds, 1992).

Even though prior research has investigated the process of technology acceptance among teachers during their training period (Baydas & Goktas, 2017; Teo, Milutinović, & Zhou, 2016), most of these studies focus on instructors in their latest training stages (e.g. Baydas & Yilmaz, 2018; Parkman, Litz, & Gromik, 2018), from a perspective that considers the final results when teachers are about to complete their academic training, and only pay limited attention to the effect of the second-order variables (e.g. Baturay, Gökçearslan, & Ke, 2017, treat them as a unidimensional variable associated with attitudes toward acceptance of computer assisted-education). Because of the changes in pre-service teachers' conceptions about teaching during their whole training years, that approach fails to explain which variables determine their future intention to use a certain technology, such as mobile technologies, during the earlier stages of training.

Identifying and understanding these variables is necessary in order to define educational and academic training processes that fit the needs and characteristics of students when they start assuming teaching roles. Therefore, this study investigates the variables that predict the intention to use mobile technologies in the future practice of pre-service teachers. Specifically, the study aims to give answer to the following research questions:

RQ 1. Which variables related to second-order barriers can help predict the intention to use mobile technologies by pre-service teachers during their first years of training?

RQ 2. What is the relative importance of each of these variables in explaining pre-service teachers' intention to use mobile technologies?

By answering these two questions, this research aims to gain understanding about the relative importance of second-order barriers in the adoption of mobile technologies for educational purposes among pre-service teachers in the earlier years of their training. In order to answer both research questions, the study proposes the development and validation of a theoretical model that considers behavioral, psychosocial and technology-related elements. The results of the research may provide further insight on the technology adoption process of pre-service teachers, and help guide the curriculum design of higher education institutions that aim to promote the use of mobile devices in the future teaching practice of their students.

In order to answer the research questions, the remainder of this study is structured as follows. Section 2 presents the literature review and methodology of the study, details the research variables and model, and formulates the research hypotheses; Section 3 details the data analysis and results; Section 4 discusses the results and highlights the main implications for the teaching practice. Finally, Section 5 summarizes the main contributions of the study.

2. Literature review and model development

2.1. TAM variables

The Technology Acceptance Model (TAM) (Davis, 1989) is one of the most widely accepted theories for the study of technology adoption in educational contexts (Cano-Giner, Fernandez, & Diaz-Boladeras, 2015). TAM, elaborated upon the ideas of the Theory of Reasoned

Action (Fishbein & Ajzen, 1975), proposes that there are two main predictors of the acceptance and use of a new information system or technology: perceived usefulness (PU) and perceived ease of use (PEU).

One of the key factors behind a teacher's decision to incorporate IT to the teaching-learning process is the perception that such change is going to have a positive effect on his or her practice and that it will significantly and effectively improve learning (Mac Callum, Jeffrey, & Kinshuk, 2014). Therefore, the assessment of teachers about the perceived usefulness of a technology is one of the main determinants of its future use (Venkatesh & Davis, 2000).

Additionally, the use of a new technology or device usually involves additional workload for instructors (Thorsteinsson & Niculescu, 2013), and this workload increases if the use of the technology is difficult or confusing. Hence, perceiving that the use of mobile devices to develop and perform educational tasks is not easy will most likely discourage teachers from using them.

In earlier stages of adoption of a given technology, perceived ease of use becomes an internal barrier that may condition not just the behavioral intention to use a technology (BI), but also its perceived usefulness (Venkatesh & Bala, 2008). More specifically, pre-service teachers are familiar with the use of mobile devices in everyday activities, but they still lack experience with using them as educational resources (Maher, 2018), and therefore they are in an early adoption stage.

Therefore, we posit that:

H1. Perceived usefulness positively predicts pre-service teachers' intention to use mobile devices in their future practice.

H2. Perceived ease of use positively predicts pre-service teachers' intention to use mobile devices in their future practice.

H3. Pre-service teachers' perceived ease of use of mobile devices in their future practice positively predicts perceived usefulness.

2.2. Perceived enjoyment

As mentioned before, motivational factors of utilitarian nature determine the decision of using or not a given technology. However, aside from extrinsic motivational factors, there are also intrinsic motivational factors that may influence technology acceptance. These factors refer to the enjoyment of using of mobile devices, regardless of the effect of their use on performance (Davis, Bagozzi, & Warshaw, 1992), and positively affect the intention to use ICTs in education, especially when instructors incorporate the technology to learning activities and tasks that are inherently interesting (Roca & Gagné, 2008).

Current pre-service teachers are digital natives who regularly use mobile devices for leisure and entertainment (Barnes, Marateo, & Ferris, 2007; So et al., 2012). Hence, they might be more inclined to use mobile technologies in their future practice because they perceive that the use of these devices adds an element of playfulness to the teaching-learning process when they use them as students (Zacharis, 2012). Nevertheless, when considering the use of mobile technologies from an instructor's perspective, one may ask if students still believe that enjoyment by itself is enough or, on the contrary, there might be additional variables affecting the adoption of mobile technologies by pre-service teachers.

The association of using mobile technologies with perceived enjoyment may cause a decrease in the perception of the cognitive effort, as users are enjoying the experience (Agarwal & Karahanna, 2000). Thus, perceived enjoyment may lead to the (false) perception that the learning curve to use the technology in a professional context is lower than it actually is (Venkatesh, 2000). Furthermore, if instructors consider that the use of the technology inducing the enjoyment does not have an impact in their performance that justifies the effort, they might feel inclined to discard the use of the technology because they are immerse in a social environment that mainly values instructional results. The cognitive dissonance arising from this conflict between utilitarian and hedonic elements may lead the individual to overestimate the usefulness of the system or technology, concluding that having fun with its use equals usefulness (Agarwal & Karahanna, 2000).

Pre-service teachers are just beginning their academic training, and therefore they lack both the professional experience and a solid theoretical foundation about their teaching role that might contextualize and make the benefits of using mLearning in the classroom apparent. Hence, it is highly likely that this mediating effect of perceived usefulness and perceived ease of use in the relation between perceived enjoyment and behavioral intention might occur.

Finally, mobile devices are mixed technologies (Gerow, Ayyagari, Thatcher, & Roth, 2013); that is, they combine characteristics from utilitarian and hedonic systems, and therefore their use may pursue both utilitarian and hedonic goals, by improving the efficacy of learning processes and enhancing enjoyment along the learning process, respectively (Sun & Zhang, 2006). Consequently, the intention to use mobile devices from the perspective of a teaching role is not only directly determined by a willingness to increase the effectiveness of teaching, but also by the objective of enriching the learning experience through higher enjoyment in the classroom (Gerow et al., 2013). Therefore, we posit that:

H4. Perceived ease of use mediates the relation between perceived enjoyment and pre-service teachers' intention to use mobile devices in their future teaching practice.

H5. Perceived usefulness mediates the relation between perceived enjoyment and pre-service teachers' intention to use mobile devices in their future teaching practice.

H6. Perceived enjoyment positively predicts pre-service teachers' intention to use mobile devices in their future practice.

2.3. Compatibility

Instructional methods also might influence the potential use of mobile technologies (Kiraz & Ozdemir, 2006). In contexts where the teacher uses a traditional learning model, mobile devices will most likely be just a lecture companion or a tool to take notes, whereas within constructivist models the instructor may unleash the full potential of mLearning for mobility and interactivity, and develop innovative learning activities (Maher, 2018).

Accordingly, the incompatibility between new instructional practices associated to the technology and the teachers' preferred way of work arises as another important internal barrier. The use of a tool that is not compatible with the preferred teaching approach leads the instructor to question his or her own professional model and discourages further use of the technology (Ritchie & Wiburg, 1994; Valtonen et al., 2011). Conversely, if teachers feel that a technology may help them work in a way consistent with the way they like to teach, it is more likely that successful adoption will happen (Karahanna, Agarwal, & Angst, 2006). Therefore, compatibility with the preferred work style determines both the extent to which using mobile technologies is perceived as beneficial to improve the quality of teaching and the intention to use them.

Even though pre-service teachers still lack actual professional experience when they begin their training, they do have an idea of what teaching is and what they consider good practices, ideas built upon observational learning that might condition their adoption of mobile technologies. Hence, we posit that:

H7. Compatibility between mobile technologies and the preferred work style positively predicts pre-service teachers' intention to use mobile devices in their future practice.

H8. Compatibility between mobile technologies and the preferred work style positively predicts pre-service teachers' perceived usefulness of using mobile devices in their future practice.

2.4. Subjective norm

Finally, a certain teaching model is being created and assimilated through an evolutionary process that occurs during the whole life of the instructor. The model is not static, and many different elements may influence its development, such as the knowledge acquired, professional practice and experience, and influences from the environment (Beijaard, Meijer, & Verloop, 2004; Day, Kington, Stobart, & Sammons, 2006; Lasky, 2005). That is, despite instructors having the last word regarding the use of a technology for educational purposes in their classroom, social pressure also influences this decision (Teo, 2015). In other words, teachers are aware that their peers and superiors have a series of expectations about how they should practice teaching.

Pre-service teachers that are in the initial stages of academic training are more prone to receive feedback and value it more positively, because they lack the required experience to contrast or contest that information (Lamote & Engels, 2010). For this reason, the perception of pre-service teachers that there is a pressure to use mobile technologies in their teaching practice may determine their intention to use them in order to fulfil these expectations (Teo, 2010; Valtonen et al., 2011).

Therefore, we posit that:

H9. Subjective norm positively predicts pre-service teachers' intention to use mobile devices in their future practice.

Fig. 1 depicts the research model, summarizing the different research hypotheses.

3. Method

3.1. Population and sample

An invitation to participate in the study was extended to all first-year students of the Degree in Primary School Teaching at the University of Salamanca, along three different campuses that are geographically separated by approximately 100 km each. This research design ensures heterogeneity of the sample, as students share the same programme across the three campuses, but not the same instructors –each campus may have developed their own prevailing teaching models and practices, with different levels of social influence. A total of 177 respondents participated voluntarily in the study and completed a questionnaire, for a total of 160 valid questionnaires which is higher than the 147 samples necessary to detect a minimum R-square of 0.10 at a significance level of 5% for a statistical power of 80% (Cohen, 1991). Of these, 73 (45.6%) were enrolled in Campus A, 44 (27.5%) in Campus B, and 43 (26.9%) in Campus C. The mean age of the sample is 19.78 years old (SD = 2.69), with the majority of students being female (68.1%). The distribution of the sample is similar to that of total enrollments (49.4% in Campus A, 30% in Campus B, and 20.6% in Campus C).

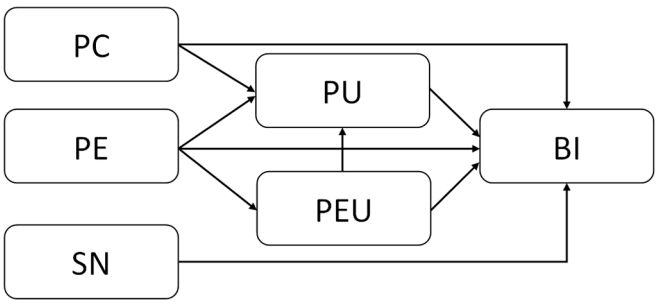

Fig. 1. Research model.

3.2. Measurement instrument

The questionnaire was delivered on paper and comprised two sections. The first section includes sample demographics–gender, age and campus–and the second section consists of 22 items to measure the study variables using a Likert-7 scale (0 = completely disagree; 6 = completely agree). Appendix A offers a detailed list of the 22 items.

The measurement instrument was developed from existing literature and required adaptation of the different items to the context, technology and behavior of the study–use of mobile devices in the future teaching practice of pre-service teachers. Thus, items to measure intention to use, perceived usefulness and perceived ease of use are adapted from TAM3 (Venkatesh & Bala, 2008). Items measuring perceived enjoyment are adapted from a validated scale for the assessment of primary school teachers' intention to use mobile technologies in their future practice (Sánchez-Prieto, Olmos-Migueláñez, & García-Peñalvo, 2016). Compatibility with the preferred work style adapts Moore and Benbasat (1991).

The initial proposal to operationalize subjective norm initially proposed an adaptation of TAM2 (Venkatesh & Davis, 2000). This approach defines subjective norm as "the people who is important for me" and "the people who have influence on my behavior" (*Idem,* p. 27). This operationalization of the construct is the most frequently used in technology acceptance studies, but the definition is general and unspecific, and does not correspond to the definition of subjective norm in this study. Therefore, the questionnaire includes additional items to measure this latent variable, with a formulation that is closer to Fishbein and Ajzen (1975), Ajzen (1985) and Taylor and Todd (1995). This formulation, adapted from (Sánchez-Prieto et al., 2016) considers subjective norm as the sum of the influences of different reference groups–in this case, peers and superiors. The differences in both formulations also translate to their representation in the structural model, with the first approach implying a reflective specification and the second approach implying a composite variable, defined formative and caused by non-interchangeable indicators that are independent from one another and that do not need to share the same antecedents and consequences (Hair, Hult, Ringle, & Sarstedt, 2017). The study compares the models resulting from both specifications in order to empirically test the adequacy of both approaches.

3.3. Analysis technique

This study uses Partial Least Squares Structural Equation Modeling (PLS-SEM) and the software SmartPLS 3.2.6 (Ringle, Wende & Becker, 2017) to analyze the data. One of the main goals of PLS-SEM is the prediction of a target variable–in this case pre-service teachers' intention to use mobile technologies in their future teaching practice. PLS-SEM also helps assessing the predictive power of antecedent variables.

The model analysis in PLS-SEM is a two-stage approach. The first step consists on the assessment of the quality of the measurement model in order to confirm the validity and reliability of the different model variables. The second step focuses on evaluating the relationships in the structural model by testing the significance of the relationships, the explained variance of the endogenous variables and the predictive power of the different variables (Hair et al., 2017).

The use of PLS-SEM makes it possible to analyze subjective norm as a formative construct, which is not only more appropriate to model this variable, according to the definition provided in the research, but also facilitates assessment of the relative weight of each of the sources of influence in the formation of subjective norm.

4. Data analysis and results

4.1. Global model assessment

The analysis includes observation of goodness of fit of the overall

model as the first part of model assessment in PLS (Henseler, Hubona, & Ray, 2016). In PLS-SEM, it is possible to evaluate the approximate fit of the estimated model by using the standardized root mean square residual (SRMR). The analysis returns a value of 0.062, below the recommended value of 0.08 (Hu & Bentler, 1998), which suggests a good fit. Besides the SRMR for the estimated model, it is also necessary to assess fit of the saturated model, which returns a value of 0.059 and confirms goodness of fit.[1]

4.2. Measurement model assessment

Measurement model assessment includes assessment of measurement instrument reliability and validity, which requires separate analysis of formative and reflective variables. The analysis will consider the formulation of subjective norm as a formative composite variable.

The results (Table 1) confirm item reliability, with reflective indicators loadings higher than 0.7 (Nunnally, 1978). The results also confirm convergent validity, with Cronbach's alpha (α), composite reliability (CR) and average variable extracted (AVE) values above 0.7, 0.6 and 0.5, respectively (Fornell & Larcker, 1981).

Assessment of reliability and validity of the formative construct (Table 2) includes observation of the variance inflation factor (VIF) to discard multicollinearity issues. VIF values are lower than 3.3 (Diamantopoulos & Siguaw, 2006), confirming that there are no multicollinearity issues. Furthermore, a bootstrapping with 5000 subsamples returns indicator weights higher than 0.5, and statistically significant, confirming reliability of the formative variable.

Discriminant validity assessment includes the use of two different criteria: Fornell-Larcker (Fornell & Larcker, 1981) and the heterotrait-monotrait ratio of correlations, or HTMT (Hair et al., 2017). As shown in Table 3, discriminant validity is confirmed using both criteria–square root of AVE higher than inter-construct correlations and HTMT under 0.85, respectively.

4.3. Structural model assessment

The analysis of the structural model covers the last stage of PLS-SEM analysis. Fig. 2 shows the adjusted R^2 values–i.e. variance explained, adjusted for sample size–of the latent variables. The model explains a 62% of perceived usefulness, a 21.3% of perceived ease of use and 70.8% of the variance of pre-service teachers' intention to use mobile devices and technologies in their future teaching practice. Additionally, Stone-Geisser's test returns positive values of Q^2, confirming predictive relevance of the model.

Fig. 2 also shows the standardized path coefficients. From the figure, perceived enjoyment positively predicts perceived usefulness and perceived ease of use, compatibility predicts perceived usefulness (supporting H7), and all antecedents except perceived ease of use positively predict intention to use mobile technologies by pre-service teachers (supporting H1, H6, H8 and H9, but not H2). Furthermore, perceived ease of use does not predict perceived usefulness (and therefore H3 is not supported). The results of the bootstrapping procedure (Table 4) show the significance of the proposed relations. Table 4 further includes the effect size of the relations and the results of hypothesis testing, with effect sizes between small ($0.02 < f^2 < 0.15$) and medium ($0.15 < f^2 < 0.35$) for significant relations (Cohen, 1988).

Some of the latent variables, namely compatibility, perceived enjoyment and perceived ease of use, may have both a direct and indirect effect on other endogenous variables–perceived usefulness and behavioral intention. Therefore, it is necessary to analyze these effects in order to have a complete understanding of the model. Table 5 shows the indirect effects and the significance of these effects. From Table 5, compatibility has both a direct and indirect effect on intention to use mobile technologies by pre-service teachers, and perceived enjoyment has an indirect effect on behavioral intention via perceived usefulness.

So far, the analysis has tested hypotheses including direct relations. The results show that there is no relation between perceived ease of use and behavioral intention, which does not support a mediation of perceived ease of use in the relation between perceived enjoyment and behavioral intention (Hair et al., 2017), therefore rejecting H5. In order to test H4, the *variance accounted for* (VAF) of the moderating effect (Nitzl, Roldan, & Cepeda, 2016) returns a value of 29.35%, confirming a typical partial complementary mediation, and supporting H4.

The observation of total effects (Table 6) shows that the two main predictors of pre-service teachers' intention to use mobile technologies in their future teaching practice are perceived enjoyment and compatibility with the work style, whereas perceived ease of use does not have a significant relation with perceived usefulness or behavioral intention.

Finally, as noted in section 2.2.1, this study aims to compare the research model using the formative formulation of subjective norm (M1) and an alternative model that includes a traditional reflective TAM specification of subjective norm (M2). After confirming the validity of M2–item reliability, convergent and discriminant validity–, the results show important differences between both models. Thus, in M1 the relation between subjective norm and intention to use mobile technologies by pre-service teachers is significant and with a medium effect size, whereas in M2 this relation is not significant ($p = .410$). Additionally (Table 7), observation of Q^2 and information criteria confirm that M1 is a more parsimonious and generalizable model (Sharma & Kim, 2012).

Table 1
Item reliability and convergent validity analysis (reflective variables).

Latent variable	Indicator	Loading	α	CR	AVE
Behavioral intention to use	BI_01	0.920	0.912	0.944	0.850
	BI_02	0.931			
	BI_03	0.915			
Compatibility	PC_01	0.884	0.891	0.932	0.821
	PC_02	0.936			
	PC_03	0.898			
Perceived enjoyment	PE_01	0.841	0.905	0.934	0.779
	PE_02	0.886			
	PE_03	0.905			
	PE_04	0.896			
Perceived ease of use	PEU_01	0.804	0.819	0.881	0.650
	PEU_02	0.798			
	PEU_03	0.881			
	PEU_04	0.735			
Perceived usefulness	PU_01	0.897	0.909	0.937	0.787
	PU_02	0.893			
	PU_03	0.926			
	PU_04	0.830			

Table 2
Formative measurement model analysis (formative variable).

Indicator	VIF	Weight	CI	p-value
SN_02	1.380	0.638	0.461–0.791	0.000
SN_03	1.380	0.505	0.322–0.673	0.000

[1] Hair et al. (2017) provide a note of caution about the use of model fit measures in PLS-SEM, indicating that "too little is known about these measures' behavior across a range of data and model constellations, so more research is needed […] PLS-SEM focuses on prediction rather than on explanatory modeling and therefore requires a different type of validation […] In this context, fit (as put into effect by SRMR, RMStheta, and the exact fit test) offer little value. In fact, their use can even be harmful as researchers may be tempted to sacrifice predictive power to achieve better "fit." […]." (*Idem,* pp. 193–194). As the concept of goodness-of-fit is still under development in PLS-SEM, this study reports SRMR for informative purposes.

Table 3
Discriminant validity analysis.

	Fornell-Larcker						HTMT				
	BI	PC	PE	PEU	PU	SN	BI	PC	PE	PEU	PU
BI	**0.922**										
PC	0.719	**0.906**					0.796				
PE	0.737	0.632	**0.882**				0.808	0.701			
PEU	0.356	0.377	0.467	**0.806**			0.407	0.433	0.539		
PU	0.746	0.708	0.722	0.386	**0.887**		0.817	0.784	0.792	0.441	
SN	0.702	0.576	0.633	0.255	0.609	–	–	–	–	–	–

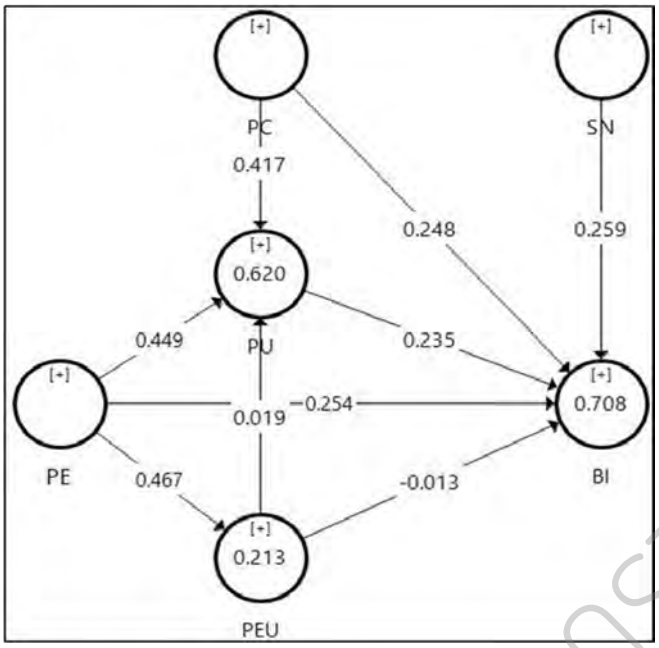

Fig. 2. Structural model analysis.

Table 4
Direct effects.

Path	Path coeff.	CI	f^2	Results
PU→BI	0.235**	0.084–0.386	0.07[a]	H1 Supported
PEU→BI	−0.013[ns]	−0.109–0.088	0.00	H2 Not supported
PEU→PU	0.019[ns]	−0.080–0.121	0.00	H3 Not supported
PE→PU	0.449*	0.343–0.575	0.29[b]	
PE→PEU	0.467*	0.359–0.575	0.28[b]	
PE→BI	0.254*	0.124–0.377	0.09[a]	H6 Supported
PC→PU	0.417*	0.283–0.530	0.28[b]	H7 Supported
PC→BI	0.248*	0.129–0.366	0.10[a]	H8 Supported
SN→BI	0.259*	0.135–0.383	0.12[a]	H9 Supported

*p < .001; **p < .01; [ns]non-significant.
[a] Small effect.
[b] Medium effect.

Table 5
Indirect effects.

Relation	Eff. Coeff.	Conf. Interv.
PC → BI	0.098*	0.032–0.168
PE → BI	0.102**	0.029–0.187
PE → PU	0.009	−0.038–0.058
PEU→ BI	0.004	−0.018–0.034

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

Table 6
Total effects.

Relation	Eff. Coeff.	CI
PC → BI	0.346*	0.226–0.455
PC → PU	0.417*	0.283–0.530
PE → BI	0.355*	0.240–0.2470
PE→ PEU	0.467*	0.359–0.575
PE → PU	0.458*	0.347–0.588
PEU → BI	−0.009	−0.101–0.091
PEU → PU	0.019	−0.080–0.121
PU → BI	0.235*	0.084–0.386
SN → BI	0.259*	0.135–0.383

*p < .001.

Table 7
Model comparison (M1, formative formulation of subjective norm; M2, reflective formulation of subjective norm).

	Model 1 (M1)	Model 2 (M2)
Q^2	0.562	0.533
CAIC	1035.676	1054.290
BIC	1023.676	1042.290
HC	1001.759	1020.370

5. Discussion of results and implications for theory and practice

The study highlights the pivotal role of internal barriers in the adoption of mobile technologies by pre-service teachers from the very beginning of their academic training. In answer to the original research questions RQ1 and RQ2, the intention of first-year pre-service teachers to use mobile technologies in their future practice is mostly predicted by perceived enjoyment and compatibility with their work style, followed by social influence and perceived usefulness; perceived ease of use does not seem to be a relevant predictor of behavioral intention. By answering these questions, this research fills an important gap in the literature focused on both the technology acceptance of first-year pre-service teachers and the adoption of mobile devices among future educators. In consequence, the results have important ramifications for the study of the adoption of mobile technologies and also for the design of teacher training programs.

5.1. Implications for research on technology acceptance of pre-service teachers'

The research model predicts and explains 70% of the variance of the target variable, emphasizing the importance of considering the impact of second-order or internal barriers in the adoption process. Additionally, the percentage of variance explained is considerably higher than in prior research, where second-order barriers are far less accounted for (Jeong & Kim, 2017; Sanchez-Mena et al., 2017; Teo, Ursavas, & Bahcekapili, 2012). This finding indicates that it is necessary to pay more attention to the factors present at a teacher level and their interplay with the external barriers (Lucas, 2018).

The results also show important differences with prior adoption studies. As usual in technology acceptance studies (Camadan, Reisoglu, Ömer, & Mcilroy, 2018; Escobar-Rodriguez & Monge-Lozano, 2012), the findings support the relation between perceived usefulness and behavioral intention, both directly and as a mediator of the relationship between perceived enjoyment and behavioral intention, and between compatibility and the intention to use mobile technologies by pre-service teachers. However, the results do not support the effect of perceived ease of use on perceived usefulness or behavioral intention, which contradicts the findings from previous studies with pre-service teachers in 3D multi-user virtual environments (Fokides, 2017) or computer-assisted learning (Okyere-Kwakye, Md Nor, & Ologbo, 2016; Parkman et al., 2018).

The explanation to this finding may lie in the moderating effect of experience on the relationship between perceived ease of use and perceived usefulness. Users in this study are at an initial adoption stage because they do not have enough experience with mobile technologies *as teaching tools*. However, the items measuring perceived ease of use do not make an explicit reference to the teaching role, which might be a source of misunderstanding for respondents. If that is the case, participants are digital natives, experts in the use of mobile technologies in their everyday activities and experienced users outside of the educational context (Baltaci-Goktalay & Ozdilek, 2010; Teo et al., 2016), and therefore the non-significant relationship between perceived ease of use and perceived usefulness could be explained by the mediating role of experience, in line with Davis, Bagozzi and Warsaw (1989). Because contexts where users are experts in the use of the technology in their daily life but not in a professional setting are not usual in technology acceptance studies, refining the measurement instrument of perceived ease of use by clearly positioning the respondent on his/her user role under study could help confirm the results of this study.

The study also supports the relation between compatibility with the preferred work style and perceived usefulness, and between compatibility and behavioral intention, confirming that pre-service teachers have already formed an idea of the teaching role by observational learning prior to their training, as suggested in the literature (Holt-Reynolds, 1992). This idea determines their perception about the educational potential of the application of mobile technologies and the benefits they can expect from their use, as well as their plans to use mobile technologies in the future. During their academic teacher training in the University, the initial identity that instructors have created in their minds will experience changes as they gain knowledge in the field of education, get acquainted with new instructional models and paradigms, and have their first hands-on experience as teachers during their practice time in educational centers (Stock, Sameshima, & Slingerland, 2016; Trent, 2013). Hence, the findings from this study stress the importance of analyzing the process by which the professional identity of teachers is created before entering higher education, and how this identity influences–and is influenced by–the use of new technologies in their role as students.

Regarding subjective norm, the results lead to different conclusions depending on the operationalization of the variable. Thus, from the view of Venkatesh and Bala (2008) and the idea of social pressure exerted by generic agents as a starting point, social influence does not seem to influence behavioral intention. However, an explicit formulation of the sources of influence in terms of peers and superiors confirms the relevance of social influence in pre-service teachers' intention to use mobile technologies in their future teaching practice. The results, coupled with better parsimony and generalizability of model M1, suggest that future research on technology acceptance should study subjective norm by clearly differentiating the different sources of social influence, under a lens that is closer to the proposals of Ajzen (1985) or Taylor and Todd (1995) than to Venkatesh and Bala (2008).

5.2. Implications for teaching practice

The results of the study also have important implications for practice. First, the findings underline the need to develop teaching and learning processes that go beyond a mere transmission of the technical knowledge required to use mobile technologies with educational purposes, as is the case in many countries nowadays (e.g. Suárez-Rodríguez, Almerich, Orellana, & Díaz-García, 2018; Tanak, in press), focusing instead on *raising students' awareness about the educational benefits* that the integration of mobile technologies can bring to formal education.

The development of these new processes involves fostering *a curriculum that highlights the benefits of specific teaching and learning scenarios of application of mobile technologies* in educational contexts, such as authentic experiences in classrooms (Tondeur et al., 2012). This curriculum should also stress the usefulness of mobile technologies for the development of key competences. Additionally, the academic programs should cover *both extrinsic and intrinsic motivational elements*; that is, they also need to emphasize the hedonic aspects of mobile technologies, and how playfulness can improve activities in the classroom, both for students and teachers (Teo & Noyes, 2011). In this sense, it would be interesting to explore the use of mobile technologies within gamified learning design as well as in game-based learning.

The study also underscores the fundamental role of the teaching model taught in Higher Education institutions. These academic training years play a critical part in the creation of the professional identity of future teachers, who will assimilate the instructional model promoted or favored by the institution (Martínez-de-la-Hidalga & Villardón-Gallego, 2016; Oruç, 2013). From the analysis, *if this model is not compatible with the technology*, or makes a limited use of new technologies, *students will most likely not consider their use as positive*. Teaching models are not only taught via contents of academic programs, and the method used by academic trainers has a strong influence on students through observational learning (Tondeur, Aesaert, Prestridge, & Consuegra, 2018). It is crucial then *not only to observe what* –content, concepts and practices– pre-service teachers are being taught, *but also how the content is delivered and how they are being taught*. If future teachers have remarkable learning experiences using mobile technologies during their training, they will be more inclined to reuse this kind of instructional approaches once they start their professional practice.

Further, the relationship between teaching beliefs and technology is bidirectional, and the presence of mobile technologies in schools has the potential to change teachers' beliefs towards more student-centered, constructivist conceptions of learning through experimentation (Tondeur, van Braak, Ertmer, & Ottenbreit-Leftwich, 2016). However, learning to teach with technology is an iterative process in which teaching beliefs are the first step; this way, beliefs leads to actions, and the critical reflection on the results of these actions lead to the confirmation or the change of these teaching beliefs (Haney, Lumpe, Czerniak, & Egan, 2002). Pre-service teacher training programs are essential in the formation of these first conceptions of teaching, which can be a barrier or a catalyst for the integration of mobile devices in educational activities.

Teacher education programs must also take into consideration the influence of the educational environment over the choice of instructional method. This influence may reinforce learning during the academic training period as pre-service teachers *when what is taught goes in line with the existing practices*. However, if prevailing practices in the educational institution are contrarian to what is being taught, novice teachers might feel inclined to dismiss the delivered instructional contents and instilled beliefs (Darban & Amirkhiz, 2015).

6. Concluding remarks

The adoption of technologies with educational purposes by pre-service teachers has been the subject of prior research, largely focusing

on computer-assisted education. Given the pervasive use of mobile devices in everyday activities but their low adoption rates for educational purposes, this study shifts the focus toward the investigation of the influence of second-order barriers on the intention to use mobile devices in the future teaching practice of first-year pre-service teachers. The investigation contributes to advances in current research from a theoretical, methodological and practical perspective, mainly in four areas.

First, the study provides empirical evidence on the influence of second-order or internal barriers not only in the late years of training of pre-service teachers but also during their initial stages. The study then fills a research gap by investigating the adoption of mobile devices among first-year pre-service teachers, a relatively unexplored collective in the study of the acceptance of educational technologies. This is relevant because the early years of training of pre-service teachers are critical for the creation and development of their professional identity. Further, regardless of students' attitudes toward the use of mobile technologies for education–even though they are important in closing the adoption process–, the ultimate decision to incorporate them to the teaching practice falls on the instructor.

Second, the results of the study suggest that second-order barriers have high predictive power of the acceptance of mLearning by pre-service teachers from the moment they begin their training. Interestingly, the results highlight the essential role of compatibility with existing practices and perceived enjoyment. This finding sets this research apart from previous research on technology acceptance of educational technologies by pre-service teachers, shifting the focus away from traditional acceptance variables, i.e. perceived usefulness and perceived ease of use. As a note of caution, it is not possible from the results to discern if this result is a consequence of the incorporation of a technology that has already been accepted for everyday uses to the teaching practice, or if the results might be generalizable to any other context. Either way, the findings suggest the need to incorporate both compatibility with the preferred work style and perceived enjoyment as determinants of technology adoption in future studies to confirm the results of this study.

Third, the findings of the study have important implications for practice. As a summary of the ideas explained in more detail in section 4.2, the results suggest that, besides the acquisition of theoretical and technical knowledge about the use of mobile technologies, mLearning adoption by first-year pre-service teachers is all about the design of academic teaching programs that aim to foster learning, to transmit the utilitarian and hedonic benefits that teachers can obtain from their use, and to promote and facilitate the integration of these technologies with the creation of the professional identity of the students as future teachers.

Finally, the study compares two different operationalizations of subjective norm, concluding that it is preferable to use a formative modeling of the construct. This comparison represents a methodological contribution of the study to general research on technology acceptance, and provides evidence pointing out to the need to revise the operationalization of subjective norm used in previous studies (Jeong & Kim, 2017; Teo, 2012) in favor of an approach that is closer to the formulation of Taylor and Todd (1995). This finding should be confirmed in future studies.

The research is not exempt from limitations. Due to the nature of the sampling method, open to all students but with voluntary participation, the results may be affected by self-selection bias. In addition, despite the relative heterogeneity of the sample, selected from three different campuses with different instructors, all the students share the same programme and similar cultural characteristics. Therefore, an extension of the study to other institutions and cultural contexts would help ensuring generalizability of results.

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Appendix A. Questionnaire items

Behavioral intention		Reference
BI_01	Assuming that I had access to mobile technologies I intend to use them in my teaching practice.	Adapted from Venkatesh and Bala (2008)
BI_02	Given that I had access to mobile technologies I predict that I would use them.	
BI_03	I plan to use mobile technologies in my future teaching practice.	
Perceived usefulness		
PU_01	Using mobile technologies in my lessons increases my productivity.	Adapted from Venkatesh and Bala (2008)
PU_02	Using mobile technologies enhances my effectiveness in my job.	
PU_03	Using mobile technologies in my teaching improves my job performance.	
PU_04	I find mobile technologies to be useful for teaching.	
Perceived ease of use		
PEU_01	Using mobile technologies does not require a lot of my mental effort.	Adapted from Venkatesh and Bala (2008)
PEU_02	I find it easy to get mobile technologies to do what I want them to do.	
PEU_03	My interaction with mobile technologies is clear and understandable.	
PEU_04	I find mobile technologies to be easy to use.	
Perceived enjoyment		
PE_01	The use of mobile devices in my classes adds a fun aspect to my job.	Adapted from Sánchez-Prieto et al. (2016)
PE_02	I am amused by carrying out activities with my students through the use of mobile technologies.	
PE_03	I enjoy using mobile devices in my classes.	
PE_04	The use of mobile devices makes my classes more amusing.	
Compatibility with the preferred work style		
PC_01	Using mobile technologies in my lessons would be compatible with my work style.	Adapted from Moore and Benbasat (1991).
PC_02	Using mobile technologies to teach would be compatible with the way I work.	
PC_03	Using mobile technologies to teach would fit my life style.	
Subjective norm		
SN_01†	People who are important to me think that I should use mobile technologies in my teaching practice.	Adapted from Venkatesh and Davis (2000)
SN_04†	People who influence my behavior think that I should use mobile technologies in my teaching practice.	
SN_02‡	My classmates think that teachers should use mobile technologies in the classroom	Adapted from Sánchez-Prieto et al. (2016)
SN_03‡	In the schools, teachers are expected to integrate mobile devices in their lessons	

†Reflective,‡Formative.

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