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When barriers are not an issue: Tracing the relationship between hindering factors and technology use in secondary schools across Europe

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ABSTRACT

Many researchers have investigated how barriers to technology integration affect the use of digital technologies in teaching and learning. However, the results have varied across educational contexts and countries. Large-scale assessment studies have described barriers only on a descriptive level instead of analyzing the effects of barriers on actual indicators of technology integration, such as technology use. Therefore, this study investigated the effects of barriers on technology use through the lens of the "will, skill, tool" model (WST model) in different European countries while taking the countries' technological development level into account. A regression analysis showed that barriers had only a minor impact on the frequency of technology use in the classroom in the large majority of countries. In accordance with theoretical expectations, we found country-specific patterns, with a higher negative impact of technological barriers in less technologically developed countries and teacher-belief related barriers prevalent in developed countries. These findings may help policy makers identify needed interventions in different contexts.

1. Introduction

Many studies have described the barriers to technology integration in education (Ertmer, 1999, 2005; Franklin et al., 2001; Harrell & Bynum, 2018; Hew & Brush, 2007; Hsu, 2016; Keengwe et al., 2008; Kopcha, 2012; Smerdon et al., 2000; Su, 2009). Research has grouped these barriers into two broad categories: first-order barriers, related to external factors such as access to technology and equipment; and second-order barriers, related to internal factors such as beliefs and skills of the school members (Ertmer, 1999; Means & Olson, 1997). As schools became more and more equipped with digital technologies in the last decade, the focus of research shifted from first-order to second-order barriers (Ertmer, 2005). The findings of older studies examining the relevance of barriers for technology are hardly applicable to the current situation, and the exact interplay of these types of barriers remains unclear. There is not only a lack of longitudinal studies comparing the shift of barriers but also a lack of comparisons across countries or different contexts.

For highly developed countries with well-equipped schools, Ertmer (2005) stated that beliefs are especially the "final frontier" to

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teachers' technology integration whereby the internal factors underwent a hierarchization, with beliefs being more important to tackle than skills. Some studies from the United States confirm the position of Ertmer (2005) (Bowman et al., 2020; Ertmer et al., 2012; Ruggiero & Mong, 2015). Studies from other countries come to different conclusions. For Canadian teachers, Wozney et al. (2006) found technological skills to be more relevant for using ICT in the classroom than their beliefs. In India, the study of Singhavi and Basargekar (2019) reported inadequate skills of teachers to be the most important barrier in Indian English middle schools, whereas in Indian regional middle schools, it was teacher beliefs (i.e., "No or unclear benefit of using ICT for teaching"). Moreover, recent American studies, such as the one by Vongkulluksn et al. (2018), have re-emphasized that perceived support on first-order barriers still plays an important role for technology integration in class. Overall, the findings are ambivalent and, depending on the context, the importance and the interplay of first- or second-order barriers might differ. International studies comparing the impact of barriers on technology integration in different countries are scarce. In previous large scale assessment studies that involved different countries, teachers' perceptions of the main barriers to technology integration were compared in a descriptive way (European Commission, 2013, 2019a; Fraillon et al., 2014; Korte & Hüsing, 2006) but the barriers' effects on the actual use of technology in the classroom were not analyzed across countries. Thus, the first goal of this study was to compare the relative effect of barriers to technology integration on the frequency of technology in use in class across different countries.

Investigation of the relative effects of barriers to technology integration on technology use across different countries has also prompted interest in the role of the technological development level of these countries. The technological development level refers to the ICT access, usage, and skills of the country and not the ICT access, usage, and skills of a specific class or school (International Telecommunication Union, 2017). Some previous studies provided empirical evidence that the relationship between will-, skill- and tool-related factors and technology use is influenced by the technological development level of a context. For example, will (beliefs and attitudes toward technology) emerged as the strongest predictor for successful technology integration in highly technological developed countries. However, in less technological developed countries skill was the most important factor and in the least technological developed countries, access to technology in the classroom (tool-related factor) was the strongest predictor for technology integration, while will- and skill-related factors were only of minor importance (Ertmer et al., 2012; Farjon et al., 2019; Morales Velazquez, 2006, 2007). Therefore, it would be interesting for both researchers and policy makers to systematically examine the influence of the overall technological development level on the perception of barriers to educational technology use across different countries. This could help to understand which interventions are appropriate in different contexts. Hence, the second aim of the study was to evaluate the moderating effect of the countries' technological development level on the impact of barriers on the frequency of technology use in the classroom across several countries.

To investigate these issues, we used the dataset of the European 2nd Survey of Schools: Information and Communications Technology (ICT) in Education. We classified teacher ratings on barriers into three factors according to the "will, skill, tool" model (WST model) of technology integration (Knezek & Christensen, 2016; Knezek et al., 2003). The classification of the WST model is very similar to the grouping into first- and second-order barriers because first-order barriers align very well with the tool dimension of the WST model. In contrast to the countries' technological development level, the tool dimension of the WST model and the first-order barriers refer to infrastructure and access to technology in one specific class or school (Ertmer, 1999, 2005; International Telecommunication Union, 2017; Knezek & Christensen, 2016; Knezek et al., 2003). Second order barriers are typically decomposed into belief- and ability-related components which corresponds to the skill and will dimension of the WST model (for an example see Bowman et al., 2020). Using the WST model helps clarify which barrier factor explains the most degree of variance in teachers' technology integration. We tested the barriers' classification with an explorative and confirmatory factor analysis. Consequently, this study investigated barriers through the lens of the WST model to determine the most important predictors of technology use in the different countries.

Beyond the WST-based classification, we examined the effects of will-, skill-, and tool-related barriers on the frequency of students' and teachers' technology use in the classroom and conducted separate multiple linear regression analyses for a selection of European countries. Lastly, we evaluated the moderating effect of the countries' technological development level operationalized as the ICT Development Index (IDI) on the impact of barriers on the frequency of students' and teachers' technology use across several European countries by conducting a multilevel linear modeling analysis (MLM). In the next section we present a review of the existing literature about the barriers to technology integration in classroom and differences across countries.

2. Theoretical background

2.1. *Technology integration in classrooms*

When examining the effects of barriers on technology integration, it is always important to consider the operationalization of the dependent variable. Different studies have defined and measured technology integration—also referred to as technology adoption or technology uptake—in different ways (Davies & West, 2014; Franklin & Bolick, ; Niederhauser & Lindstrom, 2018). Technology integration can be conceptualized on a quantitative or a qualitative level, depending on the purpose of the study (Backfisch et al., 2021). Focusing on quantitative aspects of technology integration provides an overview of the descriptive frequency of technology usage, while a qualitative focus of technology integration includes normative measures such as the efficiency, alignment with pedagogical practices, or effectiveness of technology use for teaching and learning (Backfisch et al., 2021).

Although quantity-focused measures of technology integration seem rather straightforward, methodological problems can affect their application. For example, an estimate of the average weekly minutes a student spends using a computer or the internet has been used as a rate of educational technology use (Norris et al., 2003). However, overall time estimations might be difficult to estimate in hindsight, and it is difficult to assess fluctuations of frequency with an overall rating. Therefore, some studies have integrated more global and less fine-grained estimates that focus on the relative percentage of time spent using ICT instead of the exact minutes: In a recent large-scale European teacher survey, for example, the overall use of digital technologies was measured through separate ratings on the percentages of students' and teachers' ICT use in lessons (European Commission, 2019a). By contrast, other large-scale studies, such as ICILS or PISA, have employed 4- or 5-point ratings on the frequency of tool use as measures for technology integration (Fraillon et al., 2014; OECD., 2015). In these studies, items about the frequency of use of specific technical devices or the frequency of tool use for certain purposes have been condensed into composite indices for further analysis. However, such composite scales could be difficult to interpret, as information on the frequency of use of single tools is mixed with information on the variety of tools or purpose of tools. In fact, it is also possible that some selected digital instruments are used very frequently at the expense of other tools that are rarely or never used. The same applies to the purpose of the tools.

Other studies—most notably those referring to technology acceptance models (Davis, 1989; Scherer et al., 2019; Teo, 2011; Venkatesh et al., 2003)—have assessed technology integration by evaluating teachers' intention to use a range of ICT functions (e.g., Makki et al., 2018) or digital tools (e.g., Singhavi & Basargekar, 2019). Although use intention has been assumed to be the most influential predictor of behavior (Ajzen, 1991), it is not necessarily an indicator of actual technology adoption.

Similar problems have been presented with survey instruments that try to assess quality-related aspects of technology integration, such as making students' learning more efficient or helping students solve problems (Belland, 2009). For example, Bowman et al. (2020) measured technology integration through teachers' ratings of how often they asked students to use digital technologies for higher-order and lower-order tasks. The higher- and lower-order tasks were based on Bloom's digital taxonomy, which targets remembering, understanding, and applying as lower-order tasks, while analyzing, evaluating, and reporting are considered higher-order tasks (Bowman et al., 2020). In another study, technology integration was assessed as technology use for student-centered activities and facilitation of higher-order thinking tasks (Vongkulluksn et al., 2018). Other studies have provided rather broad and overarching ratings on the comprehensiveness and confidence of technology integration for educational innovation and have attempted to correlate it with student achievement, such as studies using the concerns-based adoption model (Christensen et al., 2001; Christensen & Knezek, 2001).

Some studies have sought to provide similar qualitative grades of technology integration with regard to degrees of pedagogical innovation (e.g., according to the substitution, augmentation, modification, redefinition model [SAMR]; Puentedura, 2006; see also Hamilton et al., 2016) or the pervasiveness of innovation (e.g., according to the diffusion of innovation process model; Rogers, 2003). Although these measures provide a broader and more quality-oriented view of technology integration, they are even more dependent on respondents' personal views and beliefs.

To be less dependent on respondents' personal attitudes and beliefs and due to the fact that in the dataset of the European 2nd Survey of Schools, only quantity-related measurements are available as possible indicators of technology integration, the relative frequency of students' and teachers' technology use in class was chosen for this study. The advantage of a simple frequency rating of teachers' and students' technology use reported by teachers over composite indices (for examples, see Miranda & Russell, 2011; Vongkulluksn et al., 2018) is that the frequency of tool use is not confounded with the type or purpose of tool use. Compared to average classroom computer use in minutes (for an example see Norris et al., 2003), this measure of technology integration also has the advantage that it is easier to estimate relative percentage frequency in retrospect than absolute frequency in minutes. Even when considering the clear limitations of a purely quantity-related measure, it seems to be the most practical for developing a baseline for future findings that might take more complex quantity-related or even quality-related dependent variables into account.

2.2. Barriers to technology integration in teaching and learning

Several theoretical models have been developed to identify and clarify the key factors that enable and hinder both teachers' and students' use of technology in the classroom. Most models that aim to explain technology use can be classified into two distinct categories: models that identify obstacles to technology use and stress the removal of barriers and models highlighting enabling factors and the accumulation of proficiencies (Ertmer, 1999; Knezek & Christensen, 2016).

Studies have shown that the removal of barriers affects not only teacher use of these technologies but also the use of computers as learning tools by students (Lowther et al., 2008; Miranda & Russell, 2011). Research on hindering factors has differentiated barriers, such as lack of hardware and software—so-called first-order barriers—and more deep-rooted barriers, such as teachers' beliefs and lack of skills—so-called second-order barriers (Ertmer, 1999, 2005; Hew & Brush, 2007; Su, 2009). This proposed categorization of barriers has been empirically tested and confirmed by several researchers (Bowman et al., 2020; Hamutoglu & Basarmak, 2020; Hew & Brush, 2007; Kopcha, 2012). According to Ertmer (2005), first-order barriers, such as the availability of digital devices, have been reduced in recent decades, but internal barriers, such as teachers' beliefs and skills, still exist and are more complicated to overcome. Recent studies from the United States seem to confirm this assumption. However, there is large variability in the barriers addressed in these studies. Ertmer et al. (2012) identified attitudes and beliefs toward technology as well as current levels of knowledge and skills as the strongest barriers preventing teachers from using technology in the United States. Ruggiero and Mong (2015) found in qualitative interviews that external barriers still exist but that overcoming internal barriers is more relevant in the United States. In another American study, Makki et al.'s (2018) regression analysis showed that computer feature comfort (second-order barrier) was one of the strongest predictors of teachers' intention to use computer features in schools with insufficient access to computers. Nevertheless, there are still studies from the United States indicating that access to technology might still play an important role in the quantity and quality of technology use; for example, perceived support in overcoming first-order barriers was shown to influence both the quality of technology integration and the quantity of technology use (Vongkulluksn et al., 2018). This mirrors previous findings from an era where technological barriers were still prevalent (Norris et al., 2003). Bowman et al.'s (2020) structural model showed that first-order barriers significantly and directly and indirectly—by reducing second order barriers—affect teachers' technology use for higher-order and lower-order tasks. Overcoming second-order barriers through mentoring and professional development activities helps to create an environment that supports teachers' decisions to integrate technology in the classroom (Franklin et al., 2001; Kopcha, 2012). The findings on barriers are supported by similar findings with regard to enabling factors. In this line of research, the WST model is one of the most popular models (Petko, 2012; Knezek & Christensen, 2016; Knezek et al., 2003; Niederhauser & Lindstrom, 2018). The WST model focuses on teachers' proficiency. This model became prominent because many studies showed that three factors—will (i.e., teachers' attitudes and skills), skill (i.e., teachers' technology-related knowledge and abilities), and tool (i.e., the availability of hardware and software)—explain a very high degree of variance in the frequency of technology use in the classroom (Petko, 2012; Knezek & Christensen, 2008, 2016; Knezek et al., 2000; Knezek et al., 2003; Morales Velazquez, 2006).

However, barriers and enablers for technology integration can be interpreted as two sides of the same coin. For example, Goktas et al. (2009) listed lack of in-service training and lack of appropriate course content and instructional programs as major barriers, while they introduced offering in-service training and designing appropriate course content and instructional programs as enablers. In a study by Ertmer et al. (2012), beliefs were simultaneously operationalized as enablers and barriers. Thus, the same aspects can be operationalized as barriers or enablers, depending on whether they are formulated positively or negatively. A meta-analysis revealed that the major obstacles to technology integration relate to the categories "lack of confidence," "lack of competence," and "lack of access to resources" (Bingimlas, 2009), and these align remarkably well with the rationale of the WST model. As stated in the introduction, the classification of the WST model is very similar to the grouping into first- and second-order barriers because first order barriers align very well with the tool dimension of the WST model and second-order barriers are typically decomposed into belief- and ability-related components, mirroring Ertmer's (2005) position that beliefs are the hardest barriers, which corresponds to the skill and will dimension of the WST model (for an example see Bowman et al., 2020).

In summary, first-, and second-order barriers have been found to impact technology use or integration in the classroom. The findings—mainly from the U.S. context—have indicated a tendency toward an increased importance of second-order barriers; however, first-order barriers might still be an issue with mediated impact. The exact interplay of these types of barriers is still unclear. One reason for this might be that research on barriers has not explicitly examined the differential effect of barriers across different countries and contexts in a study. Therefore, this study aimed to compare the relative effects of barriers across different countries and replicate the results of the structure of barriers through the lens of the WST model.

2.3. Differences across countries

From the review of the literature on barriers, we observed a lack of studies that compare the relative effects of barriers on technology integration or use across international contexts. For example, Korte and Hüsing (2006) only compared the percentage of teachers across European countries who reported specific barriers as a reason for not using digital media, but the impact of these barriers on actual indicators of technology integration was not examined. In other European large-scale assessment studies, teachers' perceptions on how inhibitory various barriers are to their teaching with digital technology were compared across countries, but how these barriers actually affect the frequency of technology use or other indicators of technology integration in the classroom was not statistically analyzed (European Commission, 2013; 2019a). In the IEA International Computer and Information Literacy Study (ICILS), teachers were only asked to agree whether certain barriers were present, without further investigation of the impact of these barriers on indicators of technology integration (Fraillon et al., 2014). Overall, it is evident that an empirical comparison of the relative effects of barriers to technology integration on technology use across different countries is needed. It is still unclear whether subjective ratings on the presence of different types of barriers have a noticeable effect on the extent of technology use in schools. Although this relationship seems obvious, it is surprisingly rarely examined in large-scale studies.

Not only are international studies comparing the relative effects of obstacles on technology use across different countries scarce, but only a few studies have considered the countries' technological development level as a moderator on the relationship between barriers and technology use. Nevertheless, Morales Velazquez (2007) proposed a very useful hypothesis based on the WST model for investigating the countries' technological development level as a moderator. He argued that tool-related factors are the best predictors for enabling technology integration into teaching and learning for teachers at lower stages of technology adoption. At higher stages, skill-related factors are more important. At the highest stages, will-related factors may replace skill as the best predictor (Morales Velazquez, 2007). A good example of this implication is demonstrated in a study that highlighted different results by region (Morales Velazquez, 2006). In the United States, skill development was the strongest predictor, while in Mexico, it was the extent of access to technology. This regional difference could be accounted for by varied accessibility to technology and training in the two countries (Morales Velazquez, 2006). Studies have supported the idea that at high levels of technology adoption, will is the most important predictor. For example, in case studies with teachers who won awards for their technology practices, the most influential factors enabling them to integrate technology were their own attitudes and beliefs (Ertmer et al., 2012). Sasota et al. (2021) indicated that for mathematics teachers' at a lower stage of technology adoption, skill is the most important predictor for ICT integration in teaching, whereas for science teachers at a higher stage of technology adoption will is the most important factor for technology integration. Furthermore, in a high-tech country such as the Netherlands, attitudes and beliefs have been found to be the strongest enabler for preservice teachers (Farjon et al., 2019). In summary, the findings of the country-specific studies by Morales Velazquez (2006) and Farjon et al. (2019) show that the technological development level of the countries influences which factor is particularly important for technology integration. Nevertheless, these previous studies have only examined one or two countries and have not systematically compared several countries with each other to verify the hypothesis of Morales Velazquez (2007) in an international context.

2.4. Hypotheses

Based upon earlier findings, the present study aimed to test the following hypotheses:

1. The empirical structure of barriers aligns with the WST model of technology integration.
2. Will-, skill-, and tool-related barriers significantly and negatively predict students' technology use in class.
3. Will-, skill-, and tool-related barriers significantly and negatively predict teachers' technology use in class.
4. The effects of will-, skill-, and tool-related barriers on teachers' and students' classroom technology use vary depending on the country's technological development level.

3. Method

3.1. Participants and procedure

The analyses were conducted on the data file provided by the 2nd European Survey of Schools: ICT in Education. Data collection took place between November 2017 and May 2018 through an online survey that was completed by mathematics, science, or language teachers from 30 European countries. The sampling procedure was based on a two-stage stratified cluster sample design to ensure the representativeness of the sample for each country represented in the study. For more detailed information about sampling and data collection, please refer to the 2nd European Survey of Schools: ICT in Education technical report (European Commission, 2019b).

Data from teachers in the educational level ISCED 2 (lower secondary education level) and ISCED 3A (upper secondary education level with general programs) were selected for the analysis. We chose this target group because we assumed that lower and upper secondary teachers face similar school conditions (e.g., school organization and programs), and we excluded primary and vocational teachers to avoid more confounding variables (e.g., pupils' age, subjects, and educational programs). The final analytical sample consisted of 6969 teachers (77.4% female, 18.7% male; 69.7% in lower secondary education, 30.3% in upper secondary education).

3.2. Measures

3.2.1. Technology use

In the European survey, students' technology use in class was assessed by the teachers. They estimated the percentage of lesson time their students had spent using digital technologies in class in the past 12 months (exact wording: "For what percentage of your lessons have students used ICT in class in the past 12 months?"). Similarly, teachers' technology use was quantified with an estimate of the percentage of time the teachers had used computers and/or the internet in class in the past 12 months (exact wording: "For what percentage of time have you used computers and/or the internet in class in the past 12 months?"). The two items were rated on a 7-point scale, where 1 = *more than 75%*, 2 = *51–75%*, 3 = *25–50%*, 4 = *11–24%*, 5 = *6–10%*, 6 = *1–5%*, 7 = *less than 1%*. The scores were recorded by combining the 4, 5, and 6 response options into a single option (*1–24%*), resulting in a 5-point scale with roughly equal intervals. The scores were then reverse coded, causing a higher score to correspond to a higher percentage of technology use in class.

3.2.2. Obstacles to technology use

The obstacles to technology use in class perceived by teachers were measured with 22 barrier-related items (e.g., "Is your use of ICT in teaching and learning adversely affected by the following? Insufficient number of computers"). Teachers were asked to indicate the extent to which the technological infrastructure provided by the schools; teachers' competence, interest, and motivation; and school support and organization affect the use of ICT in class. In the dataset, the response options ranged from 1 (*a lot*) to 4 (*a little*). All items were reverse coded to ensure that a higher score corresponds to obstacles' greater perceived influence on the use of technology in the classroom, and a lower score to less perceived influence.

3.2.3. The countries' technological development level

The ICT development index (IDI) was used as an indicator of the countries' technological development level. This index is a composite score derived from the worldwide study of the International Telecommunication Union (ITU). From the ITU study's report we took the IDI scores for the countries of our interest and we added the values into the dataset of the EU Second Survey. As described in the report, this index is a summation of weighted sub-indices called ICT access, ICT usage, and ICT skills. The ICT access and ICT usage sub-indices have the same weight (40% each), while the ICT skills sub-index was given lesser weight (20%) since it is based only on proxy indicators. ICT access is measured by fixed telephone subscriptions per 100 inhabitants, mobile cellular subscriptions per 100 inhabitants, international internet bandwidth per internet user, percentage of households with a computer, and percentage of households with internet access. ICT usage was assessed by the percentage of individuals using the internet, fixed broadband internet subscriptions per 100 inhabitants, and active mobile broadband subscriptions per 100 inhabitants. ICT skills were approximated by mean years of schooling, secondary gross enrollment ratio, and tertiary gross enrollment ratio. The scale of the IDI ranges from zero, indicating the lowest technological development level, to ten, the highest technological development level. More detailed information about the calculation of the IDI can be found in Measuring the Information Society Report 2017 (International Telecommunication Union, 2017).

3.3. Statistical analyses

3.3.1. Descriptive statistics

Descriptive statistics were generated for frequency of participants' gender and age category in each of the 30 countries included in the dataset. Means and standard deviations for the scores of students' technology use and teachers' technology use variables were calculated for each country (Table 2). Following the recommendation in the 2nd European Survey of Schools' technical report, we used sampling weights to account for the unequal number of respondents between countries. Thus, the weights were applied to yield an approximation of the distribution in the full sample (Kish & Frankel, 1974).

3.3.2. Factor analyses of barriers items

In relation to our first hypothesis, exploratory factor analysis (EFA) followed by confirmatory factor analysis (CFA) were conducted to examine the factor structure of the barrier-related items. These results and those of the reliability analysis allowed for creating new composite variables by calculating the mean of the items displaying sufficient factor loadings for each factor. The cut-off chosen was a standardized factor loading of 0.32, as suggested by Tabachnick and Fidell (2007). The variables were calculated following the rule that cases should have at least three valid values for each factor. The new barrier factor variables formed the basis for further analyses. The analyses were conducted using SPSS 26 and the lavaan package (0.6–7) in R (4.0.2).

3.3.3. Multiple linear regressions

To test the second and third hypotheses, we conducted multiple linear regression analyses for each country separately to examine the impact of the barrier factor variables on the two technology use variables (i.e., students' technology use and teachers' technology use). A power analysis conducted in advance showed that most countries had a sufficient sample size to conduct a separate multiple regression analysis on them. Further, multiple linear regression analysis has the advantage over multilevel linear modeling in that clear guidelines for reporting effect sizes are provided (see Cohen, 1992; Lorah, 2018). Gender and age were not included in the analysis, since recent studies did not find significant effects of these control variables on technology use in teaching (Farjon et al., 2019; Gil-Flores et al., 2017). Data were analyzed using SPSS version 26. We employed unweighted observations because the use of weights in regression analysis would likely reduce the efficiency of estimates (Gelman, 2007; Winship & Radbill, 1994).

Table 1
Sample size (N), frequencies (%) for educational level, gender, and age in each country.

Country	Sample	Educational Level		Gender		Age					
	N	ISCED 2 %	ISCED 3A %	Female %	Male %	≤30 %	31–35 %	36–45 %	46–55 %	>55 %	Prefer not to say %
Austria	122	67.2	32.8	63.2	29.8	10.3	12.2	21.6	18.5	27.7	9.6
Belgium	200	59.1	40.9	65.8	31.2	22.9	16.0	30.3	22.2	5.8	2.9
Bulgaria	406	49.4	50.6	90.9	7.8	3.4	2.6	20.8	44.8	25.9	2.5
Croatia	662	56.7	43.3	82.0	14.0	11.7	16.7	31.0	23.7	13.5	3.4
Cyprus	24	57.6	42.4	53.6	46.4	0	0	20.6	37.7	38.0	3.7
Czech Republic	570	70.1	29.9	75.3	17.9	7.9	7.0	24.8	29.0	24.0	7.2
Denmark	209	60.8	39.2	52.2	43.6	6.3	12.5	32.0	14.3	28.2	6.7
Estonia	369	61.0	39.0	84.7	11.6	5.7	3.8	16.1	35.4	34.5	4.6
Finland	276	62.4	37.6	70.7	25.9	9.8	9.8	38.4	26.4	12.6	3.0
France	49	62.6	37.4	47.7	49.5	17.7	14.5	35.6	20.6	10.1	1.5
Germany	54	85.8	14.2	58.3	37.9	14.5	12.4	25.7	28.4	13.7	5.3
Greece	35	58.0	42.0	61.2	38.8	0	1.6	31.1	53.2	14.1	0
Hungary	704	49.5	50.5	75.4	20.5	2.3	5.6	27.3	36.3	23.6	5.0
Iceland	43	45.8	54.2	91.1	7.5	3.5	14.9	37.9	30.1	12.2	1.4
Ireland	11	54.1	45.9	77.9	22.1	3.7	21.4	47.6	24.2	3.1	0
Italy	207	42.0	58.0	75.9	22.1	1.3	4.1	13.0	27.6	51.1	2.9
Latvia	473	58.5	41.5	92.6	3.7	5.1	4.9	19.0	30.5	36.7	3.8
Lithuania	724	56.4	43.6	87.6	9.2	3.7	5.1	19.0	37.6	30.0	4.6
Malta	28	44.5	55.5	64.2	35.8	28.6	18.8	40.9	7.6	4.1	0
Netherlands	10	74.8	25.2	6.6	93.4	5.0	11.6	24.0	6.6	52.8	0
Norway	40	68.2	31.8	39.8	59.0	27.0	0	12.5	34.5	10.7	15.3
Poland	68	42.1	57.9	83.2	4.2	4.3	2.2	21.1	38.5	19.6	14.3
Portugal	237	64.9	35.1	80.3	18.4	0.3	3.0	29.4	45.6	21.2	0.5
Romania	317	51.7	48.3	81.0	15.1	3.5	9.9	40.4	26.3	16.6	3.1
Slovakia	512	66.7	33.3	83.1	13.1	7.1	6.4	31.6	27.4	23.8	3.7
Slovenia	151	66.7	33.3	80.6	16.6	3.3	6.5	33.4	31.0	24.9	0.9
Spain	366	77.5	22.5	60.3	34.3	5.3	11.5	31.4	34.3	12.6	5.1
Sweden	83	64.0	36.0	53.9	44.6	12.7	13.7	34.1	24.9	10.9	3.7
Turkey	6	100.0	0.0	88.9	8.8	93.5	6.5	0	0	0	0
United Kingdom	13	51.0	49.0	34.5	50.3	7.0	33.8	32.2	11.8	10.5	4.7

Note. Percentages are weighted by student weight variable (FSTWT).

3.3.4. Multilevel linear modeling

To test the fourth research hypothesis, we conducted multilevel moderator analyses with the IDI. Considering that secondary school teachers (first level) are nested within countries (second level), we used multilevel linear modeling (MLM) to test our hypotheses. Schools were not taken into account as an additional level because in many schools, only one teacher completed the survey. In the MLM analyses, we included all countries with at least 10 secondary school teachers in the sample: Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. First, a fully unconditional model (null model) was estimated to test whether differences in teachers' and students' technology use could be found at the individual and country levels. Through an analysis of variance (ANOVA), this model's fit was compared to a single-level model. Moreover, the intraclass correlations (ICC) for students' and teachers' technology use were computed. Then, for each dependent variable (i.e., students' and teachers' technology use), a random intercept MLM analysis (model 1) was conducted with the following predictors: barrier factors (will-, skill-, and tool-related barriers), the IDI, and interactions between the IDI and barrier factors. Again, the fit of this model was compared with the null model's fit using an ANOVA. The three barrier factors of model 1 were cluster-mean centered because cross-level interactions between the IDI at the country level and the barrier factors at the individual level were examined (Enders & Tofighi, 2007; Lüdtke et al., 2009). When a significant interaction effect was found, simple slope analysis was carried out to investigate the interaction further. Slopes for the regression of barrier variables on ICT use were computed at three levels of the IDI variable: mean (IDI = 7.35 for teacher use and IDI = 7.36 for student use), one standard deviation below the mean (IDI = 6.83, low ICT developed country), and one standard deviation above the mean (IDI = 7.88, high ICT developed country). These analyses were conducted with the lmerTest package (3.1-2) and interactions package (1.1.3) in R (4.0.2).

Table 2
Means and standard deviations of technology use variables by country.

Country	Teachers' technology use		Students' technology use	
	M	*SD*	*M*	*SD*
AT	1.74	1.09	1.31	0.85
BE	2.68	1.32	1.63	1.16
BG	1.67	1.14	1.47	1.00
CY	2.29	1.14	1.34	1.20
CZ	2.16	1.22	1.29	0.77
DE	1.67	1.04	1.22	0.87
DK	2.93	1.15	2.84	1.19
EE	1.93	1.14	1.38	0.87
EL	1.59	1.22	1.36	1.08
ES	2.07	1.20	1.40	0.94
FI	2.15	1.05	1.54	0.84
FR	2.19	1.29	1.71	1.11
HR	2.09	1.13	1.41	0.93
HU	1.53	0.91	1.20	0.74
IE	2.82	0.70	1.65	1.03
IS	2.41	1.10	2.11	1.07
IT	1.90	1.14	1.47	1.12
LT	2.74	1.12	1.59	0.93
LV	2.24	1.16	1.63	0.94
MT	2.87	1.18	1.20	1.04
NL	1.59	1.13	1.84	1.13
NO	2.67	0.93	2.32	1.09
PL	2.02	1.19	1.51	0.97
PT	2.18	1.15	2.10	1.15
RO	1.79	1.10	1.49	1.01
SE	2.43	1.21	2.34	1.11
SI	2.28	1.19	1.22	0.75
SK	2.05	1.05	1.60	0.92
TR	3.60	0.91	2.00	0.30
UK	2.94	0.99	1.94	1.23

Note. *"For what percentage of time have you used computers and/or the Internet in class in the past* 12 months*?"* and *"For what percentage of your lessons have students used ICT in class in the past* 12 months*?":* Answer response: 1 = less than 1%, 2 = 1–24%, 3 = 25–50%, 4 = 51–75%, 5 = more than 75%. Mean (*M*) and standard deviations (*SD*) are weighted by student weight variable (FSTWT).
AT = Austria; **BE** = Belgium; **BG** = Bulgaria; **CY** = Cyprus; **CZ** = Czech Republic; **DE** = Germany; **DK** = Denmark; **EE** = Estonia; **EL** = Greece; **ES** = Spain; **FI** =Finland; **FR** = France; **HR** = Croatia; **HU** = Hungary; **IE** = Ireland; **IS** = Iceland; **IT** = Italy; **LT** = Lithuania; **LV** = Latvia; **MT** = Malta; **NL** = Netherlands; **NO** = Norway; **PL** = Poland; **PT** = Portugal; **RO** = Romania; **SE** = Sweden; **SI** = Slovenia; **SK** = Slovakia; **TR** = Turkey; **UK** = United Kingdom.

4. Results

4.1. Descriptive statistics

Table 1 shows the number of participants in each country and the descriptive statistics for the education level (i.e., lower or upper secondary level), gender, and age across countries. The percentages reported were calculated using survey weights. The majority of participants were lower secondary school teachers (60.6%). Most of the teachers were female (64.3%) and older than 36 years (71.2%). Table 2 provides an overview of the means and standard deviations of the variables for technology use. Generally, teachers reported a higher frequency of computer and internet use in class for themselves (M = 2.24, SD = 1.11) than for their students (M = 1.64, SD = 0.98). However, there were substantial differences between countries (mean scores ranging from 1.53 to 3.60 for teachers' technology use and from 1.20 to 2.84 for students' technology use). The highest mean for teachers' technology use was found in Turkey, while the lowest mean was identified in Hungary. Regarding students' technology use, the highest mean was found in Denmark, while the lowest means were identified in Hungary and Malta, with Malta having the larger standard deviation.

4.2. Factorial structure of barriers items

We investigated the underlying factor structure of the barrier items using EFA. The extraction method was principal axis factoring with Promax rotation. The Kaiser-Meyer-Olkin value was 0.96 and Bartlett's test of sphericity was significant, χ^2 (df = 210) = 44553.14, $p < .001$, supporting the rationale for performing EFA. The number of factors to extract was based on the rule that eigenvalues should be greater than one and the scree plot test. The results yielded a three-factor solution with eigenvalues of 8.95, 2.01, and 1.01. This three-factor solution was also confirmed by scree plot visual examination. The percentage of variance explained by these three components was 50.22%. We assessed factor loadings using the criteria of 0.32 = poor, 0.45 = fair, 0.55 = good, 0.63 = very good, and 0.71 = excellent (Tabachnick & Fidell, 2007). The item related to school time organization was removed from the analysis because it did not clearly correlate with one factor. As shown in Table 3, the factor loading ranged between 0.39 and 0.92, suggesting that each item substantially contributed to the factor. The EFA allowed us to identify three different factors, thereby confirming the first hypothesis. The first eight barrier items related to the lack or scarcity of digital devices and infrastructure were within the first factor (tool-related barriers), eight items referring to insufficient technical and pedagogical support and teachers' lack of digital skills were related to the second factor (skill-related barriers), and five items related to beliefs about and interest in ICT integration loaded on the third factor (will-related barriers). In summary, the EFA confirmed the first hypothesis of this study.

The EFA was followed by CFA, which indicated a good fit of the three-factor model (Chi^2 (210) = 44,645.80; p = .000; TLI = 0.96; CFI = 0.96; RMSEA = 0.05; SRMR = 0.04). For the TLI and,CFI, a value greater than 0.95 was considered a good fit, as were values of RSMEA and SRMR below 0.08 (Brown, 2015; Hu & Bentler, 1999). According to the modification indices, 18 residual correlations between items of the same barrier factors were added to improve the model fit. We also estimated the internal consistency and

Table 3
Results from factor analysis of the barriers items.

Barriers items	Factor loading		
	1	2	3
Factor 1: Tool-related barriers			
# computers	**.92**	−.04	−.04
# laptops/notebooks	**.87**	−.02	−.03
# Internet-connected computers	**.83**	−.03	.01
# tablets	**.73**	−.01	.01
Computers out of date	**.70**	.04	.03
Internet bandwidth/speed	**.55**	.08	.01
# interactive whiteboards	**.54**	.04	.10
School space organization	**.47**	.17	.08
Factor 2: Skill-related barriers			
Lack of pedagogical models	.01	**.78**	−.05
Lack of content/material	.01	**.72**	−.05
Insufficient pedagogical support	.06	**.72**	−.01
Insufficient technical support	.29	**.55**	−.02
Lack of adequate teachers 'skills	.01	**.49**	.25
Lack of content in national language	−.01	**.48**	.12
School curriculum	−.02	**.42**	.30
Pressure for exams and tests	.10	**.39**	.12
Factor 3: Will-related barriers			
Teachers not in favor	.02	−.06	**.81**
Parents not in favor	.08	−.11	**.71**
Lack of teachers' interest	−.05	.20	**.60**
School goal	.08	.02	**.57**
No or unclear benefit	−.13	.31	**.43**

Note. The extraction method was principal axis factoring with an oblique (Promax with Kaiser normalization) rotation. Factor loadings above 0.30 are in bold.

reliability of the three factors using Cronbach's α and McDonald's ω. The two reliability indices were 0.80 and 0.83 for the will-related barriers factor, 0.86 and 0.88 for the skill-related barriers factor, and 0.90 and 0.91 for the tool-related barriers factor, respectively. Overall, the results of the CFA are consistent with those of the EFA.

In the next step, we computed mean composite scores of items comprising each factor to obtain three new barrier variables (i.e., will-related barriers, skill-related barriers, and tool-related barriers) that formed the basis of all further analyses. Examining descriptive statistics for these composite scores, teachers reported that the use of technology in class was mostly affected by tool-related barriers (M = 2.42, SD = 0.77), with mean scores ranging from 1.51 in Denmark to 3.52 in Greece. Will-related barriers were reported to a lesser extent (M = 1.80, SD = 0.61), with scores ranging from 1.17 in the United Kingdom to 2.81 in Turkey. The mean score of skill-related barriers (M = 2.24, SD = 0.65) varied across countries, from 1.51 in the United Kingdom to 3.07 in Greece. There was substantial variation between countries in barrier factor scores. In general, all three types of barriers were mostly reported in countries such as Turkey, Romania, Cyprus, and Greece. By contrast, in countries such as Denmark, Norway, and the United Kingdom, teachers reported fewer barriers to technology integration. Means and standard deviations for each country are presented in Table 4.

4.3. Multiple linear regressions

Before conducting the regression analyses, the intercorrelation of composite barrier items was computed to investigate their relations. The correlation coefficients and descriptive statistical values are presented in Table 5. There were positive and significant high correlations between the three barrier variables and between the two technology use variables. Conversely, independent variables were negatively correlated with dependent variables.

With the aim of determining the extent to which the specified barriers could predict technology use in class, multiple regression analyses were performed separately for each country. A power analysis conducted with G*Power software indicated that a sample size of 119 participants was required to detect a significant ($p = .05$) medium effect ($f^2 = 0.015$) with a power of 0.95 in the regression analysis. Therefore, 15 countries were excluded from the analysis for failing to meet the above-mentioned criterion. In the first step, the statistical prerequisites of multiple linear regression were tested. Although the prerequisite for a normal distribution of residuals was not met in this dataset, this is considered to have little impact in a large sample (Bohrnstedt & Carter, 1971; Schmidt & Finan,

Table 4
Means and standard deviations of the three barrier factors by country.

Country	Will-related barriers		Skill-related barriers		Tool-related barriers	
	M	*SD*	*M*	*SD*	*M*	*SD*
AT	1.64	0.68	1.96	0.71	2.34	0.96
BE	1.57	0.63	1.96	0.63	2.33	0.84
BG	1.93	0.76	2.26	0.74	2.49	0.92
CY	2.11	0.70	2.67	0.85	3.11	0.79
CZ	1.86	0.64	2.11	0.68	2.35	0.84
DE	1.61	0.54	2.22	0.65	2.58	0.95
DK	1.29	0.44	1.69	0.56	1.51	0.60
EE	1.74	0.60	2.18	0.67	2.09	0.78
EL	2.30	0.54	3.07	0.49	3.52	0.43
ES	1.59	0.59	2.20	0.69	2.61	0.83
FI	1.52	0.48	2.01	0.63	1.96	0.85
FR	1.67	0.60	2.18	0.68	2.39	0.98
HR	1.94	0.75	2.42	0.75	2.55	0.90
HU	1.73	0.64	2.32	0.69	2.70	0.87
IE	1.71	0.67	2.26	0.56	2.61	0.77
IS	1.64	0.58	2.24	0.65	2.07	0.88
IT	1.73	0.62	2.14	0.64	2.32	0.78
LT	1.90	0.66	2.42	0.69	2.60	0.78
LV	1.90	0.61	2.37	0.69	2.40	0.78
MT	1.53	0.60	2.06	0.69	2.07	0.81
NL	1.82	0.62	1.66	0.59	2.04	0.71
NO	1.48	0.54	1.82	0.61	1.55	0.70
PL	1.87	0.67	2.23	0.69	2.65	0.80
PT	1.65	0.60	2.24	0.64	2.78	0.81
RO	2.42	0.75	2.86	0.63	3.16	0.70
SE	1.52	0.57	1.96	0.66	1.56	0.65
SI	2.07	0.61	2.29	0.64	2.31	0.73
SK	1.84	0.63	2.33	0.66	2.64	0.78
TR	2.81	0.53	2.97	0.32	3.01	0.23
UK	1.17	0.20	1.51	0.44	2.14	1.00

Note. "*Is your use of ICT in teaching and learning adversely affected by the following?*" Answer response: 1 = *Not at all*, 2 = *A little*, 3 = *Partially*, 4 = *A lot.* Mean (*M*) and standard deviations (*SD*) are weighted by student weight variable (FSTWT). **AT** = Austria; **BE** = Belgium; **BG** = Bulgaria; **CY** = Cyprus; **CZ** = Czech Republic; **DE** = Germany; **DK** = Denmark; **EE** = Estonia; **EL** = Greece; **ES** = Spain; **FI** =Finland; **FR** = France; **HR** = Croatia; **HU** = Hungary; **IE** = Ireland; **IS** = Iceland; **IT** = Italy; **LT** = Lithuania; **LV** = Latvia; **MT** = Malta; **NL** = Netherlands; **NO** = Norway; **PL** = Poland; **PT** = Portugal; **RO** = Romania; **SE** = Sweden; **SI** = Slovenia; **SK** = Slovakia; **TR** = Turkey; **UK** = United Kingdom.

Table 5
Intercorrelations between study variables.

Variable	1	2	3	4	5
1. Will-related barriers	–				
2. Skill-related barriers	.68***	–			
3. Tool-related barriers	.49***	.64***	–		
4. Students' ICT use	−.14***	−.17***	−.17***	–	
5. Teachers' ICT use	−.12***	−.15***	−.15***	.59***	–

Note.
*$p < .05$.
**$p < .01$.
***$p < .001$.

2018; Vasu & Elmore, 1975). As the dataset included more than 10 observations per variable in most countries, the regression analysis can be considered fairly robust against violations of the normal distribution of residuals (Schmidt & Finan, 2018). Although we could also observe slight deviations from the assumption of homoscedasticity, for similar reasons, this should not pose major problems (Berry & Feldman, 1985; Bohrnstedt & Carter, 1971; Osborne & Waters, 2002).

Table 6 presents the results of the multiple linear regression analysis predicting students' and teachers' technology use frequency. In contrast to hypotheses 2 and 3, will-, skill-, and tool-related barriers did not consistently predict students' and teachers' technology use in class. Instead, the effect sizes regarding the impact of barriers were rather low, and there were several countries where barriers seemed to show no significant impact at all. No significant impact regarding students' technology use was found in Belgium, the Czech Republic, Denmark, Croatia, Lithuania, and Portugal; no significant impact on teachers' technology use was present in Belgium, Spain, Croatia, Portugal, Slovenia, and Slovakia. For the other countries, there was substantial variance regarding which barrier had an effect. In particular, a significant effect of at least one barrier on students' technology use was reported for Bulgaria (will, skill), Estonia (tool), Finland (tool), Hungary (tool), Italy (skill), Latvia (skill), Romania (tool), Slovakia (skill), Slovenia (skill), and Spain (tool); significant effects on teachers' technology use were present in Bulgaria (skill), the Czech Republic (will), Denmark (skill), Estonia (will, tool), Finland (skill), Hungary (tool), Italy (skill), Latvia (skill), Lithuania (will), and Romania (will, tool). The total explained variance of students' technology use did not exceed 7% in any of the 16 countries. Instead, when teachers' technology use was the outcome variable, the explained variance ranged from 2% to 8% among the countries. The three barrier variables barely contributed to explaining the frequency of technology use in class by either students or teachers.

4.4. Multilevel linear modeling

Since the ICC analysis of the null model indicated that 18% of the variance in students' technology use and 10% of the variance in teachers' technology use could be attributed to differences between countries, and the ANOVA showed the best fit for model 1, an MLM analysis for each dependent variable was conducted. The results of the MLM analyses are presented in Table 7. For student use, only the effects of will-related barriers and the IDI were significant and positive. In addition, the interaction between will-related barriers and the IDI was significant. A closer inspection with a simple slope analysis revealed that although the general interaction effect became significant, none of the slopes were significant. Regarding the slope for countries with an IDI above one standard deviation, the significance level was narrowly missed for the negative influence of will-related barriers on students' technology use ($b = -0.07$, SE $= 0.04$, $p = .07$). The slope for countries with an average IDI was not significant ($b = -0.01$, SE $= 0.02$, $p = .59$), and the same applied for countries with an IDI below one standard deviation ($b = 0.04$, SE $= 0.03$, $p = .18$). Fig. 1 illustrates the interaction effect. Regarding the MLM analysis for teachers' technology use, tool-related barriers and the IDI were the only variables with significant effects. While the impact of tool-related barriers on teachers' technology use was negative, the IDI positively influenced teachers' technology use. Additionally, the interaction between tool-related barriers and the IDI was significant. A simple slope analysis showed that in the case of countries with an average IDI, tool-related barriers had a significant negative impact on teachers' technology use ($b = -0.06$, SE $= 0.02$, $p = .00$). Moreover, for countries with an IDI below one standard deviation, the barrier factor had a significant negative influence on teachers' technology use ($b = -0.12$, SE $= 0.03$, $p = .00$). Only for countries with an IDI above one standard deviation was no significant effect present ($b = -0.00$, SE $= 0.03$, $p = .88$). Fig. 2 presents the interaction effect.

5. Discussion

5.1. Summary of the results

Using EFA and CFA, we showed that the barriers to technology use in schools can be meaningfully grouped along the three factors of the WST model. This supports not only the differentiation of barriers into first- and second-order barriers but also the distinction between will- and skill-related barriers. The influence of these barrier-related factors on teachers' and students' use of technology in class was less apparent than expected. Although in most European countries, some minor significant effects were present, previous findings from the 2000s on the high influence of barriers to technology use and teachers' intention to integrate ICT in the classroom (Franklin et al., 2001; Lowther et al., 2008; Norris et al., 2003) were surprisingly not replicated in the present study. A possible explanation for our results might be that items assessed in the European survey referred to aspects that teachers today do not perceive

Table 6a
Results of the multiple linear regression analysis predicting the percentage of ICT use in class by students.

Country	IDI	Variable	R^2	Adj. R^2	F	B	SE	β	t	*p*	95% CI
RO	6.48		0.04	0.03	F (3,264) = 3.99**						
		Constant				2.17	0.27		7.94	0	[1.63, 2.70]
		Will barriers				0.08	0.09	0.07	0.82	0.414	[–0.11, 0.26]
		Skill barriers				0	0.13	0	0.01	0.992	[–0.26, 0.26]
		Tool barriers				**−0.30**	**0.11**	**–.23**	**−2.87**	**0.004**	**[–0.51, –0.09]**
BG	6.86		0.07	0.07	F (3,345) = 9.17***						
		Constant				2.17	0.17		12.79	0	[1.84, 2.51]
		Will barriers				**0.28**	**0.11**	**0.21**	**2.71**	**0.007**	**[0.08, 0.49]**
		Skill barriers				**−0.37**	**0.12**	**–.28**	**−3.08**	**0.002**	**[–0.61, –0.14]**
		Tool barriers				−0.15	0.08	–.13	−1.85	0.065	[–0.30, 0.10]
HU	6.93		0.03	0.03	F (3,615) = 6.18***						
		Constant				1.64	0.11		14.92	0	[1.42, 1.85]
		Will barriers				0.01	0.06	0.01	0.09	0.925	[–0.11, 0.13]
		Skill barriers				−0.09	0.06	–.08	−1.49	0.136	[–0.20, 0.03]
		Tool barriers				**−0.10**	**0.04**	**–.11**	**−2.38**	**0.017**	**[–0.18, –0.02]**
IT	7.04		0.07	0.06	F (3,170) = 4.52**						
		Constant				2.46	0.29		8.55	0	[1.89, 3.02]
		Will barriers				0.17	0.16	0.1	1.06	0.292	[–0.14, 0.47]
		Skill barriers				**−0.41**	**0.17**	**–.26**	**−2.48**	**0.014**	**[–0.74, –0.08]**
		Tool barriers				−0.14	0.11	–.11	−1.28	0.202	[–0.36, 0.08]
SK	7.06		0.03	0.03	F (3,452) = 5.11**						
		Constant				2.06	0.17		12.51	0	[1.74, 2.39]
		Will barriers				0.01	0.08	0.01	0.15	0.883	[–0.15, 0.18]
		Skill barriers				**−0.29**	**0.1**	**–.22**	**−2.98**	**0.003**	**[–0.48, –0.10]**
		Tool barriers				0.06	0.07	0.05	0.88	0.381	[–0.07, 0.19]
PT	7.13		0.04	0.02	F (3,194) = 2.33						
		Constant				3.06	0.34		9.03	0	[2.39, 3.73]
		Will barriers				0.06	0.17	0.03	0.39	0.698	[–0.26, 0.39]
		Skill barriers				−0.29	0.17	–.16	−1.67	0.096	[–0.62, 0.05]
		Tool barriers				−0.11	0.12	–.08	−0.94	0.351	[–0.33, 0.12]
CZ	7.16		0	–.01	F (3,436) = 0.29						
		Constant				1.41	0.14		9.82	0	[1.12, 1.69]
		Will barriers				−0.07	0.08	–.06	−0.87	0.384	[–0.24, 0.09]
		Skill barriers				0.02	0.1	0.02	0.25	0.802	[–0.16, 0.21]
		Tool barriers				0.01	0.06	0.01	0.11	0.913	[–0.12, 0.13]
LT	7.19		0.02	0.02	F (3,659) = 5.11**						
		Constant				2.17	0.15		14.85	0	[1.88, 2.46]
		Will barriers				−0.09	0.07	–.06	−1.24	0.214	[–0.23, 0.05]
		Skill barriers				−0.06	0.08	–.05	−0.78	0.434	[–0.22, 0.10]
		Tool barriers				−0.09	0.06	–.07	−1.41	0.16	[–0.21, 0.04]
HR	7.24		0.01	0.01	F (3, 539) = 2.48						
		Constant				1.68	0.13		13.43	0	[1,44, 1.93]
		Will barriers				−0.05	0.07	–.04	−0.69	0.488	[–0.18, 0.09]
		Skill barriers				−0.07	0.07	–.07	−0.10	0.319	[–0.22, 0.07]
		Tool barriers				−0.02	0.05	–.02	−0.39	0.695	[–0.12, 0.08]
LV	7.26		0.04	0.03	F (3,407) = 5.03**						
		Constant				2.33	0.18		13.08	0	[1.98, 2.68]
		Will barriers				0.03	0.1	0.02	0.3	0.768	[–0.17, 0.22]
		Skill barriers				**−0.28**	**0.11**	**–.20**	**−2.62**	**0.009**	**[–0.49, –0.07]**
		Tool barriers				−0.01	0.08	–.01	−0.15	0.88	[–0.16, 0.14]
SI	7.38		0.07	0.05	F (3,134) = 3.39*						
		Constant				1.48	0.24		6.16	0	[1.00, 1.95]
		Will barriers				0.18	0.13	0.16	1.41	0.16	[–0.07, 0.44]
		Skill barriers				**−0.44**	**0.14**	**–.39**	**−3.18**	**0.002**	**[–0.72, –0.17]**
		Tool barriers				0.15	0.1	0.16	1.46	0.147	[–0.05, 0.36]
ES	7.79		0.04	0.04	F (3,317) = 4.84**						
		Constant				2.14	0.19		11.39	0	[1.77, 2.51]
		Will barriers				−0.02	0.1	–.01	−0.18	0.857	[–0.22, 0.19]
		Skill barriers				−0.10	0.11	–.07	−0.93	0.354	[–0.32, 0.11]
		Tool barriers				**−0.16**	**0.08**	**–.15**	**−1.99**	**0.047**	**[–0.32, 0.00]**
BE	7.81		0.01	–.01	F (3,167) = 0.71						
		Constant				1.77	0.28		6.29	0	[1.21, 2.32]
		Will barriers				−0.22	0.17	–.13	−1.25	0.214	[–0.56, 0.13]
		Skill barriers				0.12	0.19	0.07	0.62	0.539	[–0.26, 0.49]
		Tool barriers				−0.06	0.12	–.05	−0.54	0.587	[–0.30, 0.17]
FI	7.88		0.07	0.06	F (3,252) = 5.97**						
		Constant				2.37	0.19		12.19	0	[1.99, 2.75]
		Will barriers				−0.09	0.14	–.05	−0.65	0.517	[–0.36, 0.18]

(*continued on next page*)

Table 6a (*continued*)

Country	IDI	Variable	R^2	Adj. R^2	F	B	SE	β	t	*p*	95% CI
		Skill barriers				−0.17	0.11	−.13	−1.58	0.117	[−0.38, 0.04]
		Tool barriers				**−0.15**	**0.07**	**−.14**	**−2.12**	**0.035**	**[−0.29, −0.10]**
EE	8.14		0.02	0.01	F (3,326) = 2.51						
		Constant				1.61	0.16		10.24	0	[1.30, 1.92]
		Will barriers				−0.14	0.11	−.11	−1.38	0.17	[−0.35, 0.06]
		Skill barriers				−0.12	0.11	−.10	−1.09	0.275	[−0.32, 0.09]
		Tool barriers				**0.16**	**0.07**	**0.15**	**2.08**	**0.038**	**[0.01, 0.30]**
DK	8.71		0.03	0.01	F (3,187) = 1.77						
		Constant				3.48	0.27		12.89	0	[2.95, 4.02]
		Will barriers				−0.03	0.25	−.01	−0.14	0.893	[−0.53, 0.46]
		Skill barriers				−0.29	0.23	−.14	−1.27	0.206	[−0.74, 0.16]
		Tool barriers				−0.04	0.18	−.02	−0.21	0.838	[−0.40, 0.33]

Note. Dependent variable: *Students ICT use in class*: 0 = less than 1%, 1 = 1–24%, 2 = 25–50%, 3 = 51–75%, 4 = more than 75%.
*F-value is significant at the $p < .05$.
**F-value is significant at the $p < .01$.
***F-Value is significant at the $p < .001$. **BE** = Belgium; **BG** = Bulgaria; **CZ** = Czech Republic; **DK** = Denmark; **EE** = Estonia; **ES** = Spain; **FI** =Finland; **HR** = Croatia; **HU** = Hungary; **IT** = Italy; **LT** = Lithuania; **LV** = Latvia; **PT** = Portugal; **RO** = Romania; **SI** = Slovenia; **SK** = Slovakia.

as unconquerable barriers.

It is evident that the measurement of barriers has changed in more recent studies, especially concerning barriers relating to equipment, competencies, and beliefs. Regarding first-order barriers, in the early 2000s, teachers were asked to rate barriers such as having no internet access, having an insufficient number of computers, or having no computers at all (Barras & Petko, 2007; Egloff & Liardet, 2004; Korte & Hüsing, 2006; Smerdon et al., 2000). The current discussion has shifted from computer access to the "quality" of computer use (Agyei and Voogt, 2011). More recent studies have investigated not only the lack of computers but also the lack of diverse technical equipment (e.g., tablets, laptops, or interactive whiteboards) and its quality (Basarmak & Hamutoglu, 2020; European Commission, 2013, 2019a; Kopcha, 2012).

Moreover, the focus on teachers' skills as a barrier has shifted from basic knowledge to more advanced digital competencies. In the early 2000s, researchers asked teachers whether they perceived the handling of basic functions of a computer as a barrier (Schoepp, 2004; Smerdon et al., 2000; Snoeyink & Ertmer, 2001). Since then, the demands on teachers' digital competencies have increased to include different facets of digital competence, as emphasized by the most common frameworks (e.g., Kelentrić et al., 2017; Redecker & Punie, 2017; United Nations Educational Scientific and Cultural Organization, 2011), and teachers are aware of the complex and fast-changing technology trends as well as their demands (Ertmer et al., 2012). Today, barriers might relate to more advanced computational competencies and to their integration into subject-specific knowledge, pedagogical knowledge, and pedagogical content knowledge, as detailed in the Technological Pedagogical Content Knowledge (TPACK) model by Mishra and Koehler (2006).

Further, the assessment of teachers' beliefs as barriers has changed and is more detailed today. Whereas in the early 2000s and also in this study, beliefs were operationalized as a more general like or dislike of technology (Fabry & Higgs, 1997; Hew & Brush, 2007), in current research, beliefs are assessed with components such as pedagogical beliefs in the context of technology, beliefs about self-efficacy for technology and the value of technology, and computer anxiety (Basarmak & Hamutoglu, 2020; Hsu, 2016; Makki et al., 2018). Pedagogical beliefs, in particular, are measured in even greater detail because it is assumed that they comprise a complex and multifaceted structure (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017). In summary, a shift in the measurement of barriers to technology integration is warranted, and a reconceptualization of barriers due to the permeation of technology in today's society is needed.

The results of our study are also consistent with the claim that there has been a clear drop in perceived barriers to technology use regarding insufficient computers, lack of teacher skills, lack of content, and lack of interest of teachers since 2006 in European countries (European Commission, 2013; Korte & Hüsing, 2006). Hence, barriers are no longer so difficult for European teachers to overcome, and they hardly affect technology integration into teaching and learning. The results of a longitudinal study revealed that barriers such as the lack of teachers' beliefs, training, and technological support declined consistently over three years (Francom, 2020). In another study, the lack of technological resources decreased over time (Sahin Izmirli & Kirmaci, 2017). Overall, the impact of barriers on technology use has decreased over the years. Hence, recent studies suggesting that barriers influence technology use (Makki et al., 2018; Singhavi & Basargekar, 2019) clearly assessed different indicators of technology use in the classroom (e.g., teachers' willingness to use technology).

When looking at the different sizes of the standard deviations of the variables (will, skill, and tool-related barriers as well as frequency of technology use by teachers and students) between countries, no country-specific trend between a country's diversity (standard deviation of the variables) and the null effects could be found. Instead, specific patterns of the influence of barrier factors in different countries could be observed, which can be partly explained by the extent of digital development in the surveyed countries. In our MLM analysis, the IDI variable significantly moderated the relationship between will-related barriers and students' technology use and between tool-related barriers and teachers' technology use. Regarding students' technology use, our study showed that especially in highly developed countries with a high IDI, will-related barriers had a marginally significant negative effect on the use of technology. Regarding teachers' technology use, countries with a lower or average IDI especially showed a significant negative relationship between tool-related barriers and technology use. Ertmer (2005) assumed that beliefs might be the final frontier of technology use in

Table 6b
Results of the multiple linear regression analysis predicting the percentage of ICT use in class by teacher.

Country	IDI	Variable	R^2	Adj. R^2	F	B	SE	β	t	*p*	95% CI
RO	6.48		0.06	0.05	F (3,270) = 6.11***						
		Constant				2.73	0.31		8.94	0	[2.13, 3.33]
		Will barriers				**0.22**	**0.11**	**0.17**	**2.11**	**0.036**	**[0.02, 0.43]**
		Skill barriers				−0.21	0.15	−.14	−1.43	0.154	[−0.51, 0.08]
		Tool barriers				**−0.30**	**0.12**	**−.20**	**−2.57**	**0.011**	**[−0.54, −0.07]**
BG	6.86		.04	.04	F (3,351) = 5.38**						
		Constant				2.33	0.18		12.69	0	[1.97, 2.69]
		Will barriers				0.18	0.11	0.12	1.61	0.107	[−0.04, 0.40]
		Skill barriers				**−0.28**	**0.13**	**−.19**	**−2.19**	**0.029**	**[−0.53, −0.03]**
		Tool barriers				−0.13	0.09	−.11	−1.52	0.13	[−0.30. 0.04]
HU	6.93		0.03	0.02	F (3,638) = 5.61**						
		Constant				2.04	0.13		15.29	0	[1.77, 2.30]
		Will barriers				−0.07	0.07	−.05	−0.98	0.33	[−0.22, 0.07]
		Skill barriers				−0.03	0.07	−.02	−0.36	0.72	[−0.17, 0.11]
		Tool barriers				**−0.13**	**0.05**	**−.12**	**−2.59**	**0.01**	**[−0.22, −0.03]**
IT	7.04		0.08	0.06	F (3,178) = 4.84**						
		Constant				3.09	0.31		9.83	0	[2.47, 3.71]
		Will barriers				0.15	0.17	0.08	0.88	0.379	[−0.19, 0.49]
		Skill barriers				**−0.44**	**0.18**	**−.25**	**−2.46**	**0.015**	**[−0.79, −0.09]**
		Tool barriers				−0.17	0.12	−.12	−1.44	0.153	[−0.41, 0.07]
SK	7.06		0.05	0.04	F (3,457) = 7.91***						
		Constant				2.91	0.19		15.24	0	[2.53, 3.28]
		Will barriers				−0.10	0.1	−.06	−0.99	0.321	[−0.29, 0.10]
		Skill barriers				−0.16	0.11	−.10	−1.42	0.157	[−0.39, 0.06]
		Tool barriers				−0.13	0.08	−.10	−1.70	0.09	[−0.28, 0.02]
PT	7.13		0.03	0.01	F (3,195) = 1.66						
		Constant				2.9	0.34		8.51	0	[2.23, 3.57]
		Will barriers				0.11	0.17	0.06	0.68	0.495	[−0.21, 0.44]
		Skill barriers				−0.31	0.17	−.17	−1.81	0.072	[−0.65, 0.03]
		Tool barriers				−0.04	0.12	−.03	−0.37	0.712	[−0.27, 0.19]
CZ	7.16		0.03	0.03	F (3,445) = 4.78**						
		Constant				2.85	0.2		13.93	0	[2.45, 3.25]
		Will barriers				**−0.35**	**0.12**	**−.19**	**−2.92**	**0.004**	**[−0.58, −0.11]**
		Skill barriers				0.06	0.14	0.03	0.46	0.65	[−0.21, 0.33]
		Tool barriers				−0.03	0.09	−.02	−0.35	0.729	[−0.21, 0.15]
LT	7.19		0.02	0.01	F (3,673) = 3.36*						
		Constant				2.9	0.18		16.49	0	[2.56, 3.25]
		Will barriers				**−0.25**	**0.09**	**−.14**	**−2.94**	**0.003**	**[−0.42, −0.08]**
		Skill barriers				0.13	0.1	0.07	1.29	0.196	[−0.07, 0.32]
		Tool barriers				−0.04	0.08	−.03	−0.58	0.56	[−0.19, 0.11]
HR	7.24		0.02	0.01	F (3, 561) = 2.78*						
		Constant				2.63	0.172		15.32	0	[2.29, 2.97]
		Will barriers				−0.07	0.09	−.05	−0.78	0.434	[−0.25, 0.11]
		Skill barriers				−0.06	0.01	−.04	−0.60	0.546	[−0.26, 0.14]
		Tool barriers				−0.07	0.07	−.05	−0.98	0.327	[−0.21, 0.07]
LV	7.26		0.05	0.05	F (3,419) = 7.56***						
		Constant				3.11	0.22		14.44	0	[2.68, 3.53]
		Will barriers				−0.10	0.12	−.06	−0.81	0.419	[−0.34, 0.14]
		Skill barriers				**−0.39**	**0.13**	**−.22**	**−3.05**	**0.002**	**[−0.64, −0.14]**
		Tool barriers				0.1	0.09	0.07	1.12	0.264	[−0.08, 0.29]
SI	7.38		0.03	0.01	F (3,139) = 1.57						
		Constant				3.04	0.37		8.13	0	[2.30, 3.78]
		Will barriers				0.13	0.2	0.08	0.64	0.522	[−0.27, 0.53]
		Skill barriers				−0.32	0.22	−.18	−1.48	0.142	[−0.76, 0.11]
		Tool barriers				−0.10	0.16	−.06	−0.59	0.555	[−0.42, 0.23]
ES	7.79		0.03	0.03	F (3,316) = 3.72*						
		Constant				2.71	0.23		11.88	0	[2.26, 3.16]
		Will barriers				−0.03	0.13	−.02	−0.22	0.829	[−0.28, 0.22]
		Skill barriers				−0.23	0.13	−.14	−1.75	0.081	[−0.50, 0.03]
		Tool barriers				−0.06	0.1	−.05	−0.62	0.536	[−0.25, 0.13]
BE	7.81		0.04	.02	F (3,167) = 2.15						
		Constant				3.46	0.33		10.51	0	[2.80, 4.11]
		Will barriers				−0.09	0.21	−.04	−0.41	0.68	[−0.49, 0.32]
		Skill barriers				−0.12	0.22	−.06	−0.52	0.603	[−0.55, 0.32]
		Tool barriers				−0.19	0.14	−.13	−1.35	0.179	[−0.46, 0.09]
FI	7.88		0.07	0.06	F (3,253) = 6.10**						
		Constant				3.1	0.24		12.9	0	[2.62, 3.57]
		Will barriers				0	0.17	0	0.01	0.991	[−0.33, 0.34]

(*continued on next page*)

Table 6b (*continued*)

Country	IDI	Variable	R^2	Adj. R^2	F	B	SE	β	t	*p*	95% CI
		Skill barriers				**−0.38**	**0.13**	**−.23**	**−2.93**	**0.004**	**[−0.64, −0.13]**
		Tool barriers				−0.07	0.09	−.06	−0.84	0.401	[−0.24, 0.10]
EE	8.14		0.03	0.02	F (3,331) = 3.64*						
		Constant				1.99	0.21		9.58	0	[1.58, 2.40]
		Will barriers				**−0.28**	**0.14**	**−.16**	**−2.02**	**0.044**	**[−0.55, −0.01]**
		Skill barriers				−0.05	0.14	−.03	−0.37	0.709	[−0.33, 0.22]
		Tool barriers				**0.28**	**0.1**	**0.2**	**2.84**	**0.005**	**[0.09, 0.47]**
DK	8.71		0.04	0.02	F (3,188) = 2.43						
		Constant				3.53	0.26		13.43	0	[3.01, 4.05]
		Will barriers				0.23	0.24	0.1	0.95	0.342	[−0.25, 0.71]
		Skill barriers				**−0.49**	**0.22**	**−.24**	**−2.20**	**0.029**	**[−0.93, −0.05]**
		Tool barriers				−0.01	0.18	−.01	−0.08	0.938	[−0.37, 0.34]

Note. Dependent variable: *Teacher ICT use in class*: 0 = less than 1%, 1 = 1–24%, 2 = 25–50%, 3 = 51–75%, 4 = more than 75%.
*F-value is significant at the $p < .05$.
**F-value is significant at the $p < .01$.
***F-value is significant at the $p < .001$. **BE** = Belgium; **BG** = Bulgaria; **CZ** = Czech Republic; **DK** = Denmark; **EE** = Estonia; **ES** = Spain; **FI** =Finland; **HR** = Croatia; **HU** = Hungary; **IT** = Italy; **LT** = Lithuania; **LV** = Latvia; **PT** = Portugal; **RO** = Romania; **SI** = Slovenia; **SK** = Slovakia.

Table 7
Results of the multilevel linear modeling analysis predicting the percentage of ICT use in class by students and by teachers.

	Student use		Teacher Use	
	Null model	Model 1	Null model	Model 1
Fixed				
Intercept	1.63 (0.08)***	−0.98 (0.86)	1.29 (0.09)***	−0.01 (0.77)
Will barriers		0.80 (0.37)*		0.41 (0.45)
Skill barriers		−0.07 (0.39)		0.48 (0.47)
Tool barriers		−0.45 (0.27)		−0.91 (0.33)**
IDI		0.34 (0.11)**		0.29 (0.10)**
Will barriers * IDI		−0.11 (0.05)*		−0.06 (0.06)
Skill barriers * IDI		−0.01 (0.05)		−0.08 (0.06)
Tool barriers * IDI		0.05 (0.04)		0.11 (0.04)**
Random				
Country level				
Intercept	0.17 (0.42)	0.13 (0.36)	0.13 (0.36)	0.09 (0.31)
Model fit				
Deviance (2-log)[a]	17546	15901	20602	18603
χ 2	121.27	154.83	106.30	149.73
df	26	7	26	7
p	.000	.000	.000	.000
Reference	Single level model	Null model	Single level model	Null model

Note. Estimates and standard errors from the multivariate random intercept model (dependent variables: student use and teacher use).
*significant at the .05 level.
**significant at the .01 level.
***significant at the .001 level. Barrier variables are cluster mean centered.

schools. Morales Velazquez (2007) postulated that tools are the best predictor of technology use for teachers at lower stages of technology adoption, whereas will might the best predictor for teachers at the highest stages. Our study seems to confirm these propositions. In digitally less-developed countries, first-order barriers (e.g., tool-related barriers) still seemed to play an important role in affecting teachers' technology use in class. In digitally higher-developed countries, will-related factors seemed to be more important, especially for students' technology use in class. However, there was no evidence for skill playing an important role in medium technological developed countries, which contradicts the assumption of Morales Velazquez (2007).

5.2. Limitations

The current study faced some limitations. First, all findings are based on self-report data, which could have been biased by the responding teachers. A second potential limitation is that measurement of the dependent variable required teachers to report the percentage of lesson time they or their students had devoted to ICT use in class in the past 12 months. However, the amount of computer use for teaching and learning does not necessarily correspond to the quality of use. Regarding the teacher-reported student use of technology, a third limitation is that this measurement is impaired by the teachers' self-presentation bias (Kopcha & Sullivan, 2007). Kopcha and Sullivan (2007) indicated that teachers tend to rate students' use of computers in their lessons much higher than in other teachers' lessons. Therefore, it might be more accurate to ask students to assess their own computer use in a class. Another fourth

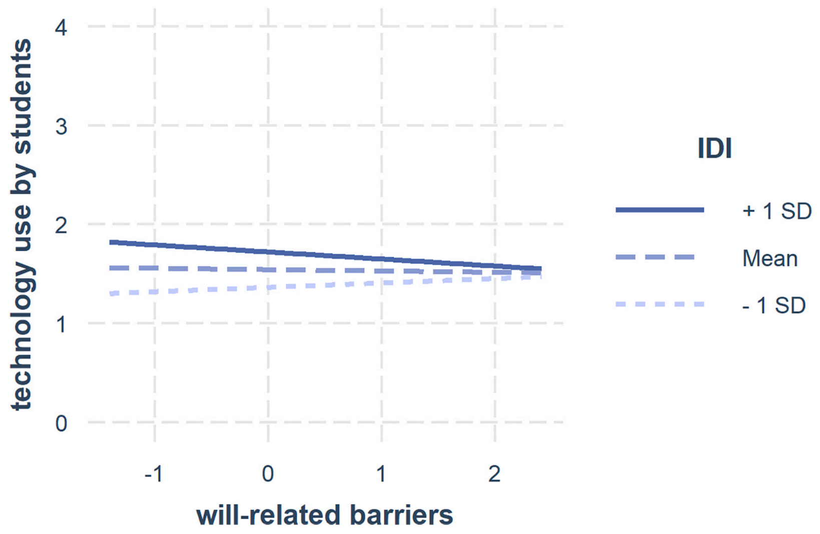

Fig. 1. Interaction between will-related barriers and IDI on technology use by students.

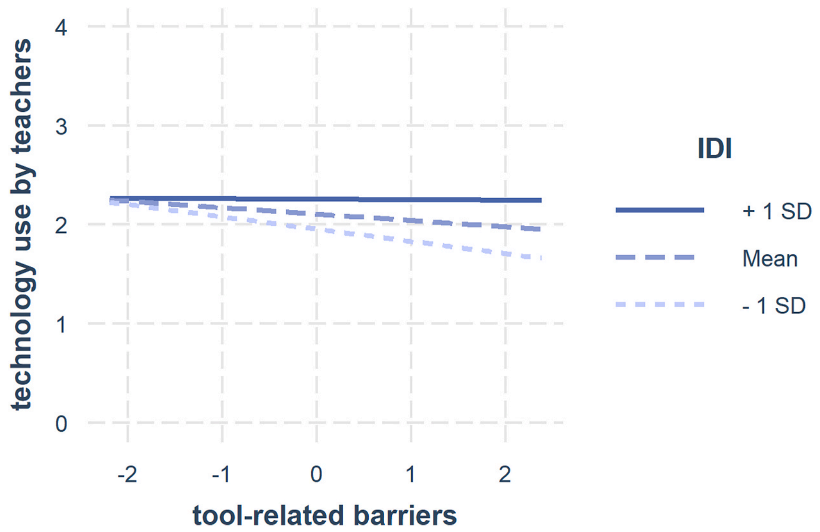

Fig. 2. Interaction between tool-related barriers and IDI on technology use by teachers.

limitation relates to the tool-related barrier items: although the current discussion of barriers to technology integration focuses on the quality of technology use rather than access to technology (Agyei and Voogt, 2011), the tool-related barrier items in this study related primarily to lack of access to various technological devices, and the dataset did not contain any barrier items that address the quality of devices. Nevertheless, we showed how important it is to re-conceptualize barriers, since pure access to technology is no longer a big obstacle, especially in technologically highly developed countries. The fifth limitation concerns the analytical sample of the study in that only secondary school teachers were examined. Besides our own interpretation of the factor analysis, additional explanations are warranted. For example, researchers have suggested extending the WST model by adding pedagogy as a fourth factor (Knezek & Christensen, 2016). In our analysis, only three factors (will-, skill-, and tool-related barriers) were present, while the items related to teaching style and pedagogical practices loaded on the skill-related barrier factor.

5.3. Practical implications and directions for future research

Future studies should investigate whether the removal of barriers will affect the quality of technology use. The limited effects reported in this study indicate that barriers cannot be considered as hard but rather as soft in most countries. Soft barriers, which at present emerge as predominant factors among teachers' perceptions, might impede the use of technology but do not make technology use impossible. In contrast, hard barriers refer to the barriers that were perceived by teachers as insurmountable in the early 2000s. With this understanding, it is possible that the elimination of barriers caused an improvement in technology integration and enhancement of the quality of technology use.

The influence of barriers on the frequency of technology use varied depending on the country's technological development level. Our study suggests that will-related barriers are more relevant for high-tech countries, whereas tool-related barriers significantly impact technology use in less-developed countries. These results could also apply to smaller entities, such as schools. Consequently, the degree of technological development indicates which kinds of barriers need to be removed, and this can be defined in the policy.

Much work remains to be done before a full understanding of the effect of barriers on technology integration in classrooms is established. Future research should attempt to identify new obstacles to teachers' use of technology in teaching and students' use of digital tools. For example, Sahin Izmirli and Kirmaci (2017) uncovered new barriers, such as believing that the top unit of an institution decides whether to engage in the process of technology integration and accepting that there are always several barriers to technology integration.

The question remains whether barriers influence other aspects of technology integration apart from the frequency of technology use. In a previous study, perceived school support for overcoming first-order barriers was found to influence the quality of technology integration, operationalized as technology use for student-centered activities and facilitation of higher-order thinking tasks (Vongkulluksn et al., 2018). Bowman et al. (2020) also showed that first-order barriers and second-order barriers (ability beliefs and value beliefs) influence the quality of technology use, which was measured by teachers rating how often they asked students to use digital technologies for higher-order and lower-order tasks. These findings should be replicated, and other measurements of the quality of technology integration should be examined in combination with barriers.

Credit author statement

Maria-Luisa Schmitz: Formal analysis, Conceptualization, Writing – original draft, Writing – review & editing, **Chiara Antonietti:** Formal analysis, Writing – original draft, Writing – review & editing, **Alberto Cattaneo:** Supervision, Writing – review & editing, **Philipp Gonon:** Supervision, Writing – review & editing, **Dominik Petko:** Supervision, Conceptualization, Writing – review & editing.

Declaration of competing interest

None.

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