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Hybrid Regression Analysis of Predictors of Teachers' ICT Use in Teaching Practices: Evidence from ICILS

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Abstract

The effective integration of Information and Communication Technology (ICT) in education is crucial for student success in the digital age, and large-scale international assessments provide valuable data for understanding and improving these practices. This study investigates the factors influencing teachers' ICT integration in teaching using the ICILS 2018 dataset. The study combines traditional methods, such as multiple linear regression, with machine learning techniques like the random forest algorithm, to comprehensively understand the factors driving teachers' ICT use. The findings reveal that the models successfully explained a significant portion of the variance in teachers' ICT practices. The random forest analysis identified country context as the most influential predictor, followed by teachers' positive views on the benefits of ICT, teacher collaboration, ICT self-efficacy, and experience with online lessons. Factors such as experience in preparing online materials and teacher age had a moderate influence, while access to computer resources and gender showed minimal impact. The results encourage educators and policymakers to invest in modifiable factors, such as teacher collaboration, self-efficacy, and positive perceptions of ICT, to enhance teachers' ICT integration.

Keywords: ICILS, ICT, multiple linear regression, random forest; teachers, UTAUT.

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Introduction

In the digital age, the effective integration of Information and Communication Technology (ICT) into education is a critical global focus, essential for transforming the educational landscape and enhancing student learning. As technology advances and permeates every aspect of daily life, these changes necessitate a continuous examination of variables affecting teachers' ICT practices to ensure their relevance and alignment with emerging pedagogical and technological demands (UNESCO, 2021). Various organizations and initiatives have called attention to the need to investigate the factors influencing ICT integration. Teachers’ use of ICT in education is a global focus, supported by international organizations aiming to enhance digital integration and reduce inequalities. For instance, UNESCO’s ICT Competency Framework for Teachers (UNESCO, 2018) provides guidelines to strengthen teachers’ pedagogical skills with technology, while the OECD examines educational technology policies through comparative studies such as PISA (OECD, n.d.). Organizations like the International Society for Technology in Education (ISTE) and the European Commission contribute by developing standards and tools, such as the ISTE Standards (ISTE, 2017) and DigCompEdu (Punie, Redecker, 2017), to improve teachers’ digital competencies. However, the mere availability of technology does not guarantee its effective use. Successful ICT integration is deeply rooted in teachers' psychological dispositions, including their beliefs about its value, their self-efficacy, and their intention to incorporate it into their teaching. From a psychological perspective, teachers' self-efficacy in ICT and their constructivist teaching beliefs can support the effective integration of these technologies in the classroom (Baek, Jung, & Kim, 2008). Additionally, teachers' beliefs about the value of ICT in education directly influence their technology integration efforts (Baek et al., 2008; Blackwell, Lauricella, & Wartella, 2014). Understanding these underlying beliefs and intentions is crucial, as they are often the primary drivers that translate policy and resources into actual classroom practice.

Building on this psychological foundation, the factors affecting teachers' use of ICT can be broadly categorized into several other key domains: sociocultural, technological, and pedagogical (Baek et al., 2008; Brenes-Monge et al., 2020; Mirzajani et al., 2016). On the sociocultural front, support from school administrators, clear guidelines on ICT usage, and opportunities within teacher training programs shape teachers' motivation and capacity to utilize technology (ChanLin et al., 2006; Spiteri & Chang Rundgren, 2020). Regarding technological factors, lack of access, inadequate infrastructure, and limited technological expertise are major barriers impeding teachers' ICT usage. Lastly, pedagogical factors, such as instructional training, curriculum integration, and the perceived positive impacts of ICT on teaching and learning, can heighten teachers' interest and engagement with these technologies (Blackwell et al., 2014; ChanLin et al., 2006; Ertmer et al., 2012). While the influence of these factors may vary based on context and individual experiences, the interplay of these elements ultimately determines the effective integration of technology within the educational setting (Blackwell et al., 2014; ChanLin et al., 2006; Ertmer et al., 2012).

The importance of understanding these interconnected influences is underscored by numerous large-scale assessments. Among these, the International Computer and Information Literacy Study (ICILS) is a particularly critical global effort for understanding digital education (Fraillon et al., 2021). Conducted by the IEA, this large-scale assessment provides comparative data on students' and teachers' digital literacy. Crucially for this study, the ICILS dataset contains rich information on the contextual factors of ICT integration, including not only school resources and infrastructure but also key teacher-level variables such as ICT self-efficacy, pedagogical beliefs about technology, collaboration practices, and professional development experiences. By evaluating these factors across multiple countries, ICILS offers invaluable insights into the challenges and successes of ICT integration.

Literature Review

To explain the factors influencing teachers' use of ICT, numerous models have been proposed, including the Technology Acceptance Model (TAM) (Davis, 1989), the Concerns-Based Adoption Model (CBAM) (Hall, 1974), the Theory of Planned Behaviour (TPB) (Ajzen, 1991), and the Diffusion of Innovations Theory (DIT) (Rogers, 2003). In addition to these, widely recognized models such as the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) further illuminate the multifaceted influences on teachers' ICT practices by integrating advanced versions of these theories under a single model. The UTAUT model emphasizes key dimensions like performance expectancy, effort expectancy, social impact, and facilitating conditions, offering a structured perspective on how various psychological, sociocultural, technological, and pedagogical factors interact to shape ICT integration in education.

UTAUT Model

According to UTAUT, teachers' perceptions of ICT usage are influenced by factors such as performance expectancy, effort expectancy, social influence, and facilitating conditions. Notably, UTAUT incorporates elements from other foundational theories. UTAUT (Venkatesh et al., 2003) leverages the strengths and addresses the limitations of earlier models, including the TRA, TPB, and TAM (Oliveira et al., 2014). Additionally, external factors such as social influence and facilitating conditions align with the principles of Social Cognitive Theory (Bandura, 1986). This integration of theoretical perspectives positions UTAUT as a comprehensive and effective framework for exploring the complexities of ICT adoption in educational settings. UTAUT aims to simplify the complexity found in earlier models of individual technology adoption and provides a holistic perspective for understanding behavioural intentions (Teo & Noyes, 2014). By integrating key factors and relationships, UTAUT serves as a robust framework for identifying the determinants of technology use (Venkatesh, Thong, & Xu, 2012). Impressively, this model has demonstrated an ability to explain approximately 70% of the variance in behavioural intention toward technology use (Venkatesh et al., 2012). This regression coefficient highlights UTAUT's robustness as a predictive model, effectively capturing the key factors influencing technology adoption. Its ability to integrate elements from earlier theories makes it a valuable framework for understanding technology use in diverse contexts. It is presented in Figure 1.

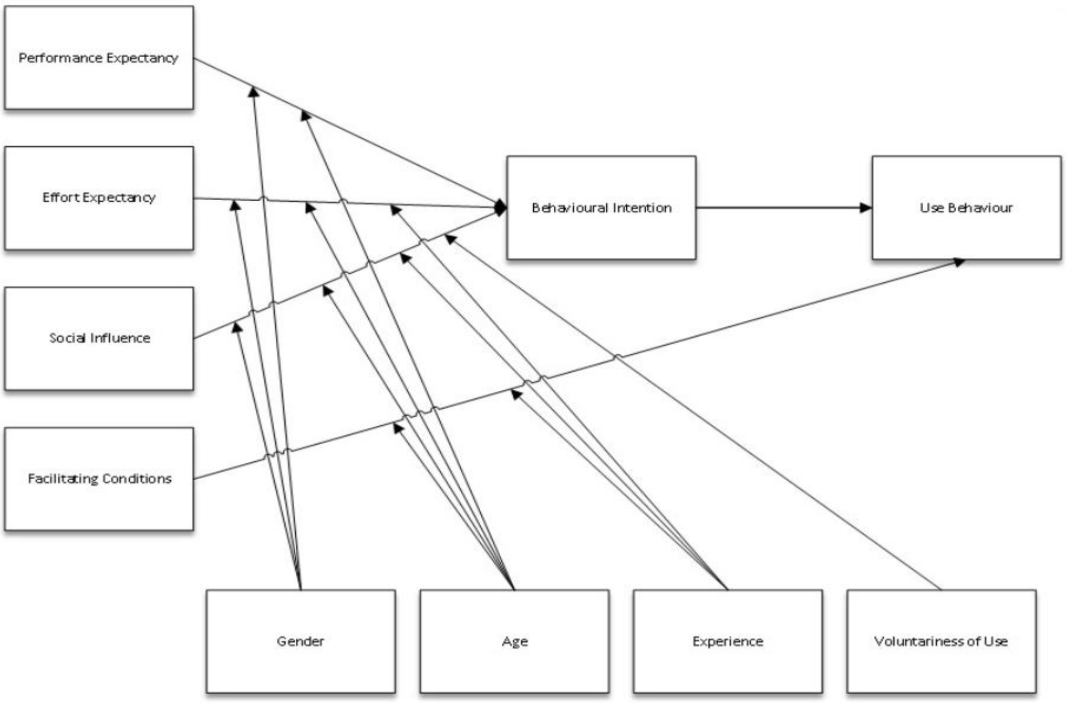

Figure 1. UTAUT model (Venkatesh et al., 2003)

The four components that make up the UTAUT model—Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions—can be moderated by factors such as age, gender, experience, and voluntariness when shaping individuals' approach to technology (Scherer, Siddiq, & Tondeur, 2019). Venkatesh et al. (2003) identified these factors as significant moderators that influence individuals' intentions and behaviours regarding technology use. According to Venkatesh et al. (2003; 2012), the main variables can be summarized as follows:

Performance Expectancy: The belief that using technology will improve performance. For example, experienced teachers may adopt new technology faster due to higher confidence, while younger teachers may find it easier to use.

Effort Expectancy: The perceived ease or difficulty of using technology. Gender can influence this perception, as male teachers may find it easier due to more experience.

Social Influence: Sensitivity to others' expectations about technology use. Teachers using technology voluntarily are more influenced by others' encouragement.

Facilitating Conditions: Belief in the availability of supportive infrastructure for using technology. Experienced teachers may be less deterred by the lack of resources than novice teachers.

In the context of the UTUAT model, behavioural intention represents an individual's willingness to use a particular technology, while use behaviour refers to the actual utilization of the technology. The strength of the relationship between behavioural intention and use behaviour has been consistently supported in the literature (Nikou & Economides, 2017), indicating that individuals who have a stronger intention to use technology are more likely to use it. For example, if a teacher believes technology improves performance and is easy to use, and observes support from colleagues and the school, their intention will likely translate into usage. Building on the well-established link between behavioural intention and technology use, it becomes essential to investigate the broader factors that influence teachers' ICT practices, particularly through advanced analytical approaches that can provide deeper insights into these dynamics

UTAUT in Educational Research: A Brief Overview and The Present Study's Contribution

The UTAUT model has been extensively applied to understand technology adoption in educational settings. A recent meta-analysis focusing on higher education instructors confirmed that Performance Expectancy (PE), Effort Expectancy (EE), and Social Influence (SI) are consistently strong predictors of teachers' behavioural intention (Noureddine, Boote, & Campbell, 2025). Similarly, individual studies have validated UTAUT's core constructs, though often in specific contexts like Ghana or China (Baako & Abroampa, 2024; Chen, 2023). However, comprehensive reviews also highlight critical gaps in the existing literature (Xue, Rashid, & Ouyang, 2024). Firstly, research shows a "strong regional dominance" and a predominant focus on higher education, limiting the generalizability of findings to K-12 settings. Secondly, the field has overwhelmingly relied on traditional statistical methods like SEM and regression, which may not fully capture complex, non-linear relationships. Recent analyses note a "significant surge" in the use of machine learning in education, emphasizing its potential to "revolutionize" the field by uncovering more nuanced patterns in large-scale data (Ayanwale, Molefi, & Oyeniran, 2024).

The present study is positioned to directly address these gaps. By utilizing the international ICILS 2018 dataset, it moves beyond the limitations of single-country and higher-education-focused studies. Furthermore, it introduces methodological diversity by complementing traditional regression analysis with a Random Forest algorithm. This approach provides a more comprehensive understanding of the factors shaping teachers' ICT practices. Accordingly, this study aims to answer the following research questions:

RQ1: To what extent do various factors predict teachers' use of ICT for teaching practices in a linear regression model?

RQ1a: What is the relationship between teachers' psychological and attitudinal factors (i.e., ICT self-efficacy, positive views on ICT) and their ICT use?

RQ1b: What is the relationship between teachers' professional and collaborative factors (i.e., teacher collaboration, experience with lesson preparation, experience during lessons) and their ICT use?

RQ1c: What is the relationship between demographic and contextual factors (i.e., country, gender, age, access to resources, teaching grade) and their ICT use?

RQ2: Which of these independent variables are the most influential predictors of teachers' ICT use, based on the variable importance ranking from a Random Forest algorithm?

Method

This study employs two distinct regression analyses to examine the relationship between independent and dependent variables. A two-step process was implemented to analyze the relationships among the variables. First, a multiple linear regression analysis was conducted to establish an initial understanding of the associations between the dependent and independent variables. This approach provides a straightforward interpretation of the coefficients and facilitates a preliminary examination of the predictors' effects (Cohen et al., 2013).

In the second step, the random forest algorithm was applied. This machine learning method was selected due to its ability to model complex, nonlinear relationships and handle datasets that include both continuous and categorical variables. A significant feature of the random forest algorithm is its ability to assess the importance of each independent variable to the dependent variable (Breiman, 2001). By calculating the percentage increase in mean squared error (%IncMSE), random forest ranks the variables according to their contribution to the model's prediction. This variable importance ranking not only identifies the most influential predictors but also provides valuable insights into the complex, nonlinear effects of the independent variables. This feature enhances the interpretability of the model, allowing for a deeper understanding of the underlying relationships within the data. The algorithm constructs multiple decision trees, each trained on a random subset of the data and predictors (Breiman, 2001). It then aggregates the predictions from all trees to improve the accuracy and robustness of the model (Liu, Wang, & Zhang, 2012). Random forest is known for its superior predictive accuracy, particularly in classification tasks, and its efficiency in handling large numbers of predictor variables (Speiser et al., 2019).

The choice to use these two methods is based on their distinct capabilities and advantages in addressing different aspects of our research objectives. Multiple linear regression provides valuable insights into the specific relationships between independent variables and the dependent variable, offering a more interpretable model. Random forest analysis complements this by exploring the relative importance of predictors and accounting for potential interactions and non-linearities, delivering a more nuanced understanding of the data. Together, these approaches enable us to comprehensively address the research questions and gain deeper insights into the dynamics of ICT integration.

This study was approved by the Ethics Committee of Hacettepe University, Institute of Educational Sciences (Approval No: E-82474949-900-00004055222). The study does not involve direct human participants; however, ethical principles such as confidentiality, responsible data handling, and adherence to research ethics guidelines were strictly followed.

Data Collection Tools

This study utilizes data from the International Computer and Information Literacy Study (ICILS) 2018, a large-scale international assessment conducted by the International Association for the Evaluation of Educational Achievement. ICILS 2018 offers a comprehensive overview of how students and teachers utilize information and communication technology in education across various participating countries, including Denmark, Finland, and Uruguay. This study focuses specifically on teacher data gathered through the ICILS 2018 teacher questionnaire, which examines teachers' ICT practices, self-efficacy, and perceptions related to technology use in teaching and learning. ICILS 2018 is particularly well-suited to this research as it provides detailed information on teacher-reported ICT use in the classroom and the factors that may influence these practices.

To investigate the factors influencing teachers' ICT practices, a multiple linear regression model was developed, drawing upon the theoretical framework of the Unified Theory of Acceptance and Use of Technology. This model explores the relationship between teachers' ICT practices (T_ICTPRAC–

Teachers' use of ICT for teaching practices) and several predictor variables: Country, collaboration between teachers in using ICT (T_COLICT), teachers' ICT self-efficacy (T_ICTEFF), negative views on using ICT in teaching and learning (T_VWNEG), positive views on using ICT in teaching and learning (T_VWPOS), availability of computer resources at school (T_RESRC), sex of teacher (T_SEX_CAT), approximate age of teacher (T_AGE), duration of ICT use for preparing lessons (T_EXPREP_CAT), duration of ICT use during lessons (T_EXLES_CAT), and teaching target grade schools in the current year (T_WGT_CAT). Variables and their corresponding ICILS 2018 questions are in Table 1.

Table 1.
Analyzed scales and items

Scale	Items	Responds
Teachers' use of ICT for teaching practices [T_ICTPRAC]	"Presentation of information through direct class instruction " "Provision of enrichment support to individual students or small groups " "Support of student-led whole-class discussions and presentations " "Assessment of students' learning through tests " "Provision of feedback to students on their work" "Reinforcement of learning of skills through repetition of examples " "Support of collaboration among students " "Mediation of communication between students and experts" "Communication with parents about students' learning " "Support of inquiry learning"	I do not use this practice with the reference class." "I never use ICT with this practice." "I sometimes use ICT with this practice." "I often use ICT with this practice." "I always use ICT with this practice."
Teachers' ICT-related self-efficacy [T_ICTEFF]	"Find useful teaching resources on the Internet." "Contribute to a discussion forum on the Internet" "Produce presentations with a simple animation function." "Use the Internet for online purchases and payments." "Prepare lessons that involve the use of ICT by students." "Using a spreadsheet program for keeping records" "Assess student learning" "Collaborate with others using shared resources." "Use a learning management system."	"I know how to do this", "I haven't done this, but I could find out how", "I do not think I could do this".
Teachers' positive views on using ICT in teaching and learning [T_VWPOS]	"Helps students develop greater interest in learning" "Helps students to work at a level appropriate to needs" "Helps students develop problem-solving skills." "Enables students to collaborate more effectively." "Helps students develop skills in planning their work." "Improves the academic performance of students" "Enables students to access better sources of information."	"Strongly agree," "agree," "disagree," or "strongly disagree".
Teachers' negative views on using ICT in teaching and learning [T_VWNEG]	"Impedes concept formation by students" "Results in students copying material from Internet sources." "Distracts students from learnin.g" "Results in poorer written expression among students" "Results in poorer calculation and estimation skills among students" "Limits the amount of personal communication among students"	
Collaboration between teachers in using ICT [T_COLICT]	"I work together with other teachers." "I collaborate with colleagues to develop ICT-based lessons." "I observe how other teachers use ICT in teaching." "I discuss with other teachers how to use ICT in teaching." "I share ICT-based resources with others in my school."	"Strongly agree," "agree," "disagree," or "strongly disagree".
Availability of computer resources at school [T_RESRC]	"ICT is considered a priority for use in teaching." "My school has sufficient ICT equipment (e.g, computers)" "The computer equipment in our school is up-to-date." "My school has access to sufficient digital resources." "My school has good connectivity to the Internet." "Enough time to prepare lessons that incorporate ICT" "Sufficient opportunity for me to develop expertise in ICT" "Sufficient technical support to maintain ICT resources"	"Strongly agree," "agree," "disagree," or "strongly disagree".

Validity and Reliability

The validity and reliability of the research were ensured through several measures. First, this study utilizes scales from the ICILS 2018 dataset, an instrument developed through a rigorous process involving expert panels and extensive piloting, which provides strong evidence for the content validity of the measures (Fraillon et al., 2021). The use of a large, multi-country sample also enhances the external validity of the findings. To assess the internal consistency reliability of the multi-item scales for the current sample, Cronbach's Alpha (α) coefficients were calculated. All scales demonstrated excellent reliability: T_ICTPRAC; α = .98, T_COLICT; α = .96, T_ICTEFF; α = .97, T_VWPOS; α = .97, T_VWNEG; α = .96, and T_RESRC; α = .96. As all coefficients far exceeded the commonly accepted threshold of .70, the scales were deemed highly reliable for this study (Cohen et al., 2013).

Evidence for construct validity is partially supported by the Pearson correlation matrix (Table 3), which demonstrates theoretically expected relationships. For instance, a significant positive correlation was found between ICT self-efficacy (T_ICTEFF) and ICT practices (T_ICTPRAC). Furthermore, the study's internal validity was strengthened by statistically controlling for multiple predictors and formally diagnosing and addressing potential multicollinearity prior to the main analysis.

Data Analysis and Analytical Models

The following model was formulated to investigate the factors influencing teachers' use of ICT in their teaching practices:

teachers' use of ICT for teaching practices = sex of teacher + approximate age of teacher + approximately how long have you been using ICT for teaching purposes/During lessons + approximately how long have you been using ICT for teaching purposes/Preparing lessons + teaching target grade schools in the current year + teachers’ views on using ICT in teaching and learning + collaboration between teachers in using ICT + teachers ICT self-efficacy + availability of computer resources at school

The formulated model, including its abbreviations, is as follows:

T_ICTPRAC ~ CNTRY + T_COLICT + T_ICTEFF + T_VWNEG + T_VWPOS + T_RESRC + T_SEX_CAT + T_AGE + T_EXPREP_CAT + T_EXLES_CAT + T_WGT_CAT

The mathematical formula is as follows:

$Y = \beta 0 + \beta 1X1\ (T\_SEX) + \beta 2X2\ (T\_AGE) + \beta 3X3\ (T\_EXLES) + \beta 4X4\ (T\_EXPREP) + \beta 5X5\ (T\_WGT) + \beta 6X6\ (T\_VWNEG) + \beta 7X7\ (T\_VWPOS) + \beta 8X8\ (T\_COLICT) + \beta 9X9\ (T\_ICTEFF) + \beta 10X10\ (T\_RECRC) + \varepsilon$

The statistical software R was used for data analysis. Several packages were employed for data manipulation, visualization, and modeling, including metaphor (Viechtbauer, 2010), Metrics (Kuhn et al., 2016), readxl (Wickham & Bryan, 2019), tibble (Müller & Wickham, 2018), tidyverse (Wickham et al., 2019), tidyr (Wickham & Henry, 2020), dplyr (Wickham et al., 2020), ggplot2 (Wickham, 2016), psych (Revelle, 2020), readr (Wickham & Hester, 2020), writexl (Seth, 2020), randomForest (Liaw & Wiener, 2002), e1071 (Meyer et al., 2019), stats (R Core Team, 2020), naniar (Tierney et al., 2020), haven (Wickham & Miller, 2020), and lm.beta (Behrendt, 2014).

Due to missing data within the ICILS 2018 teacher questionnaire dataset, the Expectation-Maximization (EM) algorithm was employed. The EM algorithm is a powerful iterative method used to tackle the challenge of missing data in various fields of research and analysis. This algorithm estimates the missing values by considering the observed data and the model parameters, enabling researchers to make the best use of the available information and obtain robust and reliable results (Moon, 1996). This is particularly important in datasets like ICILS 2018, where missing data may not be completely random and could introduce bias into the analysis. EM helps mitigate this bias by providing more accurate parameter estimates. Following the EM procedure, the dataset was completed, resulting in 3,555 valid data points from three countries for subsequent analysis. This complete dataset allows for a more comprehensive and reliable investigation of the factors influencing teachers' ICT practices.

Findings

Descriptive statistics for the key variables in this study are presented in Table 2. These statistics provide an overview of the central tendencies, dispersions, and distributions of the variables, offering a foundation for further analysis.

Table 2.
Descriptive statistics

Continuous variables						
Variable	Min	1stQu.	Median	Mean	3rdQu.	Max
Collaboration between teachers in using ICT	22.90	43.00	48.41	50.06	53.25	71.53
Teachers' ICT self-efficacy	9.45	46.11	54.24	52.01	62.82	62.82
Negative views on using ICT in teaching and learning	12.58	40.97	48.46	48.41	54.57	82.34
Positive views on using ICT in teaching and learning	12.36	40.22	45.92	47.43	54.0	75.22
Availability of computer resources at school	21.92	43.71	49.14	48.76	53.15	77.85
Approximate age of teacher	23.00	35.00	45.00	45.09	55.00	63.00
Teachers' use of ICT for teaching practices	24.66	44.16	49.39	49.62	55.23	79.73

Categorical Variables		
Variable	Category	Frequency
Sex of teacher	Female	2283
	Male	1072
Approximately how long have you been using ICT for teaching purposes/preparing lessons	0-2	207
	2-5	676
	5+	2429
	Never	43
Approximately how long have you been using ICT for teaching purposes/During lessons	0-2	284
	2-5	950
	5+	2048
	Never	73
Teaching target grade schools in the current year	1	2998
	2	297

A review of the descriptive statistics in Table 2 reveals several key characteristics of the sample. The mean age of the teachers was approximately 45, indicating a predominantly experienced cohort. In terms of gender, the sample was largely composed of female teachers (n = 2283) compared to male teachers (n = 1072). Notably, a substantial majority of teachers reported extensive experience, with over two-thirds using ICT for more than five years for lesson preparation. Interestingly, the mean score for teachers' negative views on ICT (M = 48.41) was slightly higher than for their positive views (M = 47.43), suggesting a degree of ambivalence or scepticism towards technology despite widespread experience. The average ICT use for teaching practices (M = 49.62) was moderate, situated around the midpoint of the scale.

Independent Variables and Their Influence on Teachers' ICT Use

Before conducting multiple linear regression, we examined bivariate Pearson correlations to assess the relationships between individual predictor variables and the outcome variable, as well as to check for potential multicollinearity among predictors (See Table 3).

Table 3.
Pearson Correlations (continuous variables)

	1	2	3	4	5	6	7
1. Teachers' use of ICT for teaching practices	1.00	0.30*	0.34*	0.22*	-0.21*	0.36*	0.00
2. Collaboration between teachers *in using ICT*		1.00	0.28*	0.22*	-0.20*	0.30*	-0.08*
3. Teachers' ICT self-efficacy			1.00	0.13*	-0.20*	0.20*	-0.24*
4. Availability of computer resources at school				1.00	-0.07*	0.16*	0.02
5. Negative views on using ICT in teaching and learning					1.00	-0.53*	0.04
6. Positive views on using ICT in teaching and learning						1.00	-0.06*
7. Approximate age of teacher							1.00

* *p<0.05*

The correlation matrix in Table 3 indicates several theoretically expected relationships. However, it also signalled the need for a formal multicollinearity diagnostic. To address this, we calculated the Generalized Variance Inflation Factor (GVIF) for a model including all potential predictors. The analysis confirmed a significant collinearity issue between the two experience variables: 'experience preparing lessons' (T_EXPREP_CAT, GVIF = 5.18) and 'experience during lessons' (T_EXLES_CAT, GVIF = 5.68), as both values approached or exceeded the recommended threshold of 5 (Hair et al., 2010). Given that the Random Forest analysis (see Figure 2) identified 'experience during lessons' as the more influential predictor, the “experience preparing lessons” variable was excluded from the final regression model to ensure coefficient stability. Importantly, the “positive views” and “negative views” variables did not exhibit problematic collinearity (GVIFs were 1.48 and 1.44, respectively), confirming that both could be retained in the final model. Following these diagnostic steps, the final set of predictors was determined for the main regression analysis. The results of multiple linear regression are presented in Table 4.

Table 4.
Regression Model

Predictor	*B*	*SE*	*t*	*p*
Denmark (Intercept)	18.51	1.90	9.76	< .001
Country				
Finland (vs. Denmark)	-5.33	0.32	-16.88	< .001
Uruguay (vs. Denmark)	-5.36	0.41	-13.05	< .001
Teacher Collaboration (T_COLICT)	0.15	0.02	10.11	< .001
ICT Self-Efficacy (T_ICTEFF)	0.21	0.02	13.14	< .001
Positive Views on ICT (T_VWPOS)	0.22	0.02	13.62	< .001
Negative Views on ICT (T_VWNEG)	-0.01	0.02	-0.61	.543
Computer Resources (T_RESRC)	0.07	0.02	4.32	< .001
Gender (Male vs. Female)	-0.56	0.28	-2.03	.042*
Age	0.03	0.01	2.20	.028*
Experience During Lessons (vs. 0-2 years)				
2-5 years	1.45	0.49	2.93	.003**
5+ years	2.71	0.49	5.58	< .001
Never	-6.26	0.93	-6.73	< .001
Teaching Grade (vs. Grade 1)				
Grade 2	-0.34	0.46	-0.74	.461
Grade 3	0.02	1.14	0.02	.988
Grade 4+	2.42	1.54	1.57	.116

Note. *B* = unstandardized regression coefficient; *SE* = standard error. Model summary: R^2 = .33, Adj. R^2 = .33, $F_{(15, 3715)}$ = 122.8, $p < .001$. * $p < .05$. ** $p < .01$.

The multiple linear regression analysis, summarized in Table 4, identified several significant predictors of teachers' ICT use. The overall model was statistically significant, $F_{(15, 3715)} = 122.8$, $p < .001$, and explained approximately 33% of the variance in teachers' ICT practices (Adj. $R^2 = .33$). At the individual predictor level, country of origin played a substantial role; teachers in Finland (B = -5.33, p < .001) and Uruguay (B = -5.36, p < .001) demonstrated significantly lower ICT use compared to the reference country, Denmark. Key teacher-level factors such as collaboration (B = 0.15, p < .001), ICT self-efficacy (B = 0.21, p < .001), and positive views on ICT (B = 0.22, p < .001) all emerged as strong, positive predictors. Interestingly, when controlling for other factors, negative views on ICT did not have a statistically significant effect on practices (B = -0.01, p = .543). Other significant predictors included the availability of computer resources (B = 0.07, p < .001) and teacher age (B = 0.03, p = .028). Experience during lessons also showed a strong relationship, with more experienced teachers exhibiting higher ICT use.

To assess the model's predictive accuracy, the Mean Absolute Error (MAE) was calculated. The MAE for the model was 5.87. This indicates that, on average, the model's predictions deviated from the actual observed values by 5.87 points. Given that the ICT practices scale ranges from 0 to 100, this MAE corresponds to an average prediction error of approximately 5.9% of the total scale range. While specific benchmarks for MAE can vary by field, prediction errors under 10% are often considered indicative of a strong model fit in social science research (cf. Hair et al., 2010). This level of error, combined with the significant overall model fit, suggests a reasonable predictive accuracy for the linear regression model.

Ranking the Importance of Independent Variables Using the Random Forest Algorithm

To gain a more nuanced understanding of the relative importance of the predictors, a Random Forest analysis was conducted. The analysis included all potential independent variables to explore their predictive power without the constraints of a linear model. The variable importance ranking, gauged by the percentage increase in mean squared error (%IncMSE), is presented in Figure 2.

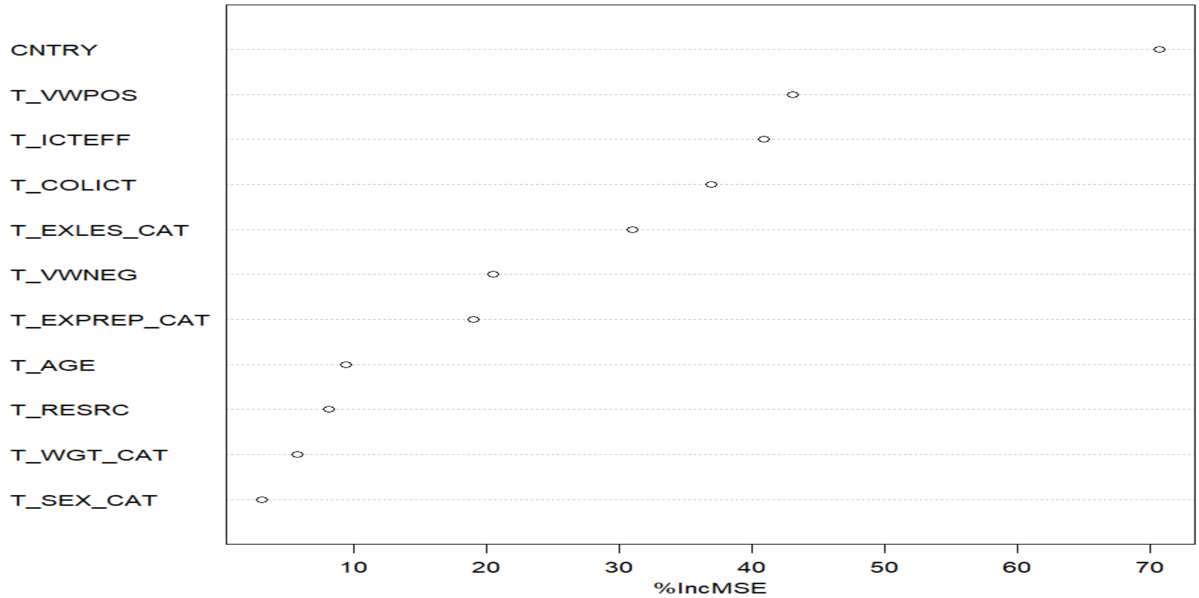

Figure 2. Importance Ranking of Independent Variables in ICT Use

T_VWPOS=Positive views on using ICT in teaching and learning, T_VWNEG=Teachers' negative views on using ICT in teaching and learning, T_COLİCT=Collaboration between teachers in using ICT, T_ICTEFF=Teachers ICT self-efficacy, T_AGE=Approximate age of teacher, T_RESRC=Availability of computer resources at school, T_SEX_CAT=Sex of teacher, T_EXLES_CAT=Approximately how long have you been using ICT for teaching purposes/During lessons, T_EXPREP_CAT=Approximately how long have you been using ICT for teaching purposes/Preparing lessons, T_WGT_CAT=Teaching target grade schools in the current year

The results confirmed that country context (CNTRY, %IncMSE = 70.74) was by far the most influential predictor of teachers' ICT use. Following the country context, a cluster of positive psychological and professional factors emerged as highly important: positive views on ICT (T_VWPOS, %IncMSE = 43.13), ICT self-efficacy (T_ICTEFF, %IncMSE = 40.97), and teacher collaboration (T_COLICT, %IncMSE = 36.95). Notably, negative views on ICT (T_VWNEG, %IncMSE = 20.57) demonstrated substantially lower predictive power, approximately half that of its positive counterpart. This key exploratory finding highlights that positive drivers are far more influential than negative barriers in this model. Experience during lessons (T_EXLES_CAT, %IncMSE = 31.07) also showed considerable importance, while factors such as age, resources, and gender had a comparatively minor impact on the model's predictive accuracy.

Discussion, Conclusion, and Suggestions

This study employed a hybrid analytical approach to investigate the intricate factors shaping teachers' ICT integration. Our findings, drawn from the large-scale ICILS 2018 dataset, provide a nuanced perspective on the hierarchy of these factors, highlighting the preeminence of the broader context while also confirming the critical role of individual teacher-level attributes.

The most striking finding from our Random Forest analysis was the overwhelming importance of the country context as the primary predictor of teachers' ICT use. This result provides strong empirical validation for recent systematic reviews that have identified a "strong regional dominance" in educational technology research, cautioning against the generalizability of single-country studies (Xue et al., 2024). Our findings suggest that even significant teacher-level factors operate within an overarching national framework. For instance, the well-developed technological infrastructure and national focus on digital pedagogy in Scandinavian countries likely create a more conducive environment for teachers in Denmark and Finland (Bocconi, Chioccariello, & Earp, 2018; Hatlevik, 2017). In contrast, disparities in resources and training programs in other regions, such as Uruguay, may present systemic barriers, even for motivated teachers (U.S. Trade and Development Agency, 2023; Tomczyk et al., 2021). This challenges a "one-size-fits-all" approach and underscores that policy and practice must be context-sensitive.

Congruent with a large body of literature, our study confirmed that teachers' positive views on ICT, ICT self-efficacy, and teacher collaboration are highly influential predictors. This aligns perfectly with a recent meta-analysis of the UTAUT model, which found Performance Expectancy (positive views) and Effort Expectancy (self-efficacy) to be the most robust predictors of behavioural intention (Noureddine et al., 2025). Our findings are also consistent with recent primary research showing positive associations between these factors and ICT engagement (Peng, Abdul Razak, & Hajar Halili, 2023). Teacher collaboration, in particular, serves as a powerful mechanism for overcoming barriers and sharing best practices, as noted by Shoraevna et al. (2021). However, our correlation analysis also revealed a strong negative relationship between positive and negative views, suggesting a polarization of teacher attitudes. This divergence may stem from a variety of psychological or contextual barriers (Ibieta et al., 2017; Kafyulilo, Fisser, & Voogt, 2016). Intriguingly, our findings from both analytical approaches provide a more nuanced interpretation of this polarization. The Random Forest analysis quantitatively demonstrated that positive views (%IncMSE = 43.13) are more than twice as influential as negative views (%IncMSE = 20.57) in predicting ICT use. This key exploratory finding provides a compelling context for our multiple regression results, which confirmed that while positive views remained a powerful statistical driver, negative views did not emerge as a significant barrier when controlling for other factors. This result aligns with a broader discussion in the literature distinguishing between powerful "drivers" of technology integration and "barriers" that may inhibit it (Ertmer et al., 2012). Our findings suggest that the presence of strong positive drivers—such as high self-efficacy and a firm belief in the pedagogical benefits of ICT—may be powerful enough to override or render the impact of negative perceptions statistically non-significant. This could imply that building teachers' confidence (self-efficacy) and fostering supportive, collaborative environments might be more effective in promoting ICT integration than solely focusing on mitigating existing negative perceptions. This complex interplay between positive and negative attitudes clearly warrants further investigation.

Interestingly, and in contrast to some foundational literature that heavily emphasized resource availability as a primary barrier (e.g., Mumtaz, 2000), our Random Forest model ranked access to computer resources as a factor of minimal influence. This does not suggest resources are unimportant, but rather that in contexts where a baseline of infrastructure exists, other factors become more decisive. Instead, our findings show that practical, hands-on experience using ICT during lessons is a far more powerful predictor. This supports the notion that the key driver shifts from 'access' to 'practice-based proficiency' (Bingimlas, 2009). Once teachers have the tools, it is their accumulated, practical experience that builds the confidence and pedagogical skill needed for meaningful integration (Wu et al., 2020).

Finally, the minimal predictive power of teacher gender in our model is a noteworthy finding. This supports a growing body of recent research suggesting that the gender gap in technology use and self-efficacy within the teaching profession is narrowing or has disappeared in many contexts (Gómez-Trigueros & Yáñez de Aldecoa, 2021). This may reflect more equitable access to training and technology over the last decade, leading to a landscape where gender is no longer a significant differentiating factor in ICT integration.

The findings emphasize that while the country context is paramount, its immutable nature necessitates a focus on modifiable factors. Policymakers and educators should prioritize interventions that: (1) foster positive perceptions of ICT by demonstrating its pedagogical benefits; (2) bolster ICT self-efficacy through sustained, practice-based professional development; and (3) promote teacher collaboration to create supportive ecosystems for innovation (Shoraevna et al., 2021).

In conclusion, this study reaffirms that effective ICT integration is a complex interplay of psychological, professional, and systemic factors. For meaningful change to occur, policy must move beyond resource provision and focus on empowering teachers by nurturing their beliefs, building their practical skills, and fostering a culture of collaboration.

Limitations

The country variable in our analysis was limited to Denmark, Finland, and Uruguay, restricting the generalizability of our findings to broader international contexts. The regression model employed was based on selected variables, and alternative modelling approaches by other researchers might uncover the influence of additional predictors that were not included in this study. Moreover, our analysis focused exclusively on quantitative data, which precludes consideration of qualitative factors, such as individual teacher motivations, classroom dynamics, or school culture, that might also shape ICT integration practices. Contextual factors, such as institutional support and opportunities for professional development, were also not included in the dataset, potentially leaving important dimensions unexplored. Lastly, while this research provides valuable insights, future studies should aim to address these limitations by incorporating more recent and diverse datasets, expanding the range of countries studied, and integrating both quantitative and qualitative methodologies to offer a more comprehensive understanding of the factors influencing ICT usage in education.

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Ethics statement: In this study, we declare that the rules stated in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with and that we do not take any of the actions based on "Actions Against Scientific Research and Publication Ethics". At the same time, we declare that there is no conflict of interest between the authors, which all authors contribute to the study, and that all the responsibility belongs to the article authors in case of all ethical violations.

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