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Research Article

Factors shaping teachers' beliefs about ICT use in mathematics teaching

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ABSTRACT

While information and communications technology (ICT) plays an increasingly pivotal role in transforming mathematics teaching and learning, the influence of teachers' beliefs often acts as either a bridge or a barrier between technological possibilities and actual classroom practices. This study was conducted to determine the factors that influence teachers' beliefs about incorporating ICT into mathematics teaching. Accordingly, a survey study with a quantitative analysis method using SPSS software was deployed through the use of questionnaires designed on the Likert scale (6 levels), with 422 secondary school teachers in 32 different provinces and cities in Vietnam participating in the feedback. The research findings indicate that self-efficacy beliefs and subjective norms from colleagues and students have a significant influence on secondary school teachers' beliefs about integrating ICT into mathematics teaching. In contrast, beliefs about ICT support and subjective norms from superiors have a minimal influence on these beliefs. Based on the achieved results and existing limitations, the study proposes directions for teacher training and educational management, as well as new research directions for the future.

Keywords: teachers' beliefs, ICT, factors, mathematics teachers, mathematics teaching

INTRODUCTION

ICT Effectiveness and Teachers' Beliefs

In recent years, especially after the COVID-19 pandemic, information and communication technology (ICT) has had an increasingly profound impact on education (Lomos et al., 2023). Thanks to the development of ICT, students and teachers can access a tremendous amount of knowledge from all over the world (Saxena, 2017), learners can study independently and flexibly anytime and anywhere (Bütün & Karakuş, 2021), as well as participate in interactive learning activities such as online learning, group discussions through digital platforms without being limited by geographical conditions (Bütün & Karakuş, 2021; Kaware & Sain, 2015). With these strengths, ICT has been applied to teaching and learning mathematics in countries worldwide, contributing to the improvement of teaching and learning mathematics (Thurm & Barzel, 2020). In mathematics education, ICT has significantly impacted teaching and learning processes as teachers have incorporated technological components into classroom and virtual learning environments, utilizing a variety of hardware, software, multimedia, and delivery systems (Saxena, 2017). Along with hardware devices such as computer and presentation devices, ICT in mathematics classrooms includes various types of general technology (e.g., authoring tools, online exercise platforms, online video clips, social media, and learning management systems), and mathematical technology like function plotters, geometry packages, spreadsheets, dynamic geometry systems and computer algebra systems (Drijvers et al., 2021; Thurm & Barzel, 2022). The categories of ICT used in this study are relevant to the context of mathematics classrooms. Although ICT has much potential in mathematics teaching, there are specific challenges in integrating information technology into teaching (Tabach, 2011). Many studies have shown that some teachers do not choose to use ICT or use it ineffectively due to concerns about their ability to use ICT in teaching (Thurm & Barzel, 2020), concerns about the effectiveness of ICT on students' mathematics learning (Erens & Eichler, 2015; Handal et al., 2011), concerns about lack of equipment, technical support (Thurm & Barzel, 2020) and time constraints (Pierce & Ball, 2009).

While the potential of ICT in mathematics teaching is significant, its effective integration hinges on a critical factor: teachers' beliefs. Many studies demonstrate that internal factors related to teachers' beliefs play a decisive role in their intention and effectiveness of integrating technology into teaching (Ertmer, 1999; Hew & Brush, 2007; Palak & Walls, 2009). Indeed, Ertmer (2005) emphasized that teachers' beliefs about the use of ICT in teaching play a crucial role in their decision-making, classroom organization, choice of teaching methods, and the effectiveness of ICT in teaching. Taylor and Todd (1995), Ndlovu et al. (2020) have confirmed that teachers' beliefs have a direct impact on their attitudes and behaviors regarding the acceptance and integration of ICT into teaching. Teachers with positive beliefs about technology are more likely to adopt modern pedagogical methods and are open to exploring new digital tools (Ottenbreit-Leftwich et al., 2010). However, if their beliefs are not consistent with their ICT-using pedagogical methods, they may struggle to integrate technology into their classrooms (Donnelly et al., 2011). Teachers' beliefs can both serve as a barrier and a motivator for integrating technology into teaching (Ertmer, 2005; Tondeur et al., 2008). Therefore, to promote the development of teaching content and methods that apply ICT, it is necessary to strengthen teachers' beliefs about the use of ICT in teaching.

Teachers' beliefs are not isolated but are shaped by educational context and personal characteristics (Rubie-Davies et al., 2012). Contextual factors include resources, administrative support, parental support, and technical support (Inan & Lowther, 2010; Lumpe & Chambers, 2001; Nagy & Dringó-Horváth, 2024; Ndlovu et al., 2020; Shin et al., 2014) as well as professional development (Ertmer & Ottenbreit-Leftwich, 2010; Lumpe & Chambers, 2001; Thurm & Barzel, 2020). Personal characteristics include self-efficacy (Nagy & Dringó-Horváth, 2024; Ndlovu et al., 2020), attitude (Shin et al., 2014), experience (Nelson & Hawk, 2020; Robinson, 2003), and technology competence (Inan & Lowther, 2010; Robinson, 2003). Understanding these influencing factors is crucial for impacting teachers' beliefs about ICT use in mathematics teaching.

Various theoretical models have been employed to investigate these influencing factors, yielding diverse results. For example, Robinson (2003) found that age, years of experience, ICT capacity, and school conditions all influenced teachers' beliefs and intentions regarding the integration of technology. Shin et al. (2014) showed that teachers' attitudes towards technology, pressure to use technology, and administrative support were influential factors. Nelson and Hawk (2020) highlighted that field experiences positively affected teachers' beliefs only when frequent technology use by experienced teachers was observed. Inan and Lowther (2010) concluded that technological competence and school-level factors (overall support, technical support, computer availability) significantly affected teachers' beliefs. Additionally, Thurm and Barzel (2020) confirmed the positive effect of professional development on novice teachers' technological beliefs.

Vietnamese Educational Context

In Vietnam, the national ICT strategy is clearly articulated through various government administrative documents. The Vietnamese Government consistently views ICT as a crucial scientific and technical tool, prioritizing it across economic sectors to achieve national development objectives, including the construction of an information society and acceleration of industrialization and modernization. Policy documents like Directive No. 16/CT-TTg in 2017 from the Vietnamese Prime Minister (2017) focus on strengthening national capacity to respond to the Fourth Industrial Revolution, requiring state agencies to develop effective adaptation strategies. Circular No. 03/2014/TT-BTTTT from the Ministry of Information and Communications (2014) sets ICT standards for personnel evaluation and supports ICT integration in Vietnamese universities and colleges. The Ministry of Education and Training (2024) has also issued official dispatches to guide the implementation of ICT tasks for each school year. Specifically in mathematics education, the 2018 general education program of mathematics emphasizes the supporting role of ICT tools and digital automation systems in problem discovery activities, practical activities, and solving real-life problems (Ministry of Education and Training, 2018). This program also mandates that mathematics teachers can incorporate information technology into their teaching.

Despite these clear directives and policies, challenges persist in the implication of ICT in Vietnamese mathematics teaching. Previous research indicates that teachers' innovation in mathematics education in Vietnamese schools is generally slower than the development of ICT (Tran et al., 2020), and the use of ICT applications in teaching practice remains limited (Le et al., 2022; Peeraer & Van Petegem, 2011). Furthermore, there is a noticeable disparity in ICT infrastructure between urban and rural schools, with rural, island, or mountainous areas often lacking adequate technological support. Additionally, teachers' opinions on the role of ICT in mathematics education vary significantly, and their levels of ICT understanding and proficiency in using ICT tools for teaching differ greatly. This suggests a complex landscape where policy aspirations meet diverse realities in classroom implementation across Vietnam.

While numerous previous studies in many countries have examined factors influencing teachers' beliefs about using technology in teaching, yielding diverse results, a significant research gap remains concerning teachers' beliefs in the context of mathematics education in Vietnam. This is particularly noteworthy, as the educational landscape of a developing nation like Vietnam, with its strong policy aspirations for ICT's role and high government investment in ICT in a centralized curriculum and assessment systems but facing huge contrasts across provinces due to the uneven resources, may present unique results about influencing factors compared to other countries. Therefore, this study aims to determine primary key factors from existing models, such as those by Robinson (2003), Ndlovu et al. (2020), and Nagy and Dringó-Horváth (2024), to gain a deeper understanding of their influence on teachers' beliefs. By broadening the participant pool and including a variety of school types, this study seeks to provide new insights within a broader research scope and facilitate comparisons with previous findings, as recommended by prior research (Inan & Lowther, 2010; Nagy & Dringó-Horváth, 2024; Ndlovu et al., 2020; Robinson, 2003). This research contributes to the enrichment of overall knowledge on factors influencing teachers' beliefs about using ICT in mathematics teaching, offering empirically-based foundations for policies aimed at effectively deploying ICT in education by impacting teachers' beliefs.

THEORETICAL FRAMEWORK

Teachers' Beliefs About the Use of Information Technology in Teaching Mathematics

According to Philipp (2007), beliefs can be defined as "understandings, assumptions, or perspectives" that individuals hold to be true about the world around them, or as "lenses through which a person looks to interpret the world." Teachers' beliefs can be viewed as filters that provide a foundation for problem-solving

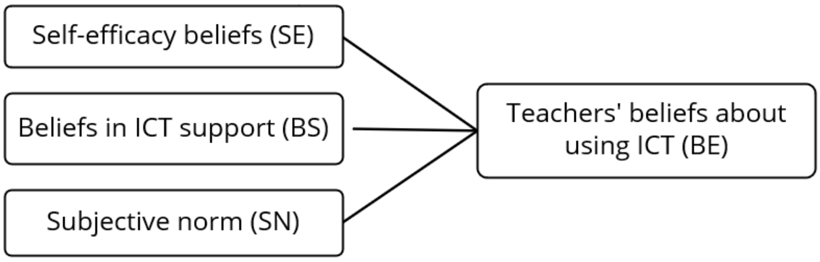

Figure 1. The theoretical model of the factors influencing teachers' beliefs about using ICT [Created by authors based on Ndlovu et al. (2020) and Inan and Lowther (2010) models]

and direct their actions (Levin, 2015). For mathematics education, teachers' beliefs about ICT are defined as their judgments about the usefulness of technology in achieving pedagogical goals, including its ability to support students in acquiring mathematical knowledge more effectively (Ndlovu et al., 2020). Previous studies have shown that teachers' beliefs about the use of ICT in mathematics teaching include aspects such as self-efficacy beliefs about using ICT (Thurm & Barzel, 2020), beliefs about teaching and learning mathematics with ICT (Eickelmann & Vennemann, 2017; Thurm & Barzel, 2020), beliefs about the ease, accessibility, and usefulness of ICT (Eickelmann & Vennemann, 2017), and beliefs about the nature of mathematics and teaching and learning mathematics or epistemological beliefs (Thurm & Barzel, 2020).

Factors Influencing Teachers' Beliefs About Using ICT in Teaching Mathematics

Factors influencing teachers' beliefs of the ICT use can be divided into external factors such as resources, administrative support, parental support, technical support (Inan & Lowther, 2010; Lumpe & Chambers, 2001; Ndlovu et al., 2020; Shin et al., 2014), and professional development (Ertmer & Ottenbreit-Leftwich, 2010; Lumpe & Chambers, 2001; Thurm & Barzel, 2020) and internal factors such as self-efficacy (Nagy & Dringó-Horváth, 2024; Ndlovu et al., 2020), attitude (Shin et al., 2014), experience (Nelson & Hawk, 2020; Robinson, 2003), and technology competence (Inan & Lowther, 2010; Robinson, 2003).

Based on the models of Ndlovu et al. (2020) and Inan and Lowther (2010), we consider the following factors influencing teachers' beliefs: self-efficacy beliefs (SE), Belief in ICT support (BS), and subjective norm (SN) (**Figure 1**). These factors are explained in more detail below.

Self-efficacy beliefs

According to Bandura (1997), self-efficacy beliefs refer to the belief in one's ability to organize and execute the actions necessary to achieve a particular goal. This concept does not reflect an individual's actual ability, but rather how they perceive their ability (Nagy & Dringó-Horváth, 2024; Thurm & Barzel, 2020; Wong, 2016). About ICT use, ICT self-efficacy beliefs refer to a person's perception and evaluation of their ability to use ICT and utilize their skills while performing tasks (Compeau & Higgins, 1995).

In this study, teachers' self-efficacy beliefs refer to teachers' use of ICT to carry out mathematics teaching and learning activities. From the teachers' perspective, self-efficacy beliefs regarding the use of ICT in teaching are divided into two levels: basic ICT competence and professional ICT competence (Rubach & Lazarides, 2023). In which, basic ICT competence is related to the skills of using technology in daily activities, such as operating hardware, software, searching for information, and evaluating the reliability of data (Rubach & Lazarides, 2023), while professional ICT competence reflects the skills of applying technology in professional contexts, such as designing digital content, managing data security, and performing professional teaching tasks (Krumsvik, 2011). Therefore, self-efficacy also plays an important role in determining the extent and manner in which teachers integrate ICT into their teaching (Clark-Wilson & Hoyles, 2019; Nagy & Dringó-Horváth, 2024). Teachers often use technology in a basic way, as a tool to support the finding and presentation of information or to reinforce knowledge, rather than fully exploiting the potential of ICT, if their self-efficacy is low (Clark-Wilson & Hoyles, 2019). In contrast, teachers with strong self-efficacy tend to associate ICT with professional activities, such as experimenting with student-centered teaching methods and leveraging ICT to encourage students to engage in creative tasks and practices (Ertmer & Ottenbreit-Leftwich, 2010).

About teachers' beliefs about using ICT, teachers' ICT self-efficacy is considered an important factor influencing teachers' perceptions of ICT integration (Dong et al., 2020; Rohatgi et al., 2016), their level of technostress (Dong et al., 2020), and their technological pedagogical competence (Dong et al., 2020; Wang et al., 2021), which in turn influence teachers' perceptions (or beliefs) of ICT usability and their intention to use ICT in teaching (Nagy & Dringó-Horváth, 2024; Wong, 2016). The model of factors influencing teachers' beliefs about using ICT in teaching, including self-efficacy beliefs, was examined in the studies of Ndlovu et al. (2020) and Inan and Lowther (2010), as mentioned above.

Beliefs in ICT support

Beliefs in ICT support referred to in this study is teachers' beliefs in the support in using IT in teaching, guaranteed by support from the government, friends, parents and the community integrating technology in schools or the adequacy of technical support, the availability of resources, and support for computer software and troubleshooting (Inan & Lowther, 2010; Nagy & Dringó-Horváth, 2024), as well as policies and incentives from the management agency (Nagy & Dringó-Horváth, 2024). According to Inan and Lowther (2010), technical support includes three aspects:

(1) ICT resources,

(2) ICT infrastructure, and

(3) availability of computer equipment.

Regarding ICT resources, supporting conditions are divided into two categories: resource support conditions (e.g., access to software and equipment) and ICT support conditions (e.g., access to data and/or computer labs). Meanwhile, ICT infrastructure refers to the adequacy, quality, and reliability of the technology infrastructure (e.g., network connectivity and hardware availability) needed to support the use of ICT in teaching and learning. On the other hand, the availability of computer equipment refers to the number of computers available in the classroom that students can use. According to Inan and Lowther (2010), Ndlovu et al. (2020), and Nagy and Dringó-Horváth (2024), these factors may influence teachers' perceptions of technology and their trust in it.

Subjective norms

Subjective norms are defined as an individual's perception of a behavior and the social pressure that important people expect them to perform (or not perform) that behavior (Fishbein & Ajzen, 1975). Normative beliefs are expressed in terms of expectancies or probabilities about these beliefs to be true (e.g., it is very likely that my direct colleagues think that I should use ICT and it is unlikely that my pupils think that I should use ICT). Moreover, normative beliefs are influenced by the person's motivation to comply, which refers to the extent to which the person wishes to conform to the thinking of these important individuals (Kreijns et al., 2013). Unlike attitudes, which refer to an individual's positive or negative judgment about performing a specific behavior, subjective norms refer to an individual's belief that an important person or organization will or will not support that behavior (Ham et al., 2015). The influence of subjective norm beliefs depends on the individual's motivation to comply with the expectations of others. Specifically, subjective norms are divided into the influence of superiors, peers, and learners, and may include other significant sources of pressure on teachers to change their behavior (Ham et al., 2015). In the educational context, subjective norms are influenced not only by students and colleagues but also by expectations from administrators and cultural and social factors (Wong, 2016). Studies by Hew and Brush (2007) and Sang et al. (2010) demonstrate that social contexts and educational policies that promote the integration of ICT will significantly influence teachers' beliefs and intentions to use ICT in teaching. In the context of this study, we examine two main categories of subjective norms: subjective norms from superiors and subjective norms from peers and learners.

Based on the model in **Figure 1**, this study builds three hypotheses:

H1: Self-efficacy beliefs (SE) have a positive influence on teachers' beliefs about using ICT (BE).

H2: Beliefs in ICT support (BS) have a positive influence on teachers' beliefs about using ICT (BE).

H3: Subjective norm (SN) has a positive influence on teachers' beliefs about using ICT (BE).

Table 1. Questionnaire of the factors influencing teachers' beliefs about ICT use

Item	Question
SE. Self-efficacy beliefs	
SE1	I possess the knowledge and ability to utilize ICT tools in teaching mathematics.
SE2	I can comfortably use ICT tools in teaching mathematics.
SE3	I have sufficient knowledge to utilize ICT tools in teaching mathematics.
BS. Beliefs in ICT support	
BS1	The ICT tools used in teaching Math are compatible with the computers I use in the classroom.
BS2	I can use ICT tools in teaching Math through the use of computers connected to the internet.
BS3	The school has created favorable conditions for teachers to implement teaching with ICT tools.
BS4	The school has issued many policies to support the necessary resources for the use of ICT facilities.
SN. Subjective norms	
SN1	My superiors believe that I possess the ability and knowledge to utilize ICT tools in math class effectively.
SN2	My superiors think I should use ICT tools in teaching mathematics.
SN3	My superiors emphasized the importance of utilizing ICT tools in teaching mathematics effectively.
SN4	My colleagues have been using ICT tools to teach mathematics in their classrooms.
SN5	My colleagues suggest that I should use ICT tools to teach mathematics in the classroom.
SN6	My colleagues felt that learning how to teach mathematics with ICT tools was necessary.
SN7	Students think that I should use ICT tools to teach mathematics in the classroom.
SN8	Students appreciate math lessons that use ICT tools.
SN9	My colleagues think that using ICT tools in teaching mathematics will benefit me.
SN10	My supervisor thinks that using ICT tools to teach mathematics is important.
SN11	My students think that using ICT tools to teach maths is important.
BE. Teachers' beliefs about the ICT use	
BE1	I plan to use ICT tools to teach mathematics in my future classroom.
BE2	I can effectively integrate ICT tools into my daily mathematics teaching activities.
BE3	I understand the strengths and limitations of teaching mathematics with ICT tools.
BE4	The use of IT tools in teaching mathematics is entirely within my control.

METHODS

Research Design

A survey study employing a quantitative research method was conducted to investigate the factors influencing teachers' beliefs about the application of information technology in teaching mathematics. The quantitative research method is considered an effective tool for simplifying data analysis, focusing on the aspects of the data that interest the researcher (Player-Koro, 2012).

Sample

The study was conducted with 422 mathematics teachers teaching at high and secondary schools in Vietnam. Of these, 207 were male teachers (49.05%) and 215 were female teachers (50.95%). In terms of work, 190 teachers (45.02%) and 249 (59.00%) were teaching at secondary schools. Geographically, the teachers participating in the survey came from 32 different provinces and cities in Vietnam, with 287 teachers coming from urban areas (68.00%) and 135 teachers coming from rural, mountainous, or island areas (32%), of which the highest proportion was in Ho Chi Minh City (166 teachers, 39.33%).

Instrument

The questionnaire (both offline and online) was used to survey teachers' opinions on factors influencing their beliefs about the application of information technology in teaching mathematics. In particular, the questionnaire was designed using a six-level Likert scale, where teachers would assign scores from 1 to 6, corresponding to increasing levels of agreement with the statements about factors affecting their beliefs regarding the application of information technology in teaching mathematics mentioned in the survey. Specifically, the levels were scored as follows: 1 point–strongly disagree, 2 points–disagree, 3 points–almost disagree, 4 points–almost agree, 5 points–agree, and 6 points–strongly agree. The use of a six-point Likert scale is intended to provide more options for responses and create more combinations for segmentation (Miller, 1956). It is also suitable for behavioral and psychological assessment. **Table 1** presents the content of the questionnaire, which was designed based on the scale development by Ndlovu et al. (2020).

Data Analysis

The analysis of the data collected through the questionnaire was carried out in four steps.

Step 1. Use Cronbach's alpha test to assess the internal reliability of the scale

Cronbach's alpha (also known as the alpha coefficient) measures reliability or internal consistency. The term "reliability" refers to the extent to which a survey (or questionnaire) measures what it is supposed to measure. In the context of this article, we used Cronbach's alpha to test the reliability of surveys based on multiple-item Likert scales. A high Cronbach's alpha result for a factor indicates that the observed variables listed are closely related, accurately reflecting the characteristics of the original factor. Conversely, a low result indicates that the observed variables may be measuring a different factor (or not measuring anything at all). In the statistical results, we would consider the following indicators: the overall Cronbach's alpha (raw_alpha) of the factors, the alpha coefficient of each observed variable in the "raw_alpha" column of the "Reliability if an item is dropped" table, and the adjusted correlation coefficient between the variable and the total score in the "r. drop" column of the "Item statistics."

According to Hair et al. (2018) and Henseler et al. (2009), a suitable scale should have an overall Cronbach's alpha greater than 0.7. More specifically, according to (Cristobal et al., 2007), the values of the alpha coefficient are as follows: if the alpha coefficient is between 0.8 and 1, the scale is very good; if the alpha coefficient is between 0.7 and 0.8, the scale is good; if the alpha coefficient is greater than 0.6, the scale is acceptable.

For the "reliability if an item is dropped" table, each row represents each observed variable and its alpha if that item were dropped. This value will be evaluated along with the adjusted correlation coefficient between the variable and the total score in the "item statistics" table. A good scale will have an adjusted correlation coefficient between the variable and the total score greater than 0.3 (Cristobal et al., 2007). If the alpha coefficient after removing an item is greater than the overall Cronbach's alpha and the adjusted correlation coefficient of that item is less than 0.3, the observed variable will be dropped to increase the reliability of the scale. If the alpha coefficient after removing an item is greater than the overall Cronbach's alpha, but the difference is small (less than 0.1), and the adjusted correlation coefficient of that item is greater than 0.3, we will consider retaining the observed variable.

Step 2. Exploratory factor analysis

In this study, many items in the questionnaire may be correlated with each other, which complicates the interpretation and analysis of the data. We used exploratory factor analysis (EFA) to group the correlated variables into more general latent factors, thereby providing a clearer view of the data by reducing the original list of variables into fewer, more general factors that are easier to interpret. Before performing EFA, we needed to ensure that our dataset was suitable for this type of analysis. To do this, we used the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test. According to Kaiser (1974), a KMO value greater than 0.5 and a p-value less than 0.05 indicate that the correlation between the observed variables is sufficient to perform EFA. For Bartlett's test, if the p-value is less than 0.05, this indicates that the observed variables within a factor are correlated.

We used parallel analysis to determine the number of factors to be extracted from the data for EFA. Next, we evaluated the scale's values through EFA, considering two important aspects: convergent validity and discriminant validity. According to Hair et al. (2018), in the rotated matrix table, if the factor loading of an observed variable in a factor is greater than 0.5, the observed variable has good quality. According to Pituch and Stevens (2015), a factor is considered reliable if it includes 3 to 5 or more measurement variables. For convergent validity, observed variables of the same type will converge on the same factor; when displayed in the rotated component matrix, these variables will be in the same column. For discriminant validity, observed variables converge on this factor and must be distinct from those converging on other factors. When displayed in a rotated component matrix, each group of variables will be separated into distinct columns. After removing observed variables with factor loadings less than 0.5, we rearranged the factors and conducted a second round of EFA analysis using these revised variables.

Step 3. Multiple linear regression analysis

The factors were included in the regression model. We used multiple linear regression analysis to test the hypotheses about the impact of the new factors on BE in the model, thereby testing the three proposed hypotheses at a 5% statistical significance level.

Step 4. Multiple linear regression analysis to test the impact of factors in the model

The factors were entered into the regression model. We employed multiple linear regression analysis to test the hypotheses regarding the impact of the new factors on behavioral intention (BE) in the model, thereby examining the five proposed hypotheses at a 5% statistical significance level.

After the analysis, we tested the five assumptions of the linear regression model to ensure that the model was statistically significant.

Assumption 1. Normal distribution of residuals in the model: The residuals are normally distributed when the p-value of the Anderson-Darling test is less than 0.05, or the normal Q-Q plot of the residuals shows that the points are concentrated around the line $y = x$. The residuals have a mean of 0 if the p-value of the t-test is greater than 0.05.

Residuals have homoscedasticity: This is tested either through the Goldfeld-Quandt test (when the p-value is greater than 0.05) or by using a scatter plot of the standardized residuals and standardized predicted values, where the standardized residuals are randomly distributed around the $y = 0$ line.

Assumption 2. Linear relationship between the dependent variable and the independent variables: This assumption can be checked using a partial residual plot. If the purple line is "close" to the blue line, then the relationship between the dependent and independent variables is linear.

Assumption 3. There is no autocorrelation in the residual series: This assumption is tested using the Durbin-Watson test. If the d value of the test is between 1.5 and 2.5, then there is no autocorrelation.

Assumption 4. No outliers or high-impact points: A point is considered an outlier if it lies too far from the line $y = x$ on the Q-Q plot. A point can be a high-impact point if its Cook's distance value is greater than 0.5.

Assumption 5. No multicollinearity: Multicollinearity occurs when the variance inflation factor (VIF) exceeds 5. Additionally, if the absolute value of the Pearson correlation coefficient exceeds 0.8, multicollinearity may occur (Young, 2017). Next, we assessed the importance of each independent variable in relation to the dependent variable, based on the coefficient of determination (multiple R-squared, R^2), following the method of Lindeman et al. (1980).

Step 5. Study the impact of moderator variables on the model

The moderator variables "gender", "place of teaching", "public/private school", "teaching level", and "number of years of teaching" were considered to highlight the importance of demographics in studying participants' behavioral intention (BE) to use information technology in teaching. Specifically, we examined the impact of these moderator variables on the linear regression models for the hypotheses. The measure used to test the impact was the p-value from the t-test, with a statistical significance level of 5%.

For the moderator variable "gender", when assessing the impact of each XiX_i variable (in this case, SN, BS, and SN) on the BE variable, two variables—namely, the moderator variable "male" and the interaction variable "Xi:NamX_i: Nam"—are added to the linear regression model. We conclude that the "gender" variable has an impact on the original linear regression model if the value of the interaction variable "Xi:NamX_i: Nam" is less than 0.05, even if the "Nam" variable has a p-value greater than 0.05. The hierarchy principle, as defined by James et al. (2021), states that whenever an interaction term is included in a statistical model, the main effects from that interaction should also be present in the model. This is a crucial rule to follow, even if p-values for the main effect coefficients are not statistically significant.

For the moderator variables "place of teaching", "public/private school", "teaching level", and "number of years of teaching", we applied the same statistical analysis procedure.

Table 2. Cronbach's alpha test results (first round)

Construct	Item	Cronbach's alpha, if an item is dropped	Internal reliability Cronbach's alpha	Corrected item–Total correlation
SE	SE1	0.77	0.86	0.89
	SE2	0.83		0.83
	SE3	0.77		0.90
	SN4	0.88		0.72
BS	BS1	0.74	0.76	0.76
	BS2	0.72		0.71
	BS3	0.69		0.76
	BS4	0.65		0.81
SN	SN1	0.91	0.92	0.68
	SN2	0.90		0.82
	SN3	0.90		0.83
	SN4	0.90		0.81
	SN5	0.91		0.77
	SN6	0.91		0.77
	SN7	0.91		0.75
	SN8	0.91		0.74
	SN9	0.90		0.81
BE	BE1	0.80	0.84	0.82
	BE2	0.78		0.84
	BE3	0.82		0.77
	BE4	0.77		0.84

RESULTS

Cronbach's Alpha Test Results to Assess the Internal Reliability of the Scale (First Round)

To test the reliability of our survey, which is based on a Likert scale with multiple questions, we used Cronbach's alpha reliability test to determine whether the observed variables can accurately represent the characteristics of the original factor. This tool helps us determine which observed variables are appropriate and which are not to include in the scale. The test results are presented in **Table 2**.

From **Table 2**, we can see that the internal reliability of the main factors, Cronbach's alpha, ranges from 0.76 to 0.92, which satisfies the reliability threshold (greater than 0.7). Each row in the column "Cronbach's alpha, if an item is dropped" refers to the overall coefficient if the corresponding observed variable is dropped. The results indicate that all observed variables make a significant contribution to the model. Regarding the modified item-total correlation coefficient column, all values exceed 0.3, indicating a strong correlation between each observed variable and the remaining variables in the scale.

Exploratory Factor Analysis Results (First Round)

For the EFA suitability test, the KMO value of 0.95 indicates that the data set is suitable for EFA. The result of Bartlett's test with a p-value less than 0.05 indicates that the correlation between the variables is strong enough to perform EFA.

The analysis showed that three factors needed to be extracted for the independent variables. The results from the factor rotation matrix indicated that variables BS1, BS3, BS4, and SN1, which had factor loadings below 0.5, were removed from the model. The remaining variables, each with a factor loading greater than 0.5, were organized into three factors (see **Table 3**).

A second EFA test was performed, which satisfied the criteria of the KMO test (KMO value of 0.92), Bartlett test (p-value less than 0.05), and parallel analysis (3 factors were extracted from the data). The results from the factor rotation matrix showed that the 17 observed variables were divided into three factors, but not in a manner that corresponded to the variables themselves.

Therefore, we removed the variables SE4, BS1, BS2, BS3, BS4, SN1, SN9, and divided SN into two groups: SNa (subjective norms from superiors), including SN2, SN3, SN4, and SNb (subjective norms from colleagues, students), including SN5, SN6, SN7, SN8. Next, we perform the re-examination steps.

Table 3. Rotated component matrix (first round)

Construct	Item	Factor 1	Factor 2	Factor 3
SE	SE1			0.86
	SE2			0.53
	SE3			0.86
	SE4		0.51	
BS	BS1			
	BS2		0.50	
	BS3			
	BS4			
SN	SN1			
	SN2	0.70		
	SN3	0.85		
	SN4	0.73		
	SN5		0.59	
	SN6		0.55	
	SN7		0.62	
	SN8		0.62	
	SN9	0.63		

Table 4. Cronbach's alpha test results (second round)

Construct	Item	Cronbach's alpha, if an item is dropped	Internal reliability Cronbach's alpha	Corrected item–Total correlation
SE	SE1	0.78	0.88	0.92
	SE2	0.92		0.85
	SE3	0.77		0.92
SNa	SN2	0.86	0.88	0.88
	SN3	0.80		0.93
	SN4	0.85		0.89
SNb	SN5	0.80	0.84	0.81
	SN6	0.80		0.80
	SN7	0.78		0.84
	SN8	0.79		0.82
BE	BE1	0.80	0.84	0.82
	BE2	0.78		0.84
	BE3	0.82		0.77
	BE4	0.77		0.84

Cronbach's Alpha Test Results to Assess the Internal Reliability of the Scale (Second Round)

From **Table 4**, we can see that the internal reliability of the main factors, Cronbach's alpha, ranges from 0.84 to 0.88, which satisfies the reliability threshold (greater than 0.7). Each row in the column "Cronbach's alpha, if an item is dropped" refers to the overall coefficient if the corresponding observed variable is dropped. The results indicate that all observed variables make a significant contribution to the model. Regarding the column of the modified item-total correlation coefficient, all values exceed 0.3, indicating a strong correlation between each observed variable and the remaining variables in the scale.

Exploratory Factor Analysis Results (Second Round)

For the EFA suitability test, the KMO value of 0.9 indicates that the data set is suitable for EFA. The result of Bartlett's test, with a p-value less than 0.05, indicates that the correlation between the variables is strong enough to perform EFA (see **Table 5**).

The analysis showed that three factors needed to be extracted for the independent variables. The results from the factor rotation matrix showed that each variable with a factor loading greater than 0.5 was organized into three factors.

Table 5. Rotated component matrix (secondt round)

Construct	Item	Factor 1	Factor 2	Factor 3
SE	SE1		0.86	
	SE2		0.54	
	SE4		0.87	
SNa	SN2	0.67		
	SN3	0.85		
	SN4	0.70		
SNb	SN5			0.59
	SN6			0.54
	SN7			0.69
	SN8			0.66

Table 6. Revised factors and items

Factors	Items	Variable types
X_1 (SE)	SE1, SE2, SE3	Independent
X_2 (SNa)	SN2, SN3, SN4	Independent
X_3 (SNb)	SN5, SN6, SN7, SN8	Independent
Y (BE)	BE1, BE2, BE3, BE4	Dependent

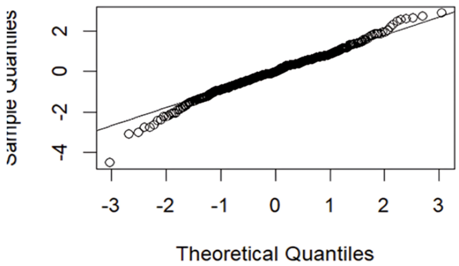

Figure 2. Normal Q-Q plot (Source: Authors)

Results of Multiple Linear Regression Analysis

According to **Table 6**, we have analytical model: $Y = f(X_1, X_2, X_3)$. By performing multiple regression analysis, we found that the effects of the variables are all statistically significant with the following statistical function:

$$\boldsymbol{Y} = 0.60960 + 0.49547 \cdot \boldsymbol{X_1} + 0.15617 \cdot \boldsymbol{X_2} + 0.23458 \cdot \boldsymbol{X_3} + \varepsilon \ (*)$$

Multiple R-squared = 0.7546: About 75.46% of the variation in the dependent variable is explained by the model, indicating that the model fits the data well. The standard error of the residuals (0.3932) is relatively low, indicating that the model's predictions are quite accurate.

Results of Multiple Linear Regression Analysis to Test the Impact of Factors in the Model

Next, we proceed to test the assumptions of the multiple linear regression model.

Assumption 1. Normal distribution of residuals in the model

The Anderson-Darling test gave a p-value = 0.006209 < 0.05, combined with the normal Q-Q plot, confirming that the residuals in the model are normally distributed (**Figure 2**).

The t-test yields a p-value of 0.9974, which is greater than 0.05, indicating that the residuals have a mean of 0.

Based on the scatter plot between the standardized residuals (**Figure 3**) and the standardized predicted values , and the p-value from the Goldfeld-Quandt test being greater than 0.05, we conclude that the residuals have constant variance.

Assumption 2. Linear relationship between the dependent variable and the independent variables

Figure 4 illustrates the linear relationship between the dependent variable and the independent variables.

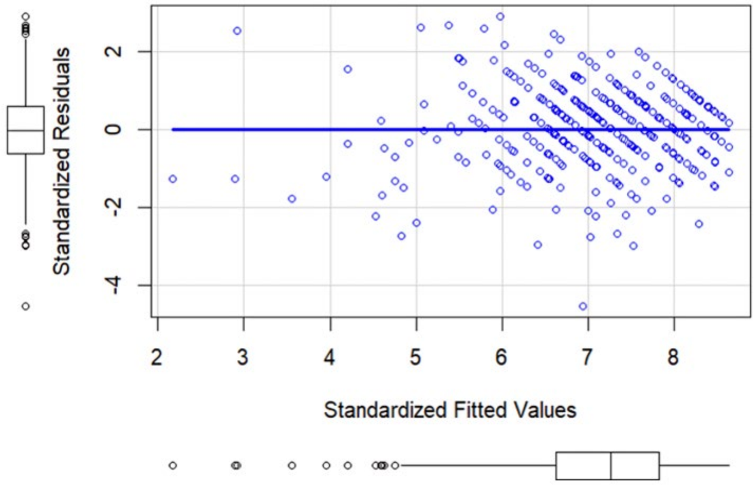

Figure 3. Standardized residuals and standardized fitted values (Source: Authors)

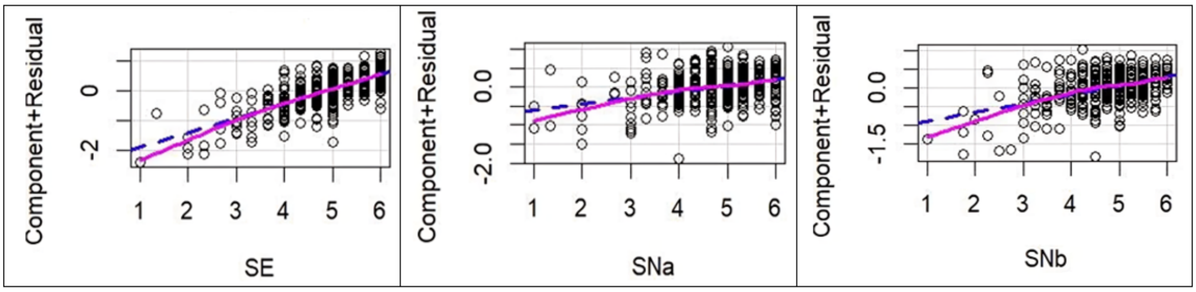

Figure 4. Partial residual plot (Source: Authors)

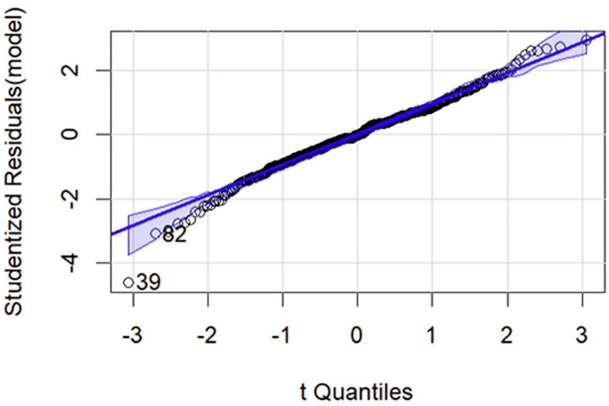

Figure 5. Q-Q plot (Source: Authors)

Assumption 3. There is no autocorrelation in the residual series

The Durbin-Watson test yields a d-value of 1.9762, which falls within the range of 1.5 to 2.5. Therefore, we conclude that there is no autocorrelation in the residual series.

Assumption 4. No outliers or high-impact points

Figure 5 and **Figure 6** show that the model has almost no significant outliers or high-impact points.

Assumption 5. No multicollinearity

The results indicate that the independent variables have a VIF of less than 2.5, and the absolute value of the Pearson correlation coefficient is less than 0.7, confirming the absence of a multicollinearity phenomenon (**Figure 7**).

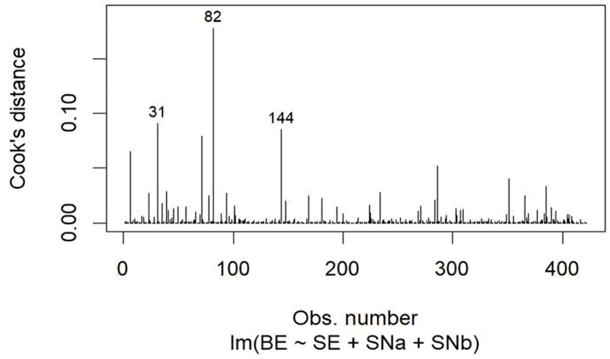

Figure 6. Cook's distance plot (Source: Authors)

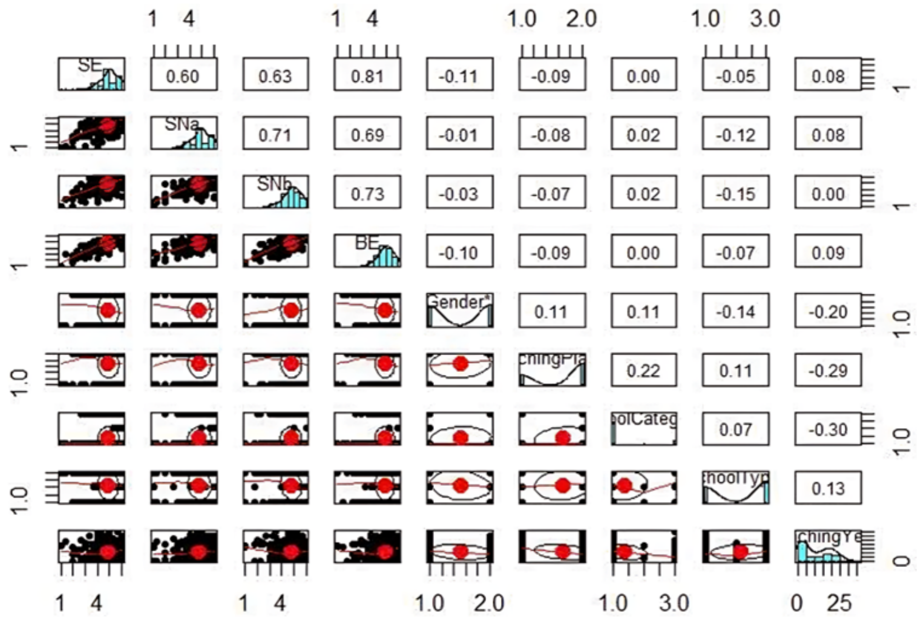

Figure 7. Pearson's correlation coefficients (Source: Authors)

Thus, the test results indicate that our model satisfies all five assumptions. Therefore, we conclude that the independent variables SE (Self-efficacy beliefs), SNa (subjective norms from superiors), and SNb (subjective norms from colleagues and students) all have positive effects on the dependent variable BE (teachers' beliefs in using information technology). Therefore, the regression equation (*) is statistically significant.

Results of Assessing the Importance of Predictor Variables

We evaluated the importance of each predictor variable to the dependent variable using the "lmg" method. The results showed that the R^2 of the model reached 75.46%, with the SE, SNa, and SNb variables having R^2 values of 35.06%, 18.61%, and 21.79%, respectively. Therefore, the SE variable had the largest influence on the dependent variable BE, while the SNa variable had the smallest influence.

Results of Assessing the Impact of Moderating Variables on the Model

We examined the impact of the moderator variables "gender" and "grade" on the linear regression models of hypotheses **H1**, **H2**, and **H3**, based on the p-values from the t-test for the coefficients of the added moderator variables and interaction variables. The results showed that all p-values were greater than the 5% significance level. This indicated that the differences were not sufficient to conclude that the moderator variables—"gender", "place of teaching", "public/private school", "teaching level", and "number of years of teaching"—had an impact on the models.

DISCUSSION

This survey study was conducted to verify three research hypotheses on the influence of self-efficacy beliefs, beliefs in ICT support, and subjective norms on teachers' beliefs (BE) towards the application of information technology in teaching mathematics. Using quantitative research methods, the study conducted Cronbach's alpha tests, EFA, multiple linear regression analysis, and multivariate linear regression analysis to examine the impact of factors in the proposed model, with the expectation of verifying the hypotheses. In general, the research results are consistent with the research hypotheses **H1** and **H3**, in which the factors of self-efficacy (SE), subjective norms from superiors (SNa) and subjective norms from colleagues and students (SNb) all have positive impacts on BE, in which SE has the largest impact (estimated coefficient = 0.49547 is the largest and statistically significant), while SNa has the lowest impact. Additionally, this study highlights the differences in the impact of the components on the acceptance and use of information technology among high school and secondary school mathematics teachers.

Specifically, the results of the first research hypothesis (**H1**) showed that self-efficacy was identified as the factor with the greatest positive influence on secondary school teachers' BE in using information technology in teaching mathematics. This result is consistent with the findings of studies by Inan and Lowther (2010), Ndlovu et al. (2020), and Yang and Leung (2015) on the central role of SE in the application of information technology in education. These studies indicate that teachers who are confident in their ability to use ICT in teaching tend to feel more ready and confident to integrate ICT, and at the same time, strengthen their confidence in using ICT in teaching (Inan & Lowther, 2010; Ndlovu et al., 2020; Yang & Leung, 2015).

Next, the results of the second hypothesis (**H2**) showed that, contrary to the initial hypothesis, BS had no impact on BE, with factor loadings below 0.5 (see **Table 3**). However, this result is inconsistent with the conclusions of some previous studies by Inan and Lowther (2010), Ndlovu et al. (2020), and Nagy and Dringó-Horváth (2024), when ICT supports were considered as a factor that indirectly and directly influenced teachers' beliefs and contributed to increasing teachers' intentions to use technology in teaching. According to Inan and Lowther (2010), factors such as school-related factors (including ICT support, overall support, technical support, and computer availability) have a lasting influence on teachers' beliefs. With 68.00% teachers coming from urban areas and 32% teachers coming from rural, mountainous, or island areas, the results may be partly due to the development of technology and the varying physical conditions of schools and regions, especially in rural, island, or mountainous schools that lack technological support, resulting in teachers not receiving adequate technology support for teaching mathematics. However, there is a noteworthy issue that arises from the results of **H2** regarding the reasons why BS have minimal impact on BE when a large proportion of teachers come from urban areas with sufficient ICT support. The study by Windschitl and Sahl (2002) suggests that the conditions of ICT alone do not automatically initiate teachers' ICT beliefs; instead, they must be personally convinced of its benefits and see the utility of using a particular technology (Lam, 2000) to incorporate ICT into their teaching practice. Therefore, it can be concluded that the impact of BS on BE may depend on other conditions, leading to the contradiction in the results of this study with those of previous studies, which can be considered an issue that needs to be explained or verified in future studies.

For the third research hypothesis (**H3**), subjective norms from peers and learners (SNb) were identified as the second most important predictor of BE. Specifically, secondary school teachers with higher SNb tended to actively use information technology in teaching mathematics. This result is consistent with that of previous studies, such as those by Ndlovu et al. (2020) and Sadaf et al. (2012). This may be explained by the specific demands in mathematics, where teachers are pressured to find active teaching approaches that help students learn more in complex lessons, explain abstract concepts, or develop students' thinking skills. On the other hand, subjective norms from superiors (SNa) had a minimal impact on BE, consistent with the research results of Ndlovu et al. (2020). The results showed that the influence of superiors had only an indirect effect on the beliefs of high and secondary school teachers about the application of information technology in mathematics teaching. Meanwhile, according to Mumtaz (2005), positive expectations from the community and management had a strong influence on teachers' beliefs about the use of ICT.

Thus, this study has deepened the understanding of secondary school teachers' beliefs regarding the application of information technology in teaching mathematics within the Vietnamese context. Therefore, the study proposes some directions for teacher training and educational organizations to positively influence teachers' beliefs and optimize the integration of information technology in mathematics teaching. Firstly, enhancing training in information technology can improve teachers' self-confidence in their abilities, through activities such as organizing specialized courses or practical training programs with a design that focuses on IT skills (such as math teaching software and online platforms) to enable teachers to apply these skills in the classroom confidently. Second, promote a culture of collaboration and sharing among colleagues through building professional learning communities, increasing positive interactions with students through surveys of student feedback on the use of ICT in teaching and learning mathematics, and increasing classroom engagement when using ICT (with online question-answering software, graphing software, or simulation applications) to create excitement for students. Third, strengthen the supportive role of school leaders by encouraging them through policies and financial support, as well as by providing facilities and building pioneering leadership models, organizing professional exchanges and feedback, and offering encouragement based on criteria for applying ICT. According to Ertmer (2005) and Inan and Lowther (2010), measures that are considered effective in changing teachers' beliefs, such as personal and vicarious experiences, should also be focused on in efforts to promote technology integration in teaching.

However, in addition to the achieved results, the study has certain limitations. Firstly, due to the limited sample size and the fact that the majority of participants (more than 65%) reside in large cities, the results may not accurately represent all secondary school teachers across different regions and socio-economic conditions in Vietnam. The studies by Klem (1995), Robinson (2003), and Player-Koro (2012) also mention this. Therefore, similar studies but with larger sample sizes and data collection in a wider geographical area can be conducted to draw more general conclusions (Nagy & Dringó-Horváth, 2024). In addition, the survey research method, which involves self-reporting questionnaires, also has certain potential limitations in cases where survey participants have overly optimistic or pessimistic assessments of themselves and external conditions. Therefore, new studies can combine quantitative and qualitative analysis, along with other research tools such as observation or tests, to collect practical, in-depth, and objective information about the research problem (Judson, 2006). On the other hand, limitations in measurement tools arise when studying variables such as SE, SNa, SNb, etc., as the specific scales used to measure these variables are subjective, and quantitative scales may not fully capture their complexity. Therefore, new studies can be conducted to in-depth analyze specific observed variables through the analysis of component factors or scales (Mumtaz, 2005). Additionally, it is worth noting that teachers' beliefs may vary depending on the specific types of ICT used (Tondeur et al., 2008), which were not considered in this study. This presents an opportunity for future research to conduct a more thorough investigation into the beliefs of mathematics teachers regarding specific types of ICT. Furthermore, the current study limited the influencing factors to three variables: self-efficacy beliefs, ICT support, and subjective norms so that future studies could expand the scope of the research variables with other factors such as school culture, teacher workload, pedagogical beliefs about teaching and learning mathematics, pedagogical training and experience (Inan & Lowther, 2010).

CONCLUSION

A survey study employing a quantitative method has verified the research hypotheses regarding the influence of self-efficacy beliefs, ICT support beliefs, and subjective norms on teachers' beliefs about using technology in teaching mathematics. The research results indicate that self-efficacy beliefs and subjective norms from colleagues and students are factors that have the most significant influence on secondary school teachers' beliefs about integrating information technology into mathematics teaching. In contrast, ICT support beliefs and subjective norms from superiors have a minimal impact. In particular, the analysis results show that self-efficacy beliefs have the most decisive influence on teachers' beliefs among the three factors considered. Based on the results achieved and the limitations of the current study, some future research directions are suggested, including expanding the sample size and geographical scope of survey participants, combining this study with other qualitative or quantitative survey tools such as observation or testing, and exploring the scope of variables or studying specific variables in depth.

Author contributions: DHT: conceptualization, writing – original draft, validation; **HTN:** writing – original draft, formal analysis, resources; **T-TN:** conceptualization, writing – original draft, formal analysis, methodology; **TTTL:** data curation, writing – review & editing; **XMV:** data curation, writing – review & editing; **LVMT:** data curation, writing – review & editing;

TMD: conceptualization, writing – review & editing, supervision, methodology. All authors approved the final version of the article.

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Ethics declaration: This study did not require ethical review and approval for the following reason: An email invitation was sent to all high and secondary school teachers to participate in the study, which included a comprehensive description of the study as a participant information sheet. They were all made aware that taking part in the online survey was voluntary and anonymous, and that they could leave the survey at any point without facing any negative consequences. All participants were informed that the results of this study would be published upon its completion. All participants were informed of their consent to participate in the study.

AI statement: During the preparation of this study, the authors used Grammarly and Quillbot in order to check English grammar and proofread sentences. After using this tool/service, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

Declaration of interest: The authors declared no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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