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Attitudes before actions: how music teachers' technological acceptance and competence shape technological behaviour in China

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Technology can be a key aspect in facilitating progress and development in education that sometimes debates the factors that determine the use of technology and its impact on teaching and learning. In education, technology integration can enhance instruction by providing educators with more pedagogical tools, facilitating student learning, and promoting active engagement in the classroom. The Unified Theory of Acceptance and Use of Technology (UTAUT) model has been used to explain teachers' technology acceptance (TA) and behavioural intentions in this regard. Debate exists as to whether teachers' technological competence (TC) improves the prediction of technology acceptance behaviour and in particular the factors that influence music teachers' technology use in China remain unclear. Considering that technological behaviour (TB) usually refers to the actions and decisions of individuals or organisations in using and adopting technological devices, this study examined the relationships between TA, TC, and TB among music teachers in China. Structural equation modelling was employed to analyse data obtained from 307 music teachers in Fujian province, China. The result identified ten influencing factors, which were then grouped into a theoretical framework entitled Technological Competence, Acceptance, and Behaviour (TCAB). This framework describes the factors influencing music teachers' use of technology from the geographical perspective of China in which TA emerges as a crucial component that directly impacts TB, and TC indirectly affects TB by influencing TA. Although TB is a complex phenomenon that can be influenced by a variety of factors and contexts, the results suggested that music teachers' attitudes can be a prerequisite for their actions in using technology and reflect the overall enthusiasm of music teachers for using technology in China. The study offers original perspectives on crafting a theoretical model adapted to diverse cultural settings and informs relevant stakeholders to better integrate technology into music education.

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Introduction

As evidenced by the surge in global development and adoption of Artificial Intelligence (AI) tools, technology is changing the lives and usage behaviour of society. In the fast-paced digital era, user behaviours and attitudes towards technology adoption are becoming a focal point of discussion. Many fields, whether it be information systems, psychology, or education, are conducting research and interpreting these phenomena (Venkatesh et al., 2003; 2012; 2016; Abraham et al., 2013; Juaneda-Ayensa et al., 2016; Teo et al., 2019; Tamilmani et al., 2021). Understanding user attitudes and behaviours towards technology becomes increasingly important for individuals seeking to encourage the use of technology and for researchers aiming to reveal the adoption, normalisation, and resulting impact of new technology.

In the field of education, there have been significant changes in the way technology is used and perceived by teachers and students. This is particularly evident with the emergence of online education and blended learning during the COVID-19 pandemic. For instance, Akram et al. (2022) highlighted the importance of addressing barriers, providing professional development opportunities, and aligning technology integration with pedagogical beliefs to enhance teaching practices and meet the learning needs of students in the digital age. In the field of music education, the trend of integrating technology into teaching and learning has become increasingly evident in the 21st century and beyond. For instance, the ongoing trend of device miniaturisation has enabled music educators and their students to access digital technology at a higher level (Dammers, 2019).

Despite the potential benefits of technology in music education, research suggests a gap between its theoretical promise and its practical implementation (Gall, 2017). This gap can be attributed to various factors influencing the integration of technology. These factors include internal aspects like teachers' attitudes and reflective practices, as well as external pressures such as social norms and examination requirements (Wise et al., 2011; Gilbert, 2015; Váradi et al., 2023). In the context of Chinese education, rapid technological advancements and ongoing educational reforms have highlighted the need to address this gap. The latest Chinese national curriculum standards for music education in China explicitly state in the teaching prompts that emerging technologies, such as AI, can be integrated into teaching practices (Ministry of Education, 2022). This mandate highlights the growing importance of technology adoption in Chinese music education, as well as the availability of technology as a tool for educators. However, there is still a lack of empirical research to explore the specific determinants that influence Chinese music educators' adoption and implementation of technology. This gap poses challenges in developing evidence-based strategies to enhance the integration of technological tools with music education practices. Therefore, understanding these factors appears necessary to overcome barriers and foster more effective and innovative pedagogical approaches.

When examining the influencing factors, Waddell and Williamon (2019) observed that musicians' positive attitudes towards technology can be influenced by perceived usefulness and ease of use. However, Henrich et al. (2010) argued that findings from Western, educated, industrialised, rich, and democratic (WEIRD) societies may not be generalisable to other cultural contexts due to differences in cognitive processes, reasoning styles, and behavioural patterns. This theoretical perspective underscores the need for China-specific research, as China—with a population of 1.4 billion exceeding Europe and North America combined (Ritchie et al. (2023)—maintains a music education system performs a complex balancing act between preserving traditional pedagogical values and integrating contemporary technological frameworks (Ministry of Education, 2022). In the current context of the intersection of technology and education in China, more empirical investigations are needed to understand the multifaceted factors that influence music teachers' adoption of technology behaviours in a non-Western cultural context. Some empirical investigations have begun in China that include Zhang et al. (2021) which argues that Chinese music teachers in higher education were found to have their beliefs and behavioural predictions influenced by technological competence, but there was no direct significant effect of technological competence on behavioural prediction. Although a valuable starting point, this work was a small-scale pilot study with a relatively small sample size when considering the size of the population in China. The current study builds on and expands this work.

The purpose of our study is to improve the theoretical understanding of the factors influencing technology adoption and usage in music education. The complexities driving music teachers' technological behaviour (TB) highlight the need for a comprehensive model that explains their technology adoption decisions. These decisions encompass the behaviours of teachers in various music domains, including the acquisition, adaptation, development, and use of technology. To address this need, we propose a new model that integrates the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003; 2012) and the Technological Pedagogical and Content Knowledge (TPACK) framework (Mishra and Koehler, 2006). This model incorporates two key dimensions – Technological Competence (TC) and Technology Acceptance (TA) – and is adapted to the specific cultural context of China.

The following section presents a review of literature related to technology integration in education and music education, as well as the theory of technology adoption and its application in music education. What follows is a report into an empirical study intended to explore the relationship between TB, TC, and TA of Chinese music teachers, based on a new theoretical model that combines the UTAUT and TPACK models. Our study aims to contribute to the literature by: (1) providing empirical evidence on the associations between music teachers' technological competence, acceptance, and behaviour in China; (2) advancing the feasibility of combining the UTAUT and TPACK frameworks in the context of music education; and (3) informing policy makers and stakeholders in developing future policies and approaches for implementing technology in music education.

Literature review

Technology integration in educational contexts. To establish a clear understanding for this study, Davies and West's (2014) definition of technology integration is used as *the effective implementation of educational technology to accomplish desired learning outcomes*. The integration of technology in educational settings provides a window into the dynamics of technological behaviour of different groups, which has been extensively studied and documented in the literature. For instance, Dexter and Richardson (2019) conducted a systematic review of the literature on technology integration in K-12 schools, highlighting its multifaceted nature. Several studies have found that technology has the potential to improve students' collaborative learning, critical thinking, and engagement (de Witt et al., 2021; Krouska et al., 2022; Su and Zou, 2022). It can also enhance the quality of education and provide opportunities for all (Visvizi and Daniela, 2019), support course objectives (Dziuban et al., 2018), and create interactive and engaging learning environments (Biber et al., 2022). As we enter the new century, proficiency in digital and technological literacy appears to be a key part of the 21st-century

skillset for both teachers and students (Kim et al., 2019). This trend is not only due to the ability of technology to enhance teachers' critical and creative thinking skills and their multidimensional skills they will need in the 21st century (Yilmaz, 2021), but also because technology integration is critical to fostering the development of instructional leadership, technology leadership, innovation management, and professional competencies in educational administration that are highly valued (Sezen-Gultekin and Hamutoglu, 2020).

In examining the technological behaviour of educators, research has identified several key factors influencing how teachers adopt and use technology in their teaching practices. These include issues with technology availability and functionality, a lack of clear vision for technology use, teachers' prior experiences and beliefs, increased time requirements, and the need for professional development (Burke et al., 2018; Kearney et al., 2017; Khlaif, 2018; Okoye et al., 2023). A systematic review by Granic (2022) also confirmed that the adoption of educational technology is most affected by self-efficacy, subjective behavioural norms, enjoyment, facilitating conditions, computer anxiety, system accessibility, and technical complexity. However, teachers' attitudes and perceptions seem to be variable and subject to change over time. Research conducted during the COVID-19 pandemic indicates that fear of COVID-19 may have indirectly fostered increased engagement with online learning tools among university students (Al-Maroof et al., 2023). Moreover, research indicates that professional development programmes are crucial in supporting educators' technology adoption behaviours, particularly in developing the necessary skills and competencies for effective integration, including pedagogical and technological competencies (Zhang, 2022a; Klimova et al., 2023). However, limited resources and time constraints often prevent teachers from receiving formal training, forcing them to learn in informal settings (Zhang, 2022a).

Integrating technology in music education. The adoption of technology can have a transformative impact in music education and has been seen to improve teaching methods, nurture creativity, and offer students immersive learning experiences (Rifai, 2016; Macrides and Angeli, 2020; Michałko et al., 2022). Music instruction can be transformed by a wide array of digital tools such as notation software, online platforms, and portable mobile devices. Information and communication technology (ICT) has been extensively studied in the field of music education, with researchers from various regions and countries, including the UK, USA, Australia, Spain, Korea, and Hong Kong, demonstrating interest in this area (e.g., Ho, 2004; Savage, 2007; Crawford, 2009; Kim, 2013; Bauer and Dammers, 2016; Calderón-Garrido et al., 2021; Merrick and Joseph, 2023). These studies examine how prepared teachers and students are for technology and its impact on music education. While some teachers express concerns that technology may diminish the quality of classroom instruction (Beardsley et al., 2021), other studies have found that integrating technology can enhance student engagement, motivation, and academic performance in music education (Powell, 2019; Uludag and Satir, 2023). In addition to more common uses of technology, the integration of AI, Virtual Reality (VR), and Augmented Reality (AR) technologies in music education has resulted in the creation of immersive learning environments, leading to enhanced learning outcomes and the development of more personalised curricula (Campo et al., 2023; Chen, 2020; Jamshidi et al., 2021). These technologies not only enhance students' understanding of musical concepts but also spark their creativity and passion for music through interactive experiences.

However, bridging the gap between optimistic perceptions of technology's potential and the practical outcomes facilitating instruction appears to remain an ongoing challenge in music education. There are varying attitudes towards the adoption of innovative technologies in education, with some favouring traditional teaching methods (Dorfman, 2016). Furthermore, teachers vary widely in their confidence and competence in using new technologies (Kibici, 2022). Effective use of technology tools is often dependent on school resources, additional training, and professional development, regardless of internal and external factors (Ottenbreit-Leftwich et al., 2018).

Technology adoption theories in music education. Several technology adoption theories and models have been formulated over the past few decades seeking to explain what factors impact human decision-making on whether, and to what extent, they will implement a new technology. The technology acceptance model (TAM) is one of the widely recognised frameworks that explores how users adopt and use technology based on perceived usefulness and ease of use (Davis, 1989). It has been applied in educational contexts and suggest that teacher perceptions of usefulness and ease of use play a significant role in their intention to integrate technologies into their practice (Scherer et al., 2019; Ursavaş et al., 2019; Vanduhe et al., 2020; Rad et al., 2023). While TAM has been applied to explain the technology adoption behaviour of musicians toward current and future technologies (Waddell and Williamon, 2019), its application within music education in China is notably scarce.

Building on existing models like TAM, the UTAUT offers a more comprehensive framework for understanding technology adoption. It integrates factors like performance expectancy, social influence, and facilitating conditions, while acknowledging the moderating effects of age, gender, voluntariness, and experience (Venkatesh et al., 2003; 2012). The UTAUT and its variations have also been widely applied in numerous technology adoption studies in educational settings given its comprehensive synthesis of key elements found to directly impact acceptance and use (e.g., Garone et al., 2019; Hu et al., 2020; Abbad, 2021). However, these models are criticised for their reductionist approach, overemphasis of individual acceptance rather than actual use, neglect of organisational factors, and limited theoretical advancement beyond predicting usage intentions (Shachak et al., 2019). In music education, UTAUT has also been employed to investigate the influence of various factors on the adoption of technology among both music educators and students. These factors encompass technological literacy, teacher perceptions, student motivations, and institutional support (Pinhati and Siqueira, 2014; Gilbert, 2015; Zhang et al., 2021).

While UTAUT offers a broad framework, it may not fully account for the complexities of integrating technology with pedagogy, content knowledge, and cultural factors. The TPACK framework, which has been extensively tested in various educational contexts (e.g., Schmidt et al., 2009; Baran et al., 2019; Roussinos and Jimoyiannis, 2019; Soszyński, 2021), addresses these limitations by explicitly considering the interplay between technological, pedagogical, and content knowledge that influences teachers' classroom technology integration (Mishra and Koehler, 2006). But TPACK faces challenges in measurement in relation to validity and reliability, in particular its epistemological foundations, operationalisation, and practical application in diverse educational contexts (Cavanagh and Koehler, 2013). Therefore, combining the UTAUT and TPACK models could create a more powerful analytical framework that simultaneously explains why teachers adopt technology and how they effectively integrate it into their subject-specific teaching practices. While

several studies have successfully integrated these frameworks (Tang et al., 2024; An et al., 2023; Anthony et al., 2023), applications within music education remain limited. This study aims to address the gap in understanding these emerging issues of technology use specifically within Chinese music education contexts by employing these models.

Methods

This study employed a quantitative research design to investigate the factors influencing music teachers' technology acceptance and use in the context of Chinese culture. Our research framework is an integrated and extended model, drawing upon different factors derived from the UTAUT (Venkatesh et al., 2003; 2012) and TPACK (Mishra and Koehler, 2006) models. Specifically, this study incorporates the constructs of technology acceptance (TA) and technological behaviour (TB) derived from the UTAUT model. Additionally, the construct of technological capability (TC) is integrated based on the TPACK framework. These constructs have been consistently shown to be relevant in prior research, demonstrating their significance in technology integration across various educational fields and disciplines (Bauer, 2012; Dorfman, 2016; Cheung et al., 2018; Mohammad-Salehi et al., 2021). Building upon the initial validation of a study conducted by Zhang et al. (2021) in the Chinese context, the present study aims to achieve three key objectives: (1) further assess the applicability of the integrated UTAUT-TPACK framework; (2) examine the relationships between the identified factors; and (3) comprehensively explore the determinants influencing music teachers' technology use in their teaching practices in China.

Data were collected via an online questionnaire distributed to music teachers in Fujian province of China. We collected data for this study from 1 October to 31 December 2019 using online questionnaires hosted on WenJuanWang, a popular Chinese online survey platform like SurveyMonkey. Purposive snowball sampling (Etikan et al. (2016)) was used as the primary data collection strategy for this study. This was due to specific challenges in accessing the target population, such as limited opportunities for direct contact with the music teacher community and their limited public contacts. Similar purposive sampling approaches have been successfully implemented in educational technology research, including studies examining teachers' ICT integration in Henan Province of China (Peng et al., 2023) and investigations of research ethical factors in higher education contexts in Pakistan (Abbas et al., 2021). Questionnaires were disseminated primarily via WeChat, a social networking application in China widely used for group communication. The collection coincided with the onset of the COVID-19 pandemic and the rapid online education shift, which facilitated music teachers' participation in the survey.

The survey comprised 62 question areas of which 46 scale items were related directly to the constructs of the UTAUT and TPACK models. The remaining 18 items collected demographic information and data on participants' technology usage situations. Measurement instruments were adapted from existing research. The constructs of Technology Acceptance (TA) were measured using a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree) aligned with the UTAUT models, including factors like performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitating conditions (FC), hedonic motivation (HM), and habit (HA) (i.e., TA = PE + EE + SI + FC + HM + HA). Similarly, Technological Behaviour (TB) was measured by the variables of behavioural intention (BI) and usage behaviour (UB) (i.e., TB = BI + UB). Finally, Technological Competence (TC) was measured aligned with the TPACK framework, assessing factors like technological knowledge (TK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPCK) (i.e., TC = TK + TCK + TPK + TPCK). As a result, the theoretical model and hypotheses for this study are presented in Fig. 1 and detailed further below:

- Hypothesis 1 (H1): Technology Acceptance (TA) would positively influence Technological Behaviour (TB) (i.e., H1: TA → TB);
- Hypothesis 2 (H2): Technological Competence (TC) would positively influence Technological Behaviour (TB) (i.e., H2: TC → TB); and
- Hypothesis 3 (H3): Technological Competence (TC) would positively influence Technology Acceptance (TA) (i.e., H3: TC → TA).

Following data collection, the data underwent screening using various techniques to ensure data availability, reliability, and validity (Fidell and Tabachnick, 2003; Tabachnick and Fidell, 2007; Kline, 2016; Hair et al., 2017). During the first stage of data screening, responses from participants outside the Fujian region were excluded based on both manual review and platform-provided analysis functions. Subsequently, additional data cleaning was conducted to remove responses from individuals who did not meet the study's inclusion criteria, such as those who identified their occupation as music students. Second, this study screened data from recorded response times and the number of consecutive identical responses provided by the respondent (Behrend et al., 2011; Meade and Craig, 2012; Desimone et al., 2015). In total, 160 irrelevant responses were excluded based on the different data screening methods described above. This resulted in the retention of 307 valid responses.

Data analysis was performed using IBM SPSS Statistics (version 27.0) and RStudio (version 1.3.959) with the 'lavaan' package (version 0.6–8). Descriptive statistics were employed to summarise the data, and structural equation modelling (SEM) was conducted to examine the relationships among the identified factors and to test the hypothesised relationships outlined in the theoretical framework (Fidell and Tabachnick, 2003; Kline, 2015; Hair et al., 2017). To ensure ethical conduct, the study received prior approval from the researchers' university ethics committee. All data collection procedures adhered to established ethical research principles, including obtaining informed consent and maintaining participant anonymity.

Results

Profile of the participants. Participants in the study comprised 307 music teachers from various educational levels and institutions within Fujian province of China. Of these, 62.2% were teachers from non-higher education schools and 37.8% were teachers from higher education institutions. Personal and demographic characteristics of the respondents, encompassing factors such as gender, age, degree, and teaching experience can be seen in Table 1. The majority of participants were female (77.9%) and relatively young, with 56.4% falling within the 24–34 years age group. Most participants held Bachelor's (59%) or master's degrees (30.3%), and the years of teaching experience varied, with the largest group having under 3 years of experience (31.6%). It is worth noting that the gender distribution of the sample in this study shows a clear imbalance, with far more females than males. This difference may represent the gender composition of music education in China, as the gender ratio of music teachers in China's large cities was originally unbalanced (Ho, 2023).

Structural equation modelling analysis. The analysis of SEM and hypothesis testing proceeded by utilising both SPSS and

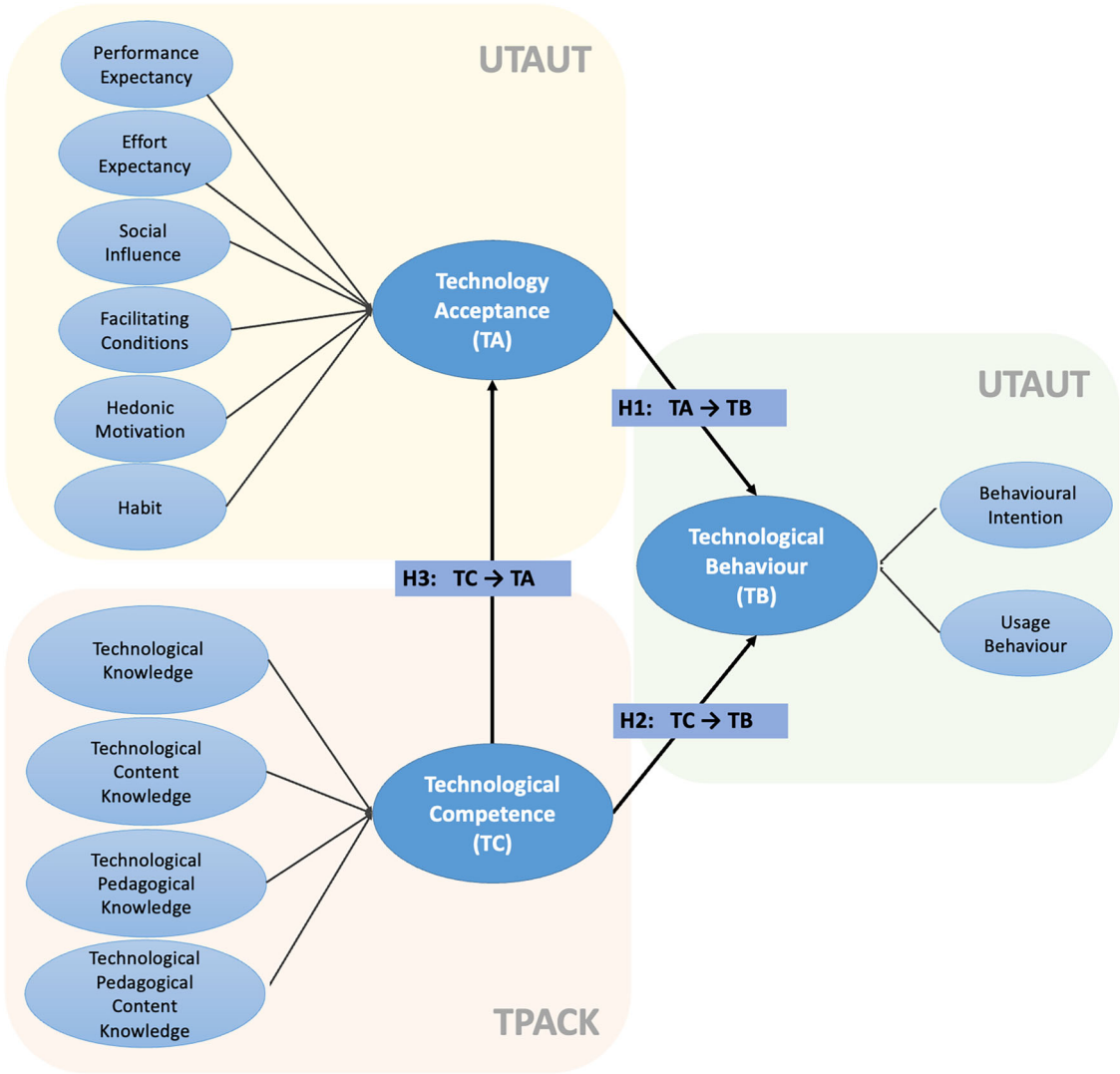

Fig. 1 A theoretical model and hypotheses of music teachers' technology acceptance, technological competence, and technological behaviour. The figure illustrates the proposed theoretical model, in which there are hypothetical directional relationships between the three core constructs. Arrows indicate direct paths, and each labelled path (i.e., H1, H2, H3) corresponds to a specific hypothesis tested in the study. This model integrates theoretical frameworks of UTAUT and TPACK to examine factors influencing music teachers' technology acceptance and use.

Table 1 Summary of demographic characteristics.

Characteristics	Variables	N	Percent
Gender	Male	68	22.1
	Female	239	77.9
Age	18–23 Years	42	13.7
	24–34 Years	173	56.4
	35–44 Years	62	20.2
	45–54+ Years	30	9.7
Degree	Associates	22	7.2
	Bachelors	181	59
	Masters	93	30.3
	Doctorates	11	3.6
Years of Teaching	Under 3 Years	97	31.6
	4–6 Years	60	19.5
	7–10 Years	63	20.5
	11–15 Years	31	10.1
	16–20 Years	20	6.5
	Over 21 Years	36	11.7
Types of Institutions	Higher Education Institutions	116	37.8
	Schools (including others and social training institutions)	191	62.2

$n = 307$.

RStudio software for further analysis and model evaluation. The SEM analysis followed a multi-stage approach recommended by previous studies (Henseler et al., 2009; Hair et al., 2014; 2017; Ali et al., 2018): (1) measurement model assessment; and (2) structural model assessment. The former stage evaluates the relationship between latent variables (representing underlying constructs) and their observed variables (specific indicators measured in the study). The latter stage focuses on examining the relationships among the latent variables themselves. The measurement model, also referred to as the outer model, focuses on the link between latent and observed variables, while the structural model, or inner model, explores the relationships between the latent variables (Shah and Goldstein 2006). In SEM, exogenous latent variables are not influenced by other latent variables within the model, while endogenous latent variables are predicted by the exogenous ones (Jöreskog and Sörbom, 1993; Byrne, 2013).

Measurement model assessment. Recognising the necessity of establishing measurement model validity before structural model

Table 2 Summary of construct reliability, factor loadings, and average variance extracted (AVE).

Construct	Variables	Factor Loadings	α	CR	AVE
Technology Acceptance (TA) CR = 0.909 AVE = 0.628	PE	0.714	0.888	0.891	0.674
	EE	0.760	0.893	0.888	0.666
	SI	0.850	0.873	0.873	0.632
	FC	0.823	0.773	0.811	0.588
	HM	0.732	0.903	0.901	0.753
	HA	0.861	0.888	0.898	0.747
Technological Competence (TC) CR = 0.903 AVE = 0.702	TK	0.739	0.940	0.940	0.758
	TCK	0.831	0.937	0.938	0.791
	TPK	0.921	0.912	0.910	0.669
	TPCK	0.850	0.938	0.939	0.795
Technological Behaviour (TB) CR = 0.933 AVE = 0.700	BI1	0.799	-	-	-
	BI2	0.791	-	-	-
	BI3	0.833	-	-	-
	UB1	0.883	-	-	-
	UB2	0.902	-	-	-
	UB3	0.805	-	-	-

PE performance expectancy, *EE* effort expectancy, *FC* facilitating conditions, *SI* social influence, *HM* hedonic motivation, *HA* habit, *BI* behavioural intention, *UB* usage behaviour, *TK* technological knowledge, *TCK* technological content knowledge, *TPK* technological pedagogical knowledge, *TPCK* technological pedagogical content knowledge, *α* Cronbach's Alpha, *CR* composite reliability, *AVE* average variance extracted.
n = 307.

Table 3 Square root of the average variance extracted (AVE) and correlations matrix (technology acceptance).

Latent Variables	PE	EE	SI	FC	HM	HA
PE	**0.820**					
EE	0.574**	**0.816**				
SI	0.608**	0.655**	**0.795**			
FC	0.531**	0.663**	0.657**	**0.767**		
HM	0.630**	0.481**	0.599**	0.638**	**0.868**	
HA	0.553**	0.658**	0.774**	0.742**	0.616**	**0.864**

The diagonal elements shown in bold are the square root of AVE, and below the diagonal elements are correlations. *n* = 307.
PE performance expectancy, *EE* effort expectancy, *FC* facilitating conditions, *SI* social influence, *HM* hedonic motivation, *HA* habit.
***p < 0.001, **p < 0.01, *p < 0.05.

assessment (Jöreskog and Sörbom, 1993), this study prioritised assessing its reliability and validity to ensure observed variables accurately represent their underlying constructs. Confirmatory Factor Analysis (CFA) was employed through the 'lavaan' programme in RStudio (Rosseel, 2012) to evaluate construct validity. Given the ordinal nature of our Likert-scale data, we used the Diagonally Weighted Least Squares (WLSMV) estimator, which is suitable for non-normality (Brown, 2015). We conducted separate CFAs for each variable set (TA, TC, and TB). Criteria such as Cronbach's Alpha (α) and Composite Reliability (CR) evaluated internal consistency (acceptable > 0.7), while factor loadings and Average Variance Extracted (AVE) assessed convergent validity, with values above 0.5 considered acceptable (Cronbach, 1951; Bagozzi and Yi, 1988; Henseler et al., 2009). In our study, the initial CFA for TB revealed a high correlation between BI and UB factors, leading to a re-specification as a single-factor model. Therefore, Table 2 summarises the internal consistency (α, CR) and convergent validity (factor loadings, AVE) of the TA and TC measurement models. We also report the factor loadings for each variable for the revised model TB, as well as the CR and AVE for the revised TB model.

Table 4 Square root of the average variance extracted (AVE) and correlations matrix (technological competence).

Latent Variables	TK	TCK	TPK	TPCK
TK	**0.871**			
TCK	0.675**	**0.889**		
TPK	0.637**	0.776**	**0.818**	
TPCK	0.638**	0.649**	0.820**	**0.892**

The diagonal elements shown in bold are the square root of AVE, and below the diagonal elements are correlations. *n* = 307.
TK technological knowledge, *TCK* technological content knowledge, *TPK* technological pedagogical knowledge, *TPCK* technological pedagogical content knowledge.
***p < 0.001, **p < 0.01, *p < 0.05.

Discriminant validity, which ensures that latent constructs are distinct from one another, was assessed in this study. The square root of AVE is a common method for evaluating discriminant validity (Fornell and Larcker, 1981; Tabachnick and Fidell, 2007; Henseler et al., 2009; Chin, 1998). Since the TB model was a single-factor structure, the concept of comparing squared AVEs (which relies on having multiple factors) was inapplicable. Therefore, we only report the square root of AVE for the multi-factor constructs (i.e., TA and TC) in Tables 3 and 4. In all cases, the square root of AVE exceeded the inter-construct correlations, supporting discriminant validity.

As the purpose of the CFA is to test whether the data fit the hypothesised measurement model, the model's Goodness-of-fit (GoF) should also be reported at this stage. Evaluation of the GoF can be tested by a range of indices such as χ^2 /df (chi-square/degrees of freedom), Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), Root Mean Square Error of Approximation (RMSEA), Comparative Goodness of Fit Index (CFI), Non-Normal Fit Index/Tucker Lewis Index (NNFI/ TLI), and the Incremental Fit Index (IFI) (Anderson and Gerbing, 1988; Bagozzi and Yi, 1988; Hair et al., 2010). Kline (2015) recommended that the four indices such as model χ^2, RMSEA, CFI, and SRMR should be reported.

The individual fit indices for each measurement model demonstrated good fit to the data, exceeding recommended thresholds (Hair et al., 2010). The TA model fit indices fell within the recommended thresholds ($\chi^2 = 149.286$, df = 183, $p = 0.968$; SRMR = 0.056; CFI = 1.00; RMSEA = 0.00), and similar patterns were observed for the TC model ($\chi^2 = 99.040$, df = 131, $p = 0.983$; SRMR = 0.054; CFI = 1.00; RMSEA = 0.00). Finally, the revised single-factor model for TB also demonstrated a good fit to the data ($\chi^2 = 6.603$, df = 9, $p = 0.678$; SRMR = 0.042; CFI = 1.00; RMSEA = 0.00). This pattern of good fit was further confirmed by the final overall fit indices for the structural model ($\chi^2 = 783.268$, df = 932, $p = 1.00$; SRMR = 0.059; CFI = 1.00; RMSEA = 0.00). Therefore, the CFA results provide strong support for the validity and reliability of the proposed measurement models for assessing music teachers' TA, TC, and TB. This in turn validates the scales used in previous studies (Venkatesh et al., 2003; 2012; Schmidt et al., 2009; Bauer, 2012).

Structural model assessment. Following the confirmation of a well-fitting measurement model, the next step involved evaluating the overall structural model. This model focuses on the hypothesised relationships between the latent constructs identified earlier. Assessing structural model fit is crucial before testing research hypotheses. Similar to the CFA process, various fit indices were employed to gauge how well the model aligns with the data. The obtained fit indices ($\chi^2 = 783.268$, df = 932,

Table 5 Results of hypotheses tests.

Hypotheses	Path	Estimation	SE	P	Std (all)	Results
H1	TA → TB	2.023	0.298	< 0.001	0.851	Supported
H2	TC → TB	0.094	0.081	0.249	0.081	Not supported
H3	TC → TA	0.348	0.063	< 0.001	0.715	Supported

Determination Coefficients: TB = 83.0%, TA = 51.1%.
SE standard error, *Std* standard estimation, *TA* technology acceptance, *TB* technological behaviour, *TC* technological competence.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

$p = 1.00$; SRMR = 0.059; CFI = 1.00; RMSEA = 0.00) indicated a good model fit.

We tested our hypotheses using path analysis within the SEM framework. Table 5 summarises the estimated coefficients, p-values, and hypothesis testing results of the structural model. The results provide support for H1, indicating a positive and statistically significant influence of TA on TB (standardised coefficient = 0.851, $p < 0.001$). However, H2 was not supported as TB did not exhibit a significant relationship with TC (standardised coefficient = 0.081, $p = 0.249$). Finally, H3 was supported, with TC demonstrating a positive and statistically significant influence on TA (standardised coefficient = 0.715, $p < 0.001$). In summary, two out of the three hypothesised relationships were confirmed (H1 and H3), while H2 was rejected. These findings align with the results of the previous pilot study by Zhang et al. (2021), suggesting no significant positive association between music teachers' TC and TB, but that music teachers' TA mediated between the two.

Figure 2 presents the final path diagram of the overall structural model, which visually depicts the hypothesised relationships between the latent constructs. The analysis confirms a good fit for the overall structural model and suggests the model effectively explains the observed data. The results reveal that TA directly influences music teachers' TB. Notably, the six factors of TA (PE, EE, SI, FC, HM, and HA) play a direct role in shaping TB. Conversely, TC, encompassing factors like TK, TCK, TPK, and TPCK, does not directly influence TB. However, TC indirectly affects TB by positively influencing TA.

Discussion

The aims of this study included understanding what determines music teacher' use of technology and assessing the feasibility of applying a more extensive theoretical model in the field of music education in China. By referring to a measurement scale previously designed by Zhang et al. (2021), 10 potential determinants were ultimately identified: Performance Expectancy (PE); Effort Expectancy (EE); Facilitating Conditions (FC); Social Influence (SI); Hedonic Motivation (HM); Habit (HA); Technological Knowledge (TK); Technological Content Knowledge (TCK); Technological Pedagogical Knowledge (TPK); and Technological Pedagogical Content Knowledge (TPCK). As mentioned earlier, these factors can be grouped into two broad constructs, TA, and TC. While an individual's TC could directly influence their TA, it does not directly influence their TB in Chinese music education. This suggests that higher TC in Chinese music teachers leads to higher TA, making them more likely to use technology in their teaching. Specifically, the six factors of PE, EE, SI, FC, HM, and HA directly influence music teachers' TB. However, music teachers' TC, encompassing TK, TCK, TPK, and TPCK, indirectly influences TB through its impact on TA. In other words, teachers who believe technology is beneficial and easy to use (high TA) are more likely to integrate it into their teaching, which is consistent with previous studies (e.g., Islahi and Nasrin, 2019; Li et al., 2019; Akram et al., 2022). While music teachers' technological literacy (TC) might not directly influence their decision to use technology, having the skills to use it effectively strengthens their belief in its usefulness, ultimately leading to more frequent integration. These are also found in other similar findings from previous studies (Taghizadeh and Hasani Yourdshahi, 2019; Alakrash and Razak, 2021).

The relationship among technological competence, technology acceptance, and technological behaviour. As scholars continue to welcome the combination of theories and call for validation of their feasibility in different fields (Venkatesh et al., 2016; Swallow and Olofson, 2017), it has become even more relevant to study the combined application of UTAUT and TPACK in music education. Our findings support the feasibility of both the UTAUT and TPACK models in the specific context of music education in China, as well as highlighting the role of cultural factors in this setting. Previously, it has been demonstrated that the TPACK emphasises cultural awareness through its pedagogical and content knowledge components (Ali and Hawk, 2024). UTAUT, on the other hand, primarily addresses behavioural intentions and usage patterns, but does not fully capture the instructional efficacy dimension (Xue et al., 2024). Therefore, the integration of these complementary theoretical frameworks enhances our understanding of technology adoption by using their respective strengths. This theoretical integration is particularly important in the context of Chinese music education, where cultural factors have a significant impact on teaching practices. For example, the collectivist cultures in Chinese music education (Ho, 2016) may influence teaching practices through the factor of social influence. This is consistent with our finding that SI is one of the significant predictors of technology adoption by Chinese music teachers.

Therefore, this study proposes a theoretical framework for music Teachers' Technological Competence, Acceptance, and Behaviour (TCAB) (see Fig. 3). In this manner, the TCAB model appears to have the potential to be used to understand the key factors that influence music teachers' use of technology in teaching and learning. In the context of evolving technology in China, it is argued that the more technologically competent music teachers are, the more likely they are to become more inclusive and accepting of the use of technology, which is facilitated by a combination of different factors (i.e., TK, TCK, TPK, TPCK, PE, EE, SI, FC, HM, and HA). The more receptive they are to technology, the more likely they are to find that its use increases the effectiveness of music instruction; the stronger their behavioural intention to use technology and the more engaged they are with technology, the more likely they are to continue to explore and use some technology to support their instruction in the future. Therefore, TA plays a fully mediating role in predicting the TC and TB of music teachers in Chinese music education.

Many studies (e.g., Mercader and Gairín, 2020; Akram et al., 2022) mentioned that one of the inherent barriers to teachers' technology integration is resistance to change. That is, if music

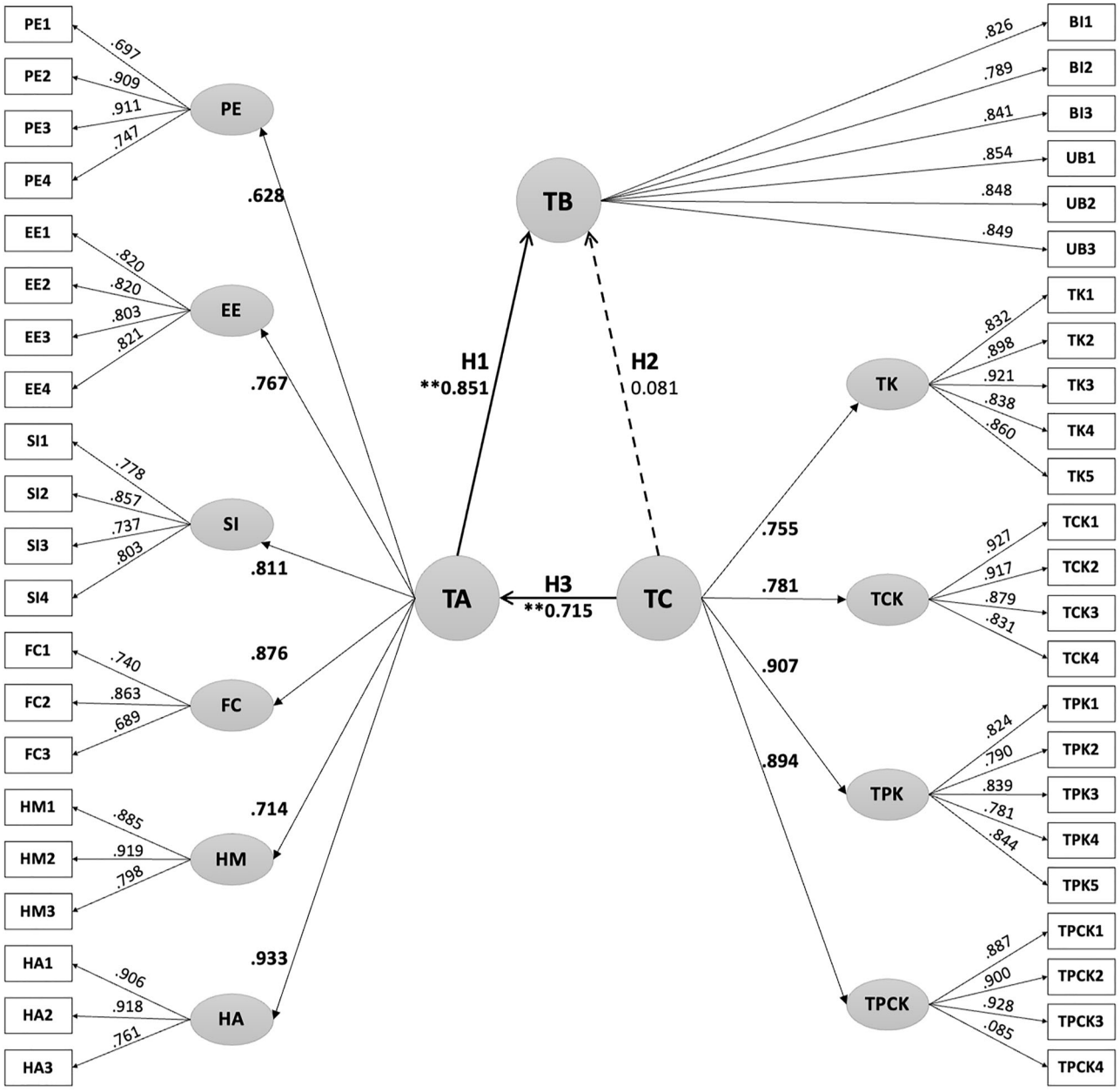

Fig. 2 Final path diagram of an overall measurement model. The diagram displays standardised path coefficients with significance levels. Latent constructs are represented by circles, with solidlines showing significant pathways and dashed lines indicating non-significant relationships. PE performance expectancy, EE effort expectancy, FC facilitating conditions, SI social influence, HM hedonic motivation, HA habit, BI behavioural intention, UB usage behaviour, TK technological knowledge, TCK technological content knowledge, TPK technological pedagogical knowledge, TPCK technological pedagogical content knowledge, TA technology acceptance, TC technological competence, and TB technological behaviour.

teachers themselves reject using technology or do not accept technology as a way into their teaching, it is unlikely that teachers' TC will directly influence their TB, regardless of the level of TC that music teachers possess. This may be related to the different teaching styles of individual music teachers and needs to be further substantiated by qualitative data. While the music teachers' individual technological skills and knowledge are important, it should be more critical to influence their usage behaviour by facilitating their acceptance of technology.

Continuing professional development for music teachers in China. Although the final SEM analysis found no direct effect of music teachers' TC on their TB, TC appeared to affect TB in the bivariate SEM regression analysis. This means that when music teachers' acceptance of technology is not considered, it can be argued that music teachers' technological skills and literacy may also directly influence their behaviour in using technology. Therefore, it is important to consider more professional development programmes for Chinese music teachers, specifically those targeting technological knowledge and literacy.

Extensive research has highlighted the complementary relationship between technology use and music teachers' professional development (Savage, 2010; Leong, 2007; Bauer et al., 2003). Furthermore, the Chinese music education curriculum emphasises the potential for technology to provide ongoing support for teachers, reinforcing the importance of technology for teachers' professional development opportunities. While technology itself did not pose a challenge to the

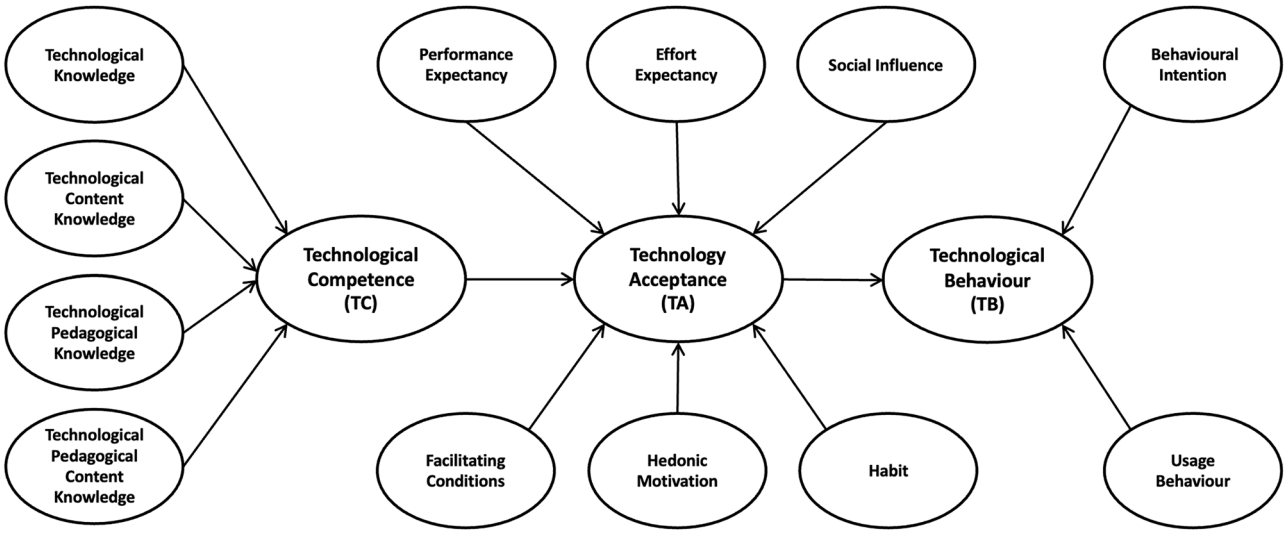

Fig. 3 A theoretical framework of music teachers' technological competence, acceptance, and behaviour (TCAB). This figure illustrates the final conceptual model developed from the study's findings. It reveals the interconnected relationships among technological competence, technology acceptance, and technological behaviour in music teachers' technology integration.

teachers or students (King et al., 2019), effective teacher education training can enhance the ability of teachers to use technology for curriculum innovation (Henley, 2011). However, it has been commented that current music professional development programmes often lack a focus on research engagement and follow-up support (Bautista et al., 2017). Given the increasing emphasis on the professional development of music teachers in China, this study may be useful to policy makers. Drawing on global experience, it is important for policy makers to be aware of the specific needs of music education and to avoid 'one-size-fits-all' technology mandates, especially for practice-based programmes. Policies that are encouraging rather than mandatory may be more effective in promoting meaningful technology integration, which is consistent with a growing body of research highlighting the potential of technology in Chinese music education (Wan, 2022; Yao and Li, 2023; Wen, 2024).

Limitations and further research. While this study has contributed to the understanding of music teachers' behaviour in using technology, some limitations pave the way for more research in the future. For example, the current study only reported the results of the quantitative data collected; a detailed exploration of the qualitative data was provided in the first author's PhD thesis (Zhang, 2022b). This qualitative exploration provides more detailed information about how the determinants influence music teachers' acceptance and use of technology. Future research could build upon this mixed-methods approach to further investigate the complex relationships between these factors and their impact on technology adoption in music education.

A further limitation relates to potential sampling bias: questionnaire participants may have a more positive attitude towards the use of technology in teaching than teachers who chose not to participate, making it possible that the proportion of teachers who were more satisfied with technology was overestimated. Furthermore, due to China's geographical diversity and uneven economic development, the region of Fujian province from which the subjects of this study were drawn may not be representative of the entire population of Chinese music teachers. Given the cultural traditions and varying levels of educational development across regions in China, the application of these findings may be geographically limited. Therefore, further empirical research in different regions of China may be necessary, especially applying TCAB theory to other regions of China as well as other parts of the world.

This research could be developed in several ways. Firstly, the TCAB theoretical model developed in this study could be used to repeat the survey in the future to see if music teachers' attitudes towards technology have changed, particularly in the post-pandemic era. Secondly, the gendered nature of technology is another aspect worth exploring, particularly in Asian countries such as China where patriarchal societies predominate. It is therefore worth considering how gender differences in the use of technology can be compared, and how such gender differences might be narrowed in China, particularly regarding female teachers empowering themselves with technology and finding ways to make technology use more appropriate. Thirdly, as technology continues to change and evolve, it is possible to investigate the use of technology in a more narrow and specific sense. For example, an investigation into music teachers' perceptions of using digitised music manuscripts, or an investigation into the impact of the use of emerging technologies such as AI/VR. Fourthly, given the phenomenon of wealth disparity in different regions of China, a comparative study to see the differences in access to technology by students/teachers from various income groups appears necessary, which may provide a more comprehensive understanding of the use of technology in both wealthy and impoverished areas of China. Finally, engagement with further mixed-methods studies would be another potential development. For example, longitudinal qualitative methods can be used over time to gain information on whether music teachers' understanding has changed at different points in time, and whether their attitudes to technology change before and after their involvement in training programmes. Qualitative methods such as case study could also be used to obtain more detailed information about the impact on music teachers of using technology.

Conclusion

This study presents a novel theoretical model, TCAB, for understanding music teachers' use of technology in China. The framework found that the relationship between music teachers' TA, TC, and TB is intertwined. The results demonstrate the feasibility of the TCAB model combining UTAUT and TPACK theories in the Chinese context. It shows the main factors that influence their use of technology, and the impact of technology on them. This includes understanding how Chinese music teachers' behaviour in using

technology is shaped not only by their attitudes and skills, but also by a deeper understanding that considers social-economic factors. This coincides with what we refer to as attitude before actions and appears to be consistent with the idea of teacher efficacy in music education. Stated differently, a positive and passionate attitude serves as the foundation for effective music instruction. It could foster enthusiasm in students, fuel creative exploration, and motivate teachers to continually develop their own skills and integrate innovative approaches. However, both attitudes (TA) and skills (TC) might be critical to the successful integration of technology (TB) in music education. Focusing solely on skills development might not be enough; fostering positive attitudes towards technology is equally important. It is worth noting that while the TCAB can be a useful tool for understanding technology adoption behaviours, it is not intended to be exhaustive in covering all influencing factors. This is particularly true in the context of music education in China, which is itself a rich and complex educational landscape, subject to a deep cultural heritage and modern influences that may vary especially in urban and rural areas.

The study also reveals the impact of the use of technology in the music classroom on key stakeholders. Music teachers, policy makers, and other stakeholders in China may need to focus on enhancing music teachers' TC and TA to assist music teachers in making greater use of technology in their classrooms. In terms of teachers' TC, the higher levels of personal technological competence might help them to discern which technology tools can be applied to which music lessons, and this is likely to lead directly to more effective teaching. Greater TC can be achieved, for example, by providing adequate training opportunities and by tracking teachers' progress through return visits. In terms of teacher TA, the more positive the attitude towards the acceptance of technology, the more likely music teachers are to use it positively. Importantly, the role of TA seems to be somewhat more important than that of TC. This is because TA acts as a complete mediator between TC and TB, meaning that if a teacher feels that the use of technology is unacceptable in certain situations, even if that teacher has a high level of TC, the TC will have little impact on the TB. Therefore, several influencing factors related to TA for music teachers need more attention to ensure effective music teaching. For example, promote the benefits of technology for teaching performance; focus on developing technology that is easy to use; create a positive and beneficial social environment; provide teachers with more adequate facilities; encourage teachers to enjoy using technology tools; and develop their habit of using technology in music lessons.

Overall, this study has provided a much-needed insight into the factors that influence the use of technology in music education from a regional perspective in non-Western cultures. It provides a valuable foundation for understanding music teachers' intentions and behaviours in using technology in China.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Author contributions

Xiangming Zhang: conceptualisation, methodology, formal analysis, investigation, data curation, writing, original draft. Andrew King: conceptualisation, supervision, methodology, review & editing. Helen Prior: supervision, data analysis, methodology, review & editing.

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Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval for this study was granted by the Ethics Committee of the Faculty of Arts, Culture and Education (FACE) at the University of Hull, UK, on 29 July 2019 (Ref: 1920PGR01). The approval covered protocols for data collection through anonymous questionnaires. All procedures performed in this study were in accordance with the ethical standards of the Declaration of Helsinki.

Informed consent

All participants provided informed consent prior to participating in the anonymous online survey, which was conducted between 1 October 2019 and 31 December 2019. The first page of the questionnaire displayed a detailed information statement explaining the purpose of the study, the voluntary nature of participation, and how their anonymous data would be used for research and publication. Participants indicated their consent by voluntarily continuing to complete the questionnaire from that information page. To protect the privacy of participants in this anonymous study, no written or signed consent forms were collected.

Additional information

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