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Adding to the knowledge of the TPACK framework: a case study of female identity in performance, education, and technology

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Introduction: The Technological Pedagogical Content Knowledge (TPACK) framework, developed by Mishra and Koehler, has served as a foundational model for aligning technology with pedagogy in educational research and practice. While TPACK emphasizes the integration of content, pedagogy, and technology in teacher knowledge, it often overlooks the role of teacher identity in shaping instructional decisions and technology use.

Methods: This study extends the TPACK framework by incorporating teacher identity as a critical component. Using a qualitative case study approach, we examined the experiences of an accomplished female music performer and educator. Data were collected through interviews and observations to explore how her musical background and personal identity intersect with her use of technology in piano teaching and performance.

Results: Findings reveal that the participant's knowledge and identity significantly influenced her pedagogical choices and technology integration.

Discussion: These results suggest that teacher identity plays a pivotal role in how educators engage with technology. By extending the TPACK framework to include identity, this study provides a more holistic understanding of teacher knowledge and offers implications for teacher education by enabling teachers to remove obstacles to technology use and adoption.

KEYWORDS

teacher identity, technology in music teaching, gender in music education, music technology, TPACK, group piano, piano performance, piano teaching

1 Introduction

As technology is ubiquitous in everyday life, its presence is found in all facets of music, whether it be performing, practicing, composing, improvising, producing, listening, or teaching. Hitchcock (2017) delineated four broad categories of technology in music education: educational, administrative, social, and music technologies. Educational technologies work to support learning and assessment, including learning management systems and virtual classrooms, while administration technologies support the management of people and resources. Social technologies facilitate interactions between individuals within communities. Music technologies are usually linked to music composition or production in which particular hardware and software (music technology) are used distinctly by the music industry to create music and by music educators to train emerging music technologists, as well as in general music classrooms. Following UNESCO's definition of Information and Communication Technologies (ICT), Merrick and Joseph (2023) delineated the term ICT as *technological tools*

and resources used to transmit, store, create, share, or exchanges information (p. 191) while defining music technology as *"any existing or emerging digital device or tools, the use of hardware and/or software and/or web-based applications in any way to support learning about, the creation of, and the performance of music"* (191). For the purposes of this study, we embrace a broad viewpoint of technology to include both delineations alongside acknowledging Hitchcock's categories for which these technologies function.

1.1 Technology use in music education

Music teacher technology use has been examined with projects such as Sound, Electronics, and Music, in which participatory workshops related to sound and music technology were provided to approximately 900 schoolchildren in Scotland evidencing "the assertion that computer music and music technology have a place within the preuniversity classroom" (Hayes, 2017, p 46). However, it was also noted that due to a lack of familiarity with the technology and content, teachers found it difficult to include the project in their curricula. Humberstone (2017) pointed out that music educators whose musical backgrounds are practically based, such as performers or directors, are less likely to include tasks such as composition in part due to a lack of access to and experience with technology. This lack of experience with technology may include educational technology and music technology. For example, Upitis et al. (2017) surveyed 1,468 independent teachers about their beliefs and studio practices, including how music teachers make use of technology in their teaching. Most of these teachers appeared to be quite comfortable with using technology and reported having Internet access in their studios. There were strong views expressed by teachers both in support of and in opposition to the use of technology to enhance specific aspects of music pedagogy and student learning. This lack of support for certain activities is not to be seen as a lack of support for technology, in general, as more than two-thirds of these teachers agreed that technology improves student learning and motivates students to learn. Rather, it would appear that some teachers were unwilling to exchange the benefits of face-to-face interaction with the benefits of technology. Merrick (2018) stated that "technophobia" still explains why many music teachers are reluctant to use new technologies (p. 314). Lack of technology integration was also found in Waddell and Williamon's (2019) survey on the use of music technology in instrumental learning, which investigated how teachers' use technology in their roles as teachers and as music learners. They found that the music teachers were generally more receptive to technology in their roles as teachers than as learners; however, their use of technology was mostly outside of instructional time and instead for scheduling lessons or advertising.

1.2 Impact of COVID-19

It has been found that COVID-19 and the pandemic substantially affected music teaching and learning due to music teaching delivery's reliance on multisensory and auditory-motor interactions (Cheng and Lam, 2021), which requires both theoretical and applied (practical) skills (Biasutti et al., 2021). Daugvilaite (2021) pointed out that although online teaching had been available prior to the COVID-19 pandemic, music teaching had overall avoided the adoption of online delivery due to its participatory nature. In effect, due to the restrictions imposed by lockdown measures, music teachers were required to not only adapt to new technologies but also immensely modify their pedagogies within this new context. Daubney and Fautley (2020) reported that not all teachers were prepared with adequate educational and technical knowledge to teach online; however, there has been an acknowledgment of the value of online teaching for certain aspects of music education, such as the community of practice for sharing pedagogical approaches and education strategies (Biasutti et al., 2021). As Calderón-Garrido and Gustems-Carnicer (2021, p.141) stated, "In short, COVID represented both an opportunity and a threat for music education".

Investigations of readiness to teach online thus far have found that the role of the institution has an important responsibility to provide support and a common view of expectations for online learning and teaching to compensate for individual perceptions of readiness (Howard et al., 2020; Martin et al., 2019; Scherer et al., 2021). Calderón-Garrido and Gustems-Carnicer's (2021) "greatest findings" in their examination of adaptations by primary and secondary music teachers were "marked by lack of methodological and instrumental preparation," while more support from conservatory level music educators' institutions and greater opportunities for professional development were also found (Biasutti et al., 2021). Music teacher readiness or unfamiliarity with the new technologies of online teaching has been found to cause fear, anxiety, and uncertainty about teaching performance, which in turn leads to frustration and depression (Cheng and Lam, 2021). These findings suggest that teachers must be supported to continue the development of skills and knowledge and "pursue transformative teacher professionalism to cope with crises and challenges that arise in the future" (Cheng and Lam, 2021). Camlin and Lisboa (2021) maintained that as the limitations of online technology are overcome, there will be more choices in how to consume and learn music, and music educators need to adapt to this progress. Merrick and Joseph's (2023) study on what technologies music teachers used and their confidence in using technology during COVID-19 found that teachers had increased their levels of competence and confidence through increased use of technology during the pandemic. He stated, "*the more confident teachers became, the more routinely they shifted between technology devices…*" (p. 203) and further mentioned that this integration of technology had a significant influence on their confidence to use it.

1.3 Music teacher education and technology use

Music teacher education has been examined in support of the integration of technology. An online survey in the USA regarding the role, nature, and efficacy of technology instruction in music teacher education programs revealed proficient levels of readiness to integrate technology, but not for classes that were fully technology-based (Bauer and Dammers, 2016). Participants responded that a lack of time and/or space, along with a lack of funding and/or access to technology, were challenges impacting teaching preservice music teachers about technology. It was recommended that preservice teachers experience technology in authentic music teaching and learning contexts throughout their teacher education, not only a single class or

experience. Gall (2013) noted that as undergraduate courses in the UK do not all require engagement with music technology, students can begin their teacher education year with no skills at all in this area because students are developing their teaching skills alongside knowledge and skills in their subject area, all within the year of teacher education. She stated, "*Helping student teachers develop personal music technology skills and the confidence to use technology in classroom settings within one year—at the same time that they are acquiring other subject knowledge and competences, honing learning and teaching skills, and completing masters level written assignments—is a difficult undertaking*" (Gall, 2017, p. 570). As Dorfman (2017) stipulated, "Developing technology skill is a different thing entirely from developing teaching skills" and further recommended the TPACK framework as a way of bringing forward that "content, pedagogy, and technology are distinct; when these three elements overlap, more sophisticated teaching may result" (p. 527).

1.4 TPACK framework

Educators and researchers seeking effective use of technology in teaching through the alignment of technology, pedagogy, and content have utilized Mishra and Koehler's Technological Pedagogical Content Knowledge (TPACK) framework (Mishra and Koehler, 2005; Mishra and Koehler, 2006). As frameworks have been developed to help educators and researchers in their efforts to integrate technology into teaching and learning in order to guide future research and practice (Hamilton et al., 2016), TPACK has provided a structure for research on and implementation of the effective use of technology in teaching and learning. Utilizing three main components of teachers' knowledge—content, pedagogy, and technology—it is the interactions between and among these bodies of knowledge which form an understanding beyond the three components individually (see Figure 1). TPACK functions to provide the basis of effective teaching with technology and understand the variance in levels of technology integration, seeks to assist the development of better teaching techniques, and promotes focused research in the use of technology in a more ecological way (Koehler et al., 2013). Pedagogical knowledge (PK) is required to effectively help students learn, while content knowledge (CK) is needed to have a well-developed understanding of the subject matter. Pedagogical content knowledge (PCK) involves both this specialized subject knowledge alongside the skills to use a variety of teaching strategies appropriate for the content. Technology content knowledge (TCK) would include an understanding of suitable technologies utilized to support or experience the content, such as software applications for composing or recording music. Technological pedagogy knowledge (TPK) would subsume technologies that fit pedagogical processes, such as interactive presentation software applications to engage students. Combining all three constructs (TPACK) is intended to support the learning of specific content through pedagogies appropriate for the content, which therein is supported by technology suitable to the pedagogy and content. For example, the use of audio-visual media (T) to model (P) correct performance technique (C).

This framework has become well established in the research on technology use in education and utilized by practitioners, teacher educators, and researchers. Zou et al.'s (2022) analysis of 1,608 empirical research studies of TPACK between 2000 and 2020 identified trends and research topics, finding that the number of studies employing the TPACK (technological, pedagogical, and content knowledge) framework had increased over the two decades which would indicate that the framework is both beneficial and effective. However, this framework has been criticized for lack of progress toward the original goals of TPACK (understanding the knowledge that educators need to teach effectively with technology) with a call to the refocusing of TPACK research (Saubern et al., 2020). Schmid et al. (2020) reported that others have questioned its lack of conceptual clarity and specificity leading to a body of literature based on a wide range of definitions and interpretations of TPACK.

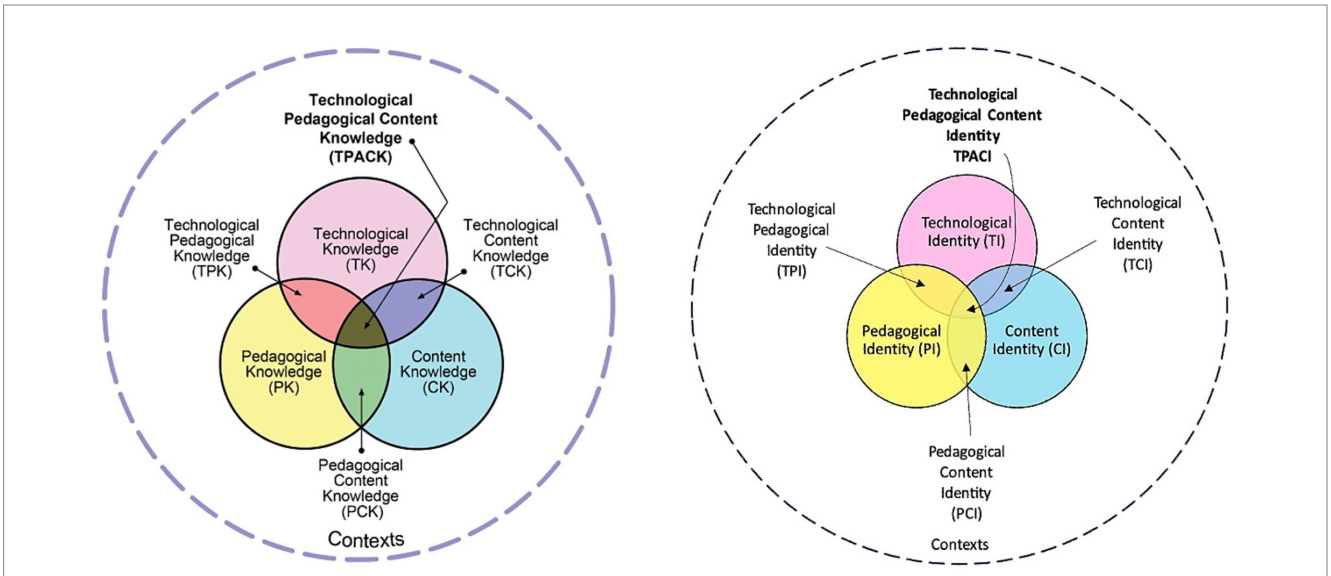

FIGURE 1
TPACK and TPACI framework. Adapted with permission from Koehler and Mishra (2009), licensed under CC BY-NC.

1.5 Teacher identity and extending the TPACK framework

As discussed above, teacher confidence has been found to improve with the increased use of technology. Might teacher self-efficacy and beliefs be a significant factor in teacher use and integration of technology? The TPACK framework considers *knowledge* in the areas of content, pedagogy, and technology without consideration identity. Teacher professional identity is commonly defined as, "…the perceptions, views, beliefs, emotions, motivations, and attitudes that teachers have about their own role" (Suarez and McGrath, 2022, p. 8). The extensive body of research on teacher identity has found that a strong professional identity is positively related to emotional well-being and the quality of teaching, which in turn can improve teachers' confidence in their decision to work in education, as well as commitment to the profession (Hanna et al., 2019). Their systematic literature review revealed six domains of teacher identity:

1. Self-image—how and in what way do individuals view and feel as teachers
2. Motivation—to be or to become a teacher
3. Commitment—dedication and responsibility to teaching profession
4. Self-efficacy—belief in their capability to organize and perform their daily teaching activities effectively
5. Task perception—beliefs about what a teacher considers to be good teaching
6. Job satisfaction—how teachers feel about the school or institution they work for and of the relevant aspects of the work and work situation

A complex and multidimensional concept, teacher identity changes over time dependent upon personal and professional experiences (Suarez and McGrath, 2022).

New technologies have disrupted traditional modes of teaching and learning and, by doing so, transformed the ways in which content and pedagogy intersect. Teacher professional identity has provided a lens for examining the impact of the transition to new technologies and online teaching. Teacher identity and the challenges of COVID were examined from the first year of lockdown measures (Chen et al., 2020; Jones and Kessler, 2020; Kim and Asbury, 2020) finding that teacher identities were indeed affected. Nazari and Seyri (2023) state that less is known about teacher identity within an online context compared to in-person teaching contexts and examined the effect of the transition to online teaching on teacher identity during COVID ("covidentity"). They found that restructured teachers' technology beliefs, enhanced interpersonal relationships with the students, and increased reflectivity were positive impacts on teacher identity during the transition. Through a thematic analysis of the literature, Foreman-Brown et al. (2023) found that the transition to online delivery threatened existing professional teacher identity within universities as teachers had to acquire new knowledge and skills while relational pedagogies, reflection and collaboration supported emergency remote teaching.

Previous discussions on the use of technology had centred around knowledge of technology, self-efficacy, pedagogical beliefs and school culture (e.g., Ertmer and Ottenbreit-Leftwich, 2010) and less so on teacher identity. Ertmer et al. (2012) further investigated the pedagogical beliefs and classroom technology practices of teachers who were recognized for their technology use and found that the teachers' attitudes and beliefs facilitated technology integration; however, teacher identity was not examined as a factor impacting or being impacted by the technology and pedagogies used. We propose that the role that teacher identity plays in technology integration should be considered in the TPACK framework. Phillips' (2016) case study investigation of the enactment of TPACK through a Community of Practice (Wenger, 1998) lens illustrated a connection between identity and practice which, as he stated,

> *"broadens out our understanding of context beyond the established considerations of context as the location of TPACK enactment. This draws attention to the socially mediated processes that shape practice and identity development and demonstrates TPACK as both current knowledge and prospective knowledge in the making"* (p. 1794).

Golzar et al. (2023) recognized the relationship between the TPACK model and teacher identity and used 'teacher identity tensions' to discuss conflicts which shape teacher self-perception, roles, and professional identities when faced with challenges or transformative events. They found that the TPACK and teacher identity tensions have a significant relationship particularly relevant to institutional, pedagogical and sociocultural constraints alongside a lack of professional support. They conclude that teachers can reduce and manage identity tensions through a TPACK-informed classroom which could provide continued education access through use of online learning.

To reveal 'hidden' teacher identities and the possible impact of teacher identity on technology use and integration, we propose furthering the knowledge of the TPACK framework to include identity within each of the constructs: content identity, pedagogical identity, and technology identity (see Figure 1). Teacher content (or subject) identity (CI) can be an influential and important part of professional identity directing the moral and ethical dimensions of a teacher's decisions. It enables teachers to operate beyond the classroom in developing curricula, engage widely in education, and reflect on their practices (Brooks, 2016). Peterman's (2017) review of literature on teacher identity as a content expert found that (1) personal history as a learner in the subject, (2) evolution of content identity when challenged and supported, and (3) the educational context were factors in the development of teacher content identity. As Olsen et al. (2023) state, "Development of teacher subject identity involves the knowledge required to teach a subject and an understanding of how to engage young people with this knowledge" (p. 854). In addition to subject matter knowledge, pedagogy involves knowledge about how to help students learn in a particular subject, as well as what is important to learn (Thompson, 2023). Bernstein (2000) discusses pedagogical identity (PI) as the selective teaching values, beliefs, norms and practices that teachers develop as to what best caters to student learning further dividing into both instructional and regulatory pedagogies. Brosseuk (2022) encapsulates pedagogic identity as a "reflexive, learning process by which pedagogic beliefs, values, attitudes, and thoughtful choices and actions accumulate over time" (p. 31), further stating that it is stable/unstable, shifting, and situated. Carter and Grover's (2015) construct, IT (information

technology) identity, advocates the relationship between technology use and identity. Information technology identity (TI) represents the extent to which individuals view the use of IT as an integral part of the self, proposing that,

> *"those who view their interactions with an IT as integral to their sense of self are likely to express a much stronger sense of connection than those who feel that these interactions are unrelated to who they are. Further, those who feel a strong sense of connection with an IT are likely to enact their IT identity across a variety of situations"* (p. 15).

In our previous investigation of teacher identities and their impact on technology use (Stephens-Himonides and Young, 2023), we incorporated teacher identity within the constructs of pedagogy, content, and technology (TPACI) of Mishra and Koehler's TPACK framework (Mishra and Koehler, 2005; Mishra and Koehler, 2006) (see Figure 1). The authors developed and utilized a measurement instrument questionnaire using Hanna's six domains of teacher identity—which include self-image, motivation, commitment, self-efficacy, task perception and job satisfaction—and integrated these with content, pedagogy, and technology. Music teachers in England ($n = 98$) representing a wide variety of teaching contexts, settings, and student ages and abilities completed the questionnaire. We found significant correlations between participants' knowledge and identity within the domains of technology, pedagogy, and content. We also found significant differences between participants identifying as males and those as females with respect to both identity and knowledge. These results led to this investigation on how content, pedagogy, and technology *knowledge* and *identity* are formed through using an extended TPACK framework and the possible impact of gender on this knowledge and identity.

Regarding gender and music education, Strong and Raine (2019) stated that "…education for the music industry is increasingly becoming formalized, with courses in this area growing exponentially in the last ten to fifteen years. This growth has not been gender-neutral; many of these new courses have a technology focus that is associated with lower enrolments of women" (p. 5). Savage (2017) cited that the differences in terms of gender within the A Level Music Technology intake are stark, noting the separation of the study of music technology from the study of music in the United Kingdom's curriculum and examination framework has created a significant gender imbalance. Peters (2017) pointed to five different issues found in music education technology—curricular, socio-cultural, ecological and economic, access, and gender issues—further stating that gender is "one example of how accessibility to music technologies is connected to social and cultural contexts" (p. 285). She recommends that teachers be mindful of the different ways in which girls and boys approach music technology to integrate strategies that might result in more inclusive pedagogical practices. Culp and Robison, 2022 echoed this recommendation and provided strategies specifically for general music teachers in order to support students of all genders. However, this issue may not be considered at the practitioner level, and educators "may not understand how their instruction can favor particular students' learning preferences or how students might frame peer expertise through gendered norms" (Tobias, 2017, p. 300), although investigations spanning the last 40 years evidence practices that lead to or reinforce differences and cause females to be neglected and disadvantaged in the area of music technology (Armstrong, 2001, 2008, 2011, 2014; Born and Devine, 2015; Caputo, 2021; Comber et al., 1993; Shibazaki and Marshall, 2013).

TPACK's consideration of teacher knowledge only within pedagogy, content, and technology intersections does not take into account teacher identity. Our findings point to the need to not only investigate teacher *knowledge* of pedagogy, content, and technology but also teacher *identity* in relation to pedagogy, content, and technology. Is *knowledge* enough? Are there hidden identities with not found within this framework? Could teacher identity formation and the possible impact of teacher identity on technology use and its integration be revealed by incorporating this domain within the TPACK framework? How might identity impact both teacher integration of technologies (educational or music) in music instruction and how technology use may impact gender differences?

2 Methods

A case study was chosen as the method to examine how knowledge and identity in technology are formed. We chose to investigate the issues of technology use and integration and gender through the lens of a female musician who is known in her field not only as an experienced performer and teacher but also as a leader of technology use and integration. The participant was invited based on her diverse musical career as a performer, educator, leader, and co-creator of a company which provides multimedia resources and curricula for teaching piano and is currently in use in K-12 schools, colleges, universities, and conservatories. This online source has been used for distance and e-learning, as well as for use in classrooms and in the private teaching studio. Recently retired as Professor Emeritus, she taught applied piano, group piano, and piano pedagogy, lectured in the Interdisciplinary Humanities program, and directed the Pedagogy Lab Program, an internship program for piano pedagogy students. She is active as a performer, both solo and chamber musician, throughout the United States and in Canada, Europe, Mexico, the Caribbean, and Ghana. She has been featured on radio and television, and she has been acknowledged in the field as an active clinician and scholar, a leader in professional organizations, and a recipient of many honors. The participant functioned within a performance classroom and studio setting in which digital technologies, including digital libraries, e-readers, video recording and playback, and internet technologies, are used for piano performance and teaching. Piano pedagogy's environment of electronic and digital keyboards, musical instrument digital interface (MIDI), online curricula, and computer software applications (including web-based) for classroom and studio performance teaching was the landscape of the participant's work.

The case study involved the participant's responses to a TPACK and TPACI questionnaire and in-depth interview. The TPACK quantitative measurement instrument was created by the researchers upon a systematic review of the TPACK research and adapted to music teachers. To integrate identity into the TPACK framework, we combined the TPCI constructs with the domains of teacher identity (Hanna et al., 2019) as used in our previous study. We chose to use a quantitative measurement for a single case study participant in order to connect the interview question responses with the questionnaire responses. A Likert-type scale from 1 (strongly disagree) to 5 (strongly agree) was used for 35 agreement statements

encompassing knowledge of content, pedagogy, and technology and identity within these constructs. Examples of the measurement statements are found in Table 1. The semi-structured interview questions were devised around the standardized measurement statements found on the questionnaire, and they included the areas of experience and relationship with technology, impacts of technology on music teaching, the role of technology in designing music instruction and how to approach issues arising, motivations for and challenges of using technology, and leadership and innovative roles in technology use in music (see Table 2). By constructing each of these areas from the TPACK and TPACI frameworks, the interview served to further probe the results of the questionnaire. A thematic analysis of the qualitative data was coded using the extended framework (TPACK and TPACI) constructs. The researchers independently coded all of the data until agreement. Further themes were agreed between the researchers. Another review of data to verify agreed coding and further themes found was undertaken again by the researchers.

3 Results

Using an extended TPACK framework with the inclusion of identity, we investigated how content, pedagogy, and technology *knowledge* and *identity* are formed to reveal possible teacher identities in the use and integration of technology. The questionnaire quantitative data revealed that the mean rating of the 35 agreement statements was 4.8 (out of 5), with 28 of the statements given the highest rating (5) and seven statements rated 4 out of 5 by the case study participant. Those which were rated 4 instead of 5 included a technology construct (TK, TI, TPI, and TCK) with the exception of one PCK statement, which also received a rating of 4. Table 3 illustrates the aggregate means of the participants' responses across the various domains of the extended TPACK framework. This extended TPACK measurement instrument illustrates the participant's self-perception of her knowledge and identity in content, pedagogy, and technology, and the intersections of these constructs were especially positive. The findings from this qualitative data illuminate further insight into these ratings, which are presented using knowledge and identity intersections with the TPACK and TPACI framework constructs of content, pedagogy, and technology, in addition to further themes revealed from the analysis.

TABLE 1 Sample questionnaire agreement statements.

Statement	Category
I can use a wide range of teaching approaches with my students.	PK
I feel committed to my role as a music teacher.	PI
My music knowledge and skills are valued by others.	CI
I feel secure in my music skills and knowledge.	CK
I know how to solve my own technical problems.	TK
I feel confident using technology.	TI
I know how to select effective teaching approaches to guide student thinking and learning in music.	PCK
I can choose technologies that enhance the teaching approaches for a lesson or class.	TPK
I feel confident in choosing technologies that enhance teaching approaches for a lesson or class.	TPI
I know how to use essential technologies which are specific to music.	TCK
I feel satisfied learning about new technology in music.	TCI
I can teach lessons or classes that appropriately combine technologies, teaching approaches, and music skills and knowledge	TPCK
I feel confident choosing technology that enhances the content and pedagogy for a lesson or class.	TPCI

3.1 Technology, pedagogy and content knowledge (TPACK)

The interview responses revealed knowledge of content, pedagogy, and technology and the intersections of these constructs. Providing further understanding of the responses to the questionnaire ratings, the participant's interview evidence her high ratings of technological and pedagogical knowledge with specific examples and explanations.

The participant discussed pedagogical knowledge (PK and PCK) from a broader perspective:

> *"There's a lot of instruction available, but a lot of it's not quality. And the average user cannot differentiate between … and then there are other philosophical questions, you know, and we have always taught in a global kind of a way where we think that we are teaching*

TABLE 2 Case study interview questions.

1	Tell us about your music learning/training and background.
2	Describe your current role.
3	What is important to you when you design instruction for students?
4	Can you describe your experience with technology? What brought you to use technology in your teaching?
5	What is important to you when choosing (and how do you choose) technologies to support the teaching approaches you use?
6	Which technological developments have made an impact on music and music teaching?
7	Can you describe what technologies you have used or those that you currently use? (Software, hardware, etc.)
8	What challenges have you faced when choosing technologies or implementing new technologies into your teaching?
9	Can you tell us about an instance when you used technology to address a teaching challenge or new opportunity? What was the situation? What motivated you to use technology to address that need? What was the outcome?
10	What importance does technology plays to your teaching practice?
11	What are some of the motivating factors and attitudes that led you to accept and use/not use technology in your teaching practice?
12	In what ways do you provide leadership in helping others to coordinate their content, technologies and teaching approaches? (Do others come to you when they need help with technology?)

TABLE 3 Aggregate means of participant's responses to the quantitative instrument.

Category	Mean
CK	5
PK	5
TK	4
PCK	4.67
TPK	5
TCK	4.5
TPCK	5
CI	5
PI	5
TI	4.67
PCI	5
TPI	4.67
TCI	5
TPCI	5

> *you skills that you can move forward with versus a trend that I see in piano teaching which is to teach things like, I'm going to teach you a song."*
>
> *"I do not mean technique by the playing of scales, arpeggios and chord progressions, I mean technique by how do you use your body at the piano or how do you move? How do you get around? How do you coordinate your hands?"*

Responses concerning the intersection of pedagogical and content knowledge (PCK) were shared by the participant when discussing the development of eNovative Piano online learning platform, such as,

> *"and the main thing that students need to be able to have is some kind of skill that they can adapt to their situation, whatever that situation is. And really what that comes down to is. I'm gonna say I'm old-fashioned saying this, but I'm going to say it comes down to piano coordination…"*

Statements supporting the participant's knowledge of how to select effective teaching approaches (PCK) were detected, such as,

> *"…we have the content of scales and chord progression, but what we usually promote are these other drills where we play a melody in one hand with a chordal accompaniment in the other, and then we vary the accompaniment style and we switch hands and we do all the keys and we were trying to wrap around all those elements, we are trying to integrate everything."*

Responses also included statements regarding PCK e, in which the participant further added the technology intersection (TPCK).

> *"I'm not talking about playing two-octave scales hands together. I'm talking about a melody and an accompaniment or a two-handed accompaniment while singing or even knowing what chords to play. If you are in an elementary music class and you have got a song they want…you do not know what the chord progression is because it's not written in front of you. and you need to do all these things, you know, the real-life skills…we decided would best be taught through demonstration like audio or video."*

Technological knowledge was evident throughout the participant responses. Technological content knowledge (TCK) was apparent through discussions in which the participant shared devices and software integrated into her teaching practice (one-to-one and group) and online learning platform, eNovative Piano. She brings forward instances of solving technical problems, such as,

> *"…So, something does not work or it's not the right tool for the job… this did not work because sometimes that helps me to find a better solution because I tried something that did not work. I think that there are things that I've wasted my time totally…but I learned from that, and I do not resent that…"*

Regarding how to use essential technologies specific to music (TCK), the participant speaks of the use of playlists and what platforms are utilized by students stating,

> *"So I might have a Spotify playlist that has 10 different versions of Midnight Special. Students can be exposed to these artists and can learn different things about style. You know, there might be a jazzy version, a bluesy, you know, there's all kinds of different versions, right? But now I've discovered that while that used to be really cool and hip, what people do more than Spotify is YouTube…"*

Her technological knowledge is revealed in her consideration of digital poverty and what students can or are willing to access and stated,

> *"So we have to learn what the challenges are, so. You know it's what's on the user end and what they are comfortable doing…Those are the main challenges. If the student cannot use it, then it's not usable. It's not worth using. Well, you'll have to find a way to help the student to get that whatever it is."*

Technology and pedagogy knowledge (TPK) intersections were found in the participant's reflection on the uses of a specific technology for pedagogical approaches. In choosing technologies that enhance teaching approaches, she stated that when conceiving of eNovative online learning platform, "*the real-life skills we decided would best be taught through demonstration like audio or video.*" and integrated OBS (Open Broadcaster software) to display multiple camera angles of piano playing and the score on the screen alongside shared notebooks, such as Evernote to take notes during lessons. These were mentioned as technologies useful during COVID-19, as well as the use of social media,

> *"I think the existence of Facebook Groups. Piano, piano teaching groups. And there's a piano teaching group for all kinds of stuff. And some of them are more credible than others. And you can tell the quality of the discussion can vary depending on the group."*

However, she also discusses the use of social media as a tool for the development of a piano teacher's course.

> *"…And there was a lot of real interesting discussion about bartering and trades and, you know, just fascinating stuff, wonderful, wonderful interviews. And that would not have been possible without social media 'cause I did not know most of these teachers… and I think that's an amazing thing about social media."*

In discussing the use of multimedia on the eNovative Piano platform, she describes the role of technology (TPK) stating that,

> *"Oh, I would say this is the thing that I noticed the most with using multimedia…if you have good content. It frees you up as a teacher, so the content does not replace the need for a teacher. It provides material for a teacher to use, it frees them up to then be able to do more complex tasks."*

The intersections of content, pedagogy, and technology knowledge (TPACK) were evident in the participant's responses, particularly in her discussion about her thinking in designing instruction.

> *"…first the content, then pedagogy, then technology…So what does that mean? That means I want to have something oral. I wanna have something physical, something tactile. I wanna have something intellectual or theoretical. And then I look for media to support all those things…"*

She additionally discusses the development of instructional videos demonstrating do's and don'ts for student viewing and reviewing both in and out of class, stating that this is content she does not have to go over in class.

> *"And because that content is there, when I come into class, I'm already starting from a different point. A higher point if I did not have that content, I would be starting with that lower point of teaching that content right and then I would get so far. …I'm going to get farther. I think it definitely extends what I can cover in class."*

Her responses explained the ways in which her use of technology afforded her the opportunity to engage differently with students in class. The intersection of technology and pedagogy (TPCK) brought about a change in instructional goals and outcomes that would not have been possible without technology. When describing the conception and beginnings of eNovative Piano learning platform, the intersections of these constructs were also apparent.

> *"We should be teaching them to use their ears and that these things are best done by video and audio. So we went out and bought a video camera…the power of multimedia teaching…So multimedia gave us the ability to focus on under-taught skills, and we saw tremendous improvement in our proficiencies after three semesters."*

The participant also mentioned her pedagogical approach of teaching sound before symbol and how technologies allow this to be achieved by extending notation-based teaching (TPCK).

> *"So they* [teachers] *do not have time to listen to an audio track and have their students, you know, play it back. I think that's really important. Here's an audio file. I want you to listen to it and play. Here's the key. OK, listen to this and be able to play it back in 5 min. That's really an important skill…but a lot of teachers are still heavily into notation-based as the main thing. And there's all these technologies that can allow you to be more than that."*

Finally, the TPACK framework illuminates the participant's use of technology to solve pedagogical challenges (a theme to be discussed below) of teaching the content of piano playing skills.

> *"…but we thought if we really wanted to teach things how to, like, coordinate their hands to where one could move and the other could move in a different way. And you had to break down those things into component skills and then make videos because we are in a piano lab and they could not see. They could not see us play anyway, right? We did not have webcams. We did not have any of that technology. They could not see us play. And if they were not in class, you know, they would never see us play. So we decided that the key would be to make some really short videos and audio."*

3.2 Technology, pedagogy, and content identity (TPACI)

The participant's identity in the content, pedagogy, and technology were detected in the interview responses, particularly in terms of commitment, confidence, enjoyment, task perception, and responsibility to the teaching profession (Hanna et al., 2019). As with the knowledge domain, her positive identity with technology, pedagogy, and content was evidenced in the qualitative as well as quantitative responses.

Her commitment and responsibility to the profession (PI) is evidenced in her strategic plans for eNovative piano, she stated,

> *"So we are thinking about that going forward as a way to grow our business. I do not frame it, only it is something about growing the business. But I also wanna frame it as a way to make quality instruction accessible to anybody in the world."*

In reference to pedagogical self-efficacy (PI) in designing instruction, she identifies teaching away from the piano (with and without technology) as part of what she always did while also indicating confidence and enjoyment within instructional design and technology integration. Additionally, she reveals her confidence within music (piano performance) content (CI) when describing her piano performance skills during her formative years.

> *"I've never had any serious injuries. I do play quite a bit and I attribute that to that early intervention by teachers who said no, this is really how you have to play to keep yourself from getting hurt. And so I learned a lot about, you know, technical approaches as well as musical approaches."*

Further to this discussion in describing what motivated her to integrate technology, her enjoyment of technology (TI) is made clear as she stated,

> *"I'm real comfortable with it* [technology]. *I've always been comfortable with it. I enjoy it. I always liked it. And I'm still interested in it. And I do really well with it. And I like it, some people*

> *do not like it when things change. Let us say you are using some platform and it changes and people go, 'why did you have to change that?' I kind of love the change."*

Responsibility and leadership in piano teaching (PCI) were evident through the development of a piano course on diversity, equality and inclusion, as presented above. She also demonstrates her responsibility and commitment to the profession (TPCI) in her work with other group piano teachers using the eNovative Piano platform and offering this platform for free during COVID-19. She stated,

> *"…that was, I regard that, as a high watermark in terms of leadership in helping others because we gave it away free through June of that year. So they could go all the way through that current semester and then if they wanted to continue to and use it, they would adopt it. And we did get a lot of new users through that. So it was a good business move, but honest to God, we did not think of it as a business move. We just thought… no piano teachers are gonna struggle with this."*

Early in the interview, when asked about her educational background, she revealed her enjoyment of technology (TI) in her response,

> "*And it was, it was really made possible by technology. The technology of recordings. And I think that it is important that we do not forget that everything is technology, you know, recordings or technology, the piano is technology. The acoustic piano is a kind of technology, you know. So I think I've always been pro-technology even before I knew that word."*

Finally, technological pedagogical identity (TPI) is evident in the participant's discussion about choosing the tools for instruction. She stated,

> *"And I think that's what problem solving really is, is whatever you need to solve a problem. If it's technology, if there's no technology there for you to use. I mean, I think it's preferable to use whatever is convenient and whatever you are most familiar with; but I think that technology is, it's there. It's there."*

Following this, she points to student use of technology and the importance of problem-solving skills, again evidencing a TPI identity (task perception).

> *"So I think really the fundamental thing here is teaching problem-solving skills to people. And I see kids give up real quickly if something they try does not work, then they just, oh, I cannot do it. Instead of going well, I mean, first place, why did not it work? What is it about the problem for which that was not the correct solution? You know you have not identified the problem to come up with a good* [solution]. *I mean I think that that problem-solving thing is the under-taught thing."*

Her identity in technology and pedagogy intersections (TPI) was iterated when reflecting on technology's importance in teaching, but this is followed by her pedagogy identity (PI).

> *"I think I always would use what's there…that's the point I'm making…if I have a beach ball in my office, and I decide your pulse is not very good, I might get that beach ball and we might throw it in time or do something in time. I'm going to use whatever I have access to help to make a point. And if it's technology, great. If it's a drum, great. If it's a beach ball, great. we had all kinds of games… You would not call that technology, but it's a mindset."*

The participant's technology identity (self-efficacy) was revealed when discussing attendance at a music board meeting where a college-aged intern spoke about a social media platform. She stated,

> *"…that's important because this is what people are using. It's not Facebook…All the action now is TikTok. I felt like he was saying to me as a board member, but also as a business owner, he was saying, you know, get with the programme, you are getting old to do some work for us."*

Identity in technology (task perception) was further noted when the participant reflected again on the perspective of younger users. She stated,

> *"He said, 'Young people do not talk about technology. It's just what is there? It's just there.' They do not have to learn how to use technology. They do not have to learn how to teach with technology. It's just there. They've grown up with this…but I got it from him, and it was the idea that if you are talking about technology, you are not quite thinking about it right."*

3.3 Further themes revealed

Further themes were found in the participant's discussions pertaining to adaptability, curiosity, problem-solving, and navigating barriers. She discussed the importance of adaptability within the context of evolving technologies, support of her pedagogies, and adaptation of her identity in the field. In discussing various piano lab hardware and software technologies and how the technology in the lab evolved over the years, a willingness to experiment and adapt to new technology was evident. She stated,

> "*So I wrote a kind of a big grant for a newer piano lab with whatever the updated controller was, we put in. I think we got five Disklaviers on that grant and a computer for every piano station. So this was one of the earliest piano labs that was equipped with student computers that I knew of at the time…I'm not going to say we are the first one, but we were one of the very first ones."*

Adjusting to students' use of technology outside of the classroom was evidenced in her responses as she stated,

> *"…but we have to keep in mind what do students use now…and you know what they use. They use their phones for everything. They use their phones to complete classwork. They do not use e-mail. They text, you know, or they chat. They do not use videos now. There's a real trend…You'll see it in marketing, and I think you'll start to see it in educational content too where they use animations instead of real video…"*

Additionally, she shows an openness to new technology chosen by students, as she stated here,

> *"…but there are things that have caught the imagination of learners like those videos that have the notes that kind of fall out of the sky. Synthesia. And kids seem to absolutely love those. I had a guy in my piano class during COVID who whenever he recorded a video for an assignment, he used Synthesia."*

She also describes an instance in which she discovered a new use for an older technology during remote piano teaching during COVID-19 and has continued using it. She stated,

> *"on that monitor I…could project whatever I want from my house, but what I projected a lot was my overhead camera with my hands…and they got so much value from that. And in a live lesson in my office, I had two pianos, I could have had that set up for 30 years. Where instead of saying 'let me show you how to do this and move over, get it and watch me do this' or 'come over here and watch me do this,' they could just be sitting at the piano watching me do it and they could kind of do it at the same time.that's not complicated technology, it's a camera and a TV."*

There was also a sense of adapting her identity from that of a pianist and teacher to that of one who develops and runs an online learning platform. Her growth in this role is apparent stating that,

> *"We're educators, we are pianists and teachers. We have very little real technology experience except making PowerPoint videos…so that having a team that can help you to build your site out in a more useful way is really important and I think we did not do this early enough."*

As mentioned above, she later discusses that she follows social media groups to learn about what teachers are experiencing, what their needs are, and in what ways they are expanding their market to the self-learner.

Within this role of owner of an online learning platform, her role as an educator has also been adapted to the situation, going from teacher of piano students to guiding others who teach piano, specifically online teaching. There is also evidence of an awareness of others' pedagogical and technological intersections and identities with technology. She shared that,

> *"…since eNovative piano is a business where we interact regularly with our teachers who have adopted it. You know, they feel comfortable calling me on the phone… And so because they can communicate with us directly we get to have a real sense of what their things about technology are and how easily they can adapt to going from a textbook…and they get the pedagogy, but they also get the technology. Some people cannot even get the pedagogy because they are so, you know, stymied by the technology…"*

The lack of adaptability within the field was also mentioned when describing participation in a conference panel presentation as she described,

> *"I did an MTNA session…called inclusive activities for group piano… One of the things I was talking about was how teachers aren't very willing to work with kids who want to learn stuff off a YouTube video, but that's how kids want to learn now you know. So as a teacher, you need to kind of get with the programme…But there's a whole pedagogy there that nobody's talking about. Nobody as a pedagogy person is talking about how you can effectively use those very appealing tools in your teaching. Well, we think we are right about everything. You know and a lot of those things that we have been thinking we are right for 1,000 years are being challenged."*

In addition to the theme of adaptability, problem-solving was also key to the participant's use of technology to support her pedagogies and integration of that technology. For example, she stated,

> *"…if you are trying to do anything aurally, you know you absolutely have to have multimedia materials. It's either gotta be a video or an audio and so the creation of those files uses different technologies…I'm trying to figure out how to make it, create something."*

Her problem-solving skills are apparent as she describes the use of the audio-video content created, how they were shared, and how these led to their online learning platform.

> *"You know, and we made these little videos and…we put them on our LMS because that was the only place we could house them… these videos were popular, and our students were getting better. And we went to a conference…were showing these videos and people said things to me like 'how can we get these?'. So then we realised, well, maybe there was some commercial value…we had developed* [an]*entire curriculum around group piano teaching with multimedia support and including an emphasis, or we thought, areas were under-taught…"*

As mentioned above concerning her pedagogical technological identity (PTI), problem-solving was key stating that,

> *"And I think that's what problem solving really is, is what are what are whatever you need to solve a problem…So I think really the fundamental thing here is teaching problem-solving skills to people…"*

Her problem-solving approach was supported by a sense of curiosity fostered by one of her teachers and mentors during her postgraduate studies, who was also a leader in music teaching and technology. She described,

> *"Martha Hilley, in her programme…was always very interested in technology. Technology was there…So I learned that kind of curiosity, and not just from her. I mean, curiosity is one of the things I learned from my most important teachers…it was just like, 'oh, there's something new. Let us look at it'…"*

This curiosity was seemingly a driver in her problem-solving when working with technology, which again reveals her technology identity (enjoyment), as she describes,

> *"Where I am really like. 'OK, let me try this. Oh, that did not work. OK, let me try this.' And what I enjoy about that is I enjoy all the*

> *information that I get. So something does not work or it's not the right tool for the job, you know. 'I go. OK. Well, this did not work because…' and sometimes that helps me to find a better solution because I tried something that did not work."*

Related to problem-solving, another theme found in the participant's responses was navigating barriers. At times, the barrier was the technology itself, as she describes a new piano lab,

> *"not very many people had a lab like this…I put this whole thing together. The computers finally came. And as soon as I connected into the keyboards, I got this 60-cycle through the headphones. That's all you heard… I tried everything…but I still had this hum. I called electricians. I called, you know, live audio guys, people that had rock rock'n'roll bands 'cause I knew they would know…I called Yamaha. I called computer people…*

From here, she used technology to find the solution to this barrier,

> *I went to a Clavinova listserv group. And I joined it and I just started reading posts. I was looking for somebody that seemed smart…I'm going to read these posts and when I get read a post by somebody who seems like they know what they are talking about, I'm going to message them. And that's what happened. I messaged this guy. Well, guess what? He turned out. He was a consultant for Yamaha, but nobody at Yamaha was able to tell me that there's a product called The Hum eliminator. And I got rid of the hum."*

This reflection on her experience illuminated her technology identity in the discussion stating that,

> *"I think that says a lot about me, you know, about how I've said that I like technology and I'm always trying to figure out how I can make it work, because I'm not exaggerating when I said I'm going to read these blog posts to find somebody smart. And that was a really smart thing to do. And I did find somebody smart and he solved my problem."*

Although her identity with technology is positive, she still felt that there were stereotypes about her ability to solve this problem due to her gender. She stated,

> *"…I had tried…the most frustrating thing is when you call up somebody and they tell you 'cause you are female, they'll tell you, 'Oh well, you should get one of those plugs, you know …a little ground wire. It's a ground problem'. And of course, that's the first thing I tried. But all I would get from people was like the first thing I tried and nothing sophisticated, and anyway that was my take… So it's always, it's always solving a problem."*

4 Discussion

The use of the TPACK and TPACI framework revealed the participant's knowledge and identity in music content, pedagogy, and technology, as well as the intersections of these constructs in both the quantitative and qualitative data. The participant's interview responses clarified and confirmed her high ratings on the extended TPACK measurement instrument. Using this framework, the participant's views were able to be critically examined with a lens through which a salient and beneficial understanding of how the participant's knowledge and identity factored into her successful use and integration of technology throughout her career.

In the interview, she shared her content and pedagogical knowledge, which she discussed from both a broader perspective of these constructs and a focused perspective with regard to the development of her online teaching platform. Her technological knowledge was apparent through her discussions on technology devices and software and how she integrated these into her teaching, which led to the development of the online learning platform. In addition to her knowledge of technology, she discussed her knowledge of how to use this technology to support her pedagogies and solve pedagogical challenges with technology. In aligning the content, pedagogy, and technology knowledge, she spoke about her thinking in designing instruction using technology for her classes (online and offline), the development of instructional videos, and pedagogy of sound before symbols and the technologies affording this. Woven through her responses were references to the various types of technologies described by Hitchcock (2017). This teacher described her development of an educational technology that integrated administrative, social, and musical capabilities. The results obtained through the TPACK framework regarding the participant's knowledge of the intersecting constructs of content, pedagogy, and technology provided insight into her effective use of technology.

However, is the participant's knowledge enough to fully discern and realize how and why technology is used and integrated into teaching? Did the participant's identity impact the use and integration of technology and approaches to any barriers or issues within this integration? Using an extension of the TPACK framework, evidence of the participant's identity in the constructs (and intersections) of content, pedagogy, and technology were found as well as how they impacted her pedagogical and technological approaches. She revealed pedagogical self-efficacy when discussing instructional design, a commitment to the profession in supporting other teachers, and confidence in her knowledge of performance. Her responses showed a clear self-awareness of her identity with technology, alongside an identity of leadership, commitment and responsibility to the profession. Her pedagogical technological identity was evident in discussions about choosing the tools for instruction, being aware of student use of technology, and the importance of technology in teaching. Through consideration of her teacher identity, we found that the participant's knowledge was driven and led by her identity in that she was keen on working toward meeting both technological and pedagogical challenges through any means. She alludes to problem-solving in the interview as "a mindset." This was a further theme found in the qualitative data as she brought this forward throughout the interview, whether it be solving a problem in designing instruction or what technology tools to use. Problem-solving came to the forefront of discussions around the challenges of using technology, particularly when it was not performing as expected. As previous examinations of technology in music teaching have reported its underuse, these results might lead music teacher educators to consider aligning the teaching of technology use in music not only with the pedagogies but also developing preservice teachers' identity with technology alongside a mindset of problem-solving. Nykvist and Mukherjee (2016) stated,

> *"In an era where the use of digital technologies should be synonymous with teacher pedagogical practices and transforming education, there is a growing need for pre-service teachers to develop an identity that resonates with pedagogical practices that engage and connect with students in a positive and productive way" (p. 851).*

In addition to problem-solving, adaptability was also found frequently throughout the interview. Adapting instruction for a learner-centred approach and adjusting the choice of technology tools was based on student preference and their use of devices or software. She exhibited an openness to consider what students prefer or what they discover on their own (e.g., Synesthesia). The participant shared examples of adapting to new technologies and the importance of this flexibility; however, she also described instances of using older technology in new ways. As with her knowledge and identity, her adaptability in pedagogies to meet her students' needs and to evolve technologies to align with her pedagogies were a factor in the effective use of technology. We also found that her technology knowledge and identity were extended throughout her career, for which adaptability was needed due to her changing roles in music, from predominantly that of a pianist and teacher to one who develops and runs an online learning platform and educates other teachers. She also pointed out the importance of adaptability and noted the lack of this within the field with regard to new technology.

In light of the COVID-19 pandemic and the transformational effect it has had on teaching and teachers, we have the opportunity to elevate and critically examine how and why we use technology to support music learning. The evidenced inequities in technology use by females in music is a cause for action. By exploring the identity and knowledge of a leading music teacher, we can use her experiences to inform teacher practices and teacher preparation programs for a more equitable future. With a strong identity in teaching with technology, we found that she navigated barriers through problem-solving, whether they be within technology or gender stereotypes, which she mentioned in her interview. Central to her understanding of a technology identity was her exposure to female mentors across her career. These impactful teachers fostered in her a sense of curiosity and an acumen for problem-solving. These two skills, alongside her TPC knowledge, helped forge her identity. Mentors have a demonstrable effect on the development of preservice teacher identities (McIntyre and Hobson, 2016) and are known to increase confidence, a stronger commitment to the profession, and improve pedagogical practices (McIntyre and Hobson, 2016; Simmonds and Dicks, 2018).

Another component to consider is the context of the participant's music career, particularly in light of Peters' (2017) research highlighting the importance of social and cultural contexts. The context of group piano classes is unique among other music learning environments in that this setting elevates the use of music and educational technologies. The growth of group piano teaching occurred alongside the development and accessibility of technology bespoke to this setting alongside other music and educational technologies (Stephens-Himonides and Hilley, 2017). As a leading figure in this technology-rich teaching and learning environment, our participant successfully navigated technological developments and served as a teacher leader for others in the field of group piano classes. Rosenberg and Koehler (2015) emphasized the importance of context as being an integral factor influencing the use of technology in teaching. If technology use is "woven together with" the teaching and learning, then the impact of our participants' teaching context must be taken into account. The rich technological history of group piano classes, alongside our participant's knowledge and identity, created the ideal conditions for her to emerge as a leader of music teaching with technology.

Central to our investigation was the question of whether knowledge was sufficient to explain why or how teachers utilize technology in their work. Following an examination of our participants' responses, it appears that knowledge and identity can create a virtuous cycle. With increased music, teaching, and technology knowledge, our participant developed an improved sense of self-efficacy alongside a more positive perception of the teaching tasks she undertook. This improvement then enhanced her confidence in using technology, which likely motivated her to gain more knowledge and experience and inspired her to gain more knowledge. Given the current research identifying a gender gap in the use of technology, it is plausible that the absence of any one of those conditions could create a vicious cycle. If teachers do not have opportunities to gain knowledge of music, teaching, and technology, then they are not likely to develop the confidence and self-efficacy necessary to continue developing their skills. Similarly, if they do not develop an interest or openness to technology, then they likely will avoid gaining the knowledge and skills necessary to effectively integrate music, pedagogy, and technology. How then do we socialize technology use, foster curiosity and enjoyment, and enable preservice teachers the opportunity to form a technology identity? Kirkup (2002) argued that "It is easier to change an activity with which you are simply associated than change your relationship with something that constitutes a key aspect of your identity" (p. 5). Further research is needed to examine how teacher educator programs could support the formation of a content, pedagogy, and technology identity alongside the development of content, pedagogy, and technology knowledge.

Due to the importance of identity in our results, future researchers may consider comparing the results found here with other gender identities. Furthermore, additional research is necessary to validate the extended TPACK framework. Additional questions regarding age and technology use should be undertaken. At the time of the interview, the participant stated that she was 67 years old and did not feel that choosing to use and integrate technology was age-related. However, she does reflect on the perspective of younger users and whether her teaching practices and technologies remain relevant to her students. This could be another area of examination of technology use and stereotypes. Could identity in a later age determine technology use more than knowledge of how to use it?

4.1 Limitations

While the case study methodology offered rich, in-depth insights into the development of participant's identity and knowledge, it also presents notable limitations when attempting to generalize findings beyond the specific context of this project. Case studies are inherently situated in particular contexts—shaped by the individual's background, experiences, and environment—which limits their

applicability to broader populations. The unique personal and professional trajectory of our participants may not reflect the experiences of other musicians, educators, or individuals with differing gender identities, cultural contexts, or stages of expertise. Additionally, the interpretive nature of case study research introduces subjectivity, both in data collection and analysis, which may influence how findings are understood and applied. As such, while this study yields valuable, nuanced understanding, it should be viewed as illustrative rather than representative, and its insights should inform—not define—broader theories of identity development and TPACK integration in music education.

5 Conclusion

Due to the seismic shift experienced by educators around the globe, the COVID-19 pandemic affords us the opportunity to view our teaching practices with technology differently. At the highest level of the TPACK framework, teachers are encouraged to select appropriate technologies that support the learning of their discipline. To do so requires that teachers not only have the knowledge to select technologies and pedagogies appropriate for effective teaching but also the confidence and belief that those choices will positively impact their students. Our participant's effective integration of content, pedagogy, and technology, alongside her steady focus on students' learning needs and their experiences, could be used as a model for practitioners and teacher educators. Cultivating a positive identity with music, pedagogy, and technology (and their intersections) could enable teachers to remove obstacles to technology use and adoption, leading to more equitable access and successful learning outcomes for students.

Data availability statement

The datasets presented in this article are not readily available because data is not anonymized. Requests to access the datasets should be directed to c.stephens-himonides@kingston.ac.uk.

Ethics statement

The studies involving humans were approved by Kingston University London Ethics Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

CS-H: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. MY: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing.

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References

Armstrong, V. (2001). Theorizing gender and musical composition in the computerized classroom. *Women: Cult. Rev.* 12, 35–43. doi: 10.1080/09574040110034101

Armstrong, V. (2008). Hard bargaining on the hard drive: gender bias in the music technology classroom. *Gend. Educ.* 20, 375–386. doi: 10.1080/09540250802190206

Armstrong, V. (2011). *Technology and the Gendering of Music Education (1st ed.)*. New York: Routledge. doi: 10.4324/9781315612003

Armstrong, V. (2014). Girls' and boys' technological toys: music composition in the computerized classroom. *GEMS (Gender, Education, Music, and Society)* 7, 12–21. doi: 10.5561/gems.v7i5.5234

Bauer, W. I., and Dammers, R. J. (2016). Technology in music teacher education: a national survey. *Res. Perspect. Music Educ.* 18, 2–15.

Bernstein, B. (2000). *Pedagogy, symbolic control, and identity*. Maryland: Rowman & Littlefield Publishers.

Biasutti, M., Antonini Philippe, R., and Schiavio, A. (2021). Assessing teachers' perspectives on giving music lessons remotely during the COVID-19 lockdown period. *Musicae Sci.* 1029864921996033.

Born, G., and Devine, K. (2015). Music technology, gender, and class: digitization, educational and social change in Britain. *Twentieth-Cent. Music* 12, 135–172. doi: 10.1017/S1478572215000018

Brooks, C. (2016). *Teacher subject identity in professional practice: Teaching with a professional compass*. New York: Routledge.

Brosseuk, D. L. (2022). Exploring the changing nature of teachers' pedagogic identities during the delivery of online literacy teaching. *Aust. J. Teach. Educ.* 47:29. doi: 10.14221/ajte.2022v47n2.3

Calderón-Garrido, D., and Gustems-Carnicer, J. (2021). Adaptations of music education in primary and secondary school due to COVID-19: the experience in Spain. *Music Educ. Res.* 23, 139–150.

Camlin, D. A., and Lisboa, T. (2021). The digital 'turn in music education. *Music Educ. Res.* 23, 129–138.

Caputo, V. (2021). Add technology and stir: Music, gender, and technology in today's music classrooms. *Visions of Research in Music Education.* 16:10.

Carter, M., and Grover, V. (2015). Me, my self, and I (T). *MIS Q.* 39, 931–958. doi: 10.25300/MISQ/2015/39.4.9

Cheng, L., and Lam, C. Y. (2021). The worst is yet to come: The psychological impact of COVID-19 on Hong Kong music teachers. *Music Educ. Res.* 23, 211–224.

Chen, H., Liu, F., Pang, L., Liu, F., Fang, T., Wen, Y., et al. (2020). Are you tired of working amid the pandemic? The role of professional identity and job satisfaction against job burnout. *Int. J. Environ. Res. Public Health* 17:9188. doi: 10.3390/ijerph17249188

Comber, C., Hargreaves, D. J., and Colley, A. (1993). Girls, boys and technology in music education. *Br. J. Music Educ.* 10, 123–134. doi: 10.1017/S0265051700001583

Culp, M. E., and Robison, T. (2022). Promoting gender inclusivity in general music (part 2): considerations for using technology. *J. Gen. Music Educ.* 35, 18–24. doi: 10.1177/27527646221089865

Daubney, A., and Fautley, M. (2020). Editorial research: Music education in a time of pandemic. *Br. J. Music Educ.* 37, 107–114.

Daugvilaite, D. (2021). Exploring perceptions and experiences of students, parents and teachers on their online instrumental lessons. *Music Educ. Res.* 23, 179–193.

Dorfman, J. (2017). "Traditions and ways forward in the United States," in *The Oxford handbook of technology and music education*. eds. S. A. Ruthmann and R. Mantie (New York: Oxford Handbooks).

Ertmer, P. A., and Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: how knowledge, confidence, beliefs, and culture intersect. *J. Res. Technol. Educ.* 42, 255–284. doi: 10.1080/15391523.2010.10782551

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., and Sendurur, P. (2012). Teacher beliefs and technology integration practices: a critical relationship. *Comput. Educ.* 59, 423–435. doi: 10.1016/j.compedu.2012.02.001

Foreman-Brown, G., Fitzpatrick, E., and Twyford, K. (2023). Reimagining teacher identity in the post-COVID-19 university: becoming digitally savvy, reflective in practice, collaborative, and relational. *Educ. Dev. Psychol.* 40, 18–26. doi: 10.1080/20590776.2022.2079406

Gall, M. (2013). Trainee teachers' perceptions: factors that constrain the use of music technology in teaching placements. *J. Music. Technol. Educ.* 6, 5–27. doi: 10.1386/jmte.6.1.5_1

Gall, M. (2017). "Technology in music initial teacher education," in *The Oxford handbook of technology and music education*. eds. S. A. Ruthmann and R. Mantie (New York: Oxford Handbooks).

Golzar, J., Sarwarzada, T., and Miri, M. A. (2023). Coping with teacher professional identity tensions: using TPACK during global crisis time. *J. Lang. Identity Educ.* 1–19. doi: 10.1080/15348458.2023.2281952

Hamilton, E. R., Rosenberg, J. M., and Akcaoglu, M. (2016). The substitution augmentation modification redefinition (SAMR) model: a critical review and suggestions for its use. *TechTrends* 60, 433–441. doi: 10.1007/s11528-016-0091-y

Hanna, F., Oostdam, R., Severiens, S. E., and Zijlstra, B. J. (2019). Domains of teacher identity: a review of quantitative measurement instruments. *Educ. Res. Rev.* 27, 15–27. doi: 10.1016/j.edurev.2019.01.003

Hayes, L. (2017). Sound, electronics, and music: a radical and hopeful experiment in early music education. *Comput. Music. J.* 41, 36–49. doi: 10.1162/comj_a_00428

Hitchcock, M. (2017). "Generating intersections between music and technology," in *The Oxford handbook of technology and music education*. eds. S. A. Ruthmann and R. Mantie (New York: Oxford Academic).

Howard, S., Tondeur, J., Siddiq, F., and Scherer, R. (2020). Ready, set, go! Profiling teachers' readiness for online teaching in secondary education. *Technol. Pedagogy Educ.* doi: 10.1080/1475939X.2020.1839543

Humberstone, J. (2017). "A pluralist approach to music education," in *The Oxford handbook of technology and music education*. eds. S. A. Ruthmann and R. Mantie (New York: Oxford Handbooks).

Jones, A. L., and Kessler, M. A. (2020). Teachers' emotion and identity work during a pandemic. *Front. Educ.* 5:583775. doi: 10.3389/feduc.2020.583775

Kim, L. E., and Asbury, K. (2020). 'Like a rug had been pulled from under you': the impact of COVID-19 on teachers in England during the first six weeks of the UK lockdown. *Br. J. Educ. Psychol.* 90, 1062–1083. doi: 10.1111/bjep.12381

Kirkup, G. (2002). *ICT as a tool for enhancing women's education opportunities; and new educational and professional opportunities for women in new technologies. Paper presented at the United Nations division for the advancement of women (DAW) expert group meeting on information and communication technologies and their impact on and use as an instrument for the advancement and empowerment of women*. Seoul: Republic of Korea.

Koehler, M. J., and Mishra, P. (2009). "What is technological pedagogical content knowledge?" in *Contemporary Issues in Technology and Teacher Education*. 9. Available at: https://citejournal.org/volume-9/issue-1-09/general/what-is-technological-pedagogicalcontent-knowledge

Koehler, M. J., Mishra, P., and Cain, W. (2013). What is technological pedagogical content knowledge (TPACK)? *J. Educ.* 193, 13–19. doi: 10.1177/002205741319300303

Martin, F., Budhrani, K., and Wang, C. (2019). Examining faculty perception of their readiness to teach online. *Online Learn.* 23, 97–119. doi: 10.24059/olj.v23i3.1555

McIntyre, J., and Hobson, A. J. (2016). Supporting beginner teacher identity development: external mentors and the third space. *Res. Pap. Educ.* 31, 133–158. doi: 10.1080/02671522.2015.1015438

Merrick, B. (2018). "Embracing new digital technologies: now and into the future" in *Music and music education in people's lives*, 312–314.

Merrick, B., and Joseph, D. (2023). ICT and music technology during COVID-19: Australian music educator perspectives. *Res. Stud. Music Educ.* 45, 189–210. doi: 10.1177/1321103X221092927

Mishra, P., and Koehler, M. (2005). "Educational technology by design: Results from a survey assessing its effectiveness," in *Society for information technology & teacher education international conference*. Association for the Advancement of Computing in Education (AACE). p. 1511–1517.

Mishra, P., and Koehler, M. J. (2006). Technological pedagogical content knowledge: a framework for teacher knowledge. *Teachers Coll. Rec.* 108, 1017–1054. doi: 10.1111/j.1467-9620.2006.00684.x

Nazari, M., and Seyri, H. (2023). Covidentity: examining transitions in teacher identity construction from personal to online classes. *Eur. J. Teach. Educ.* 46, 397–416. doi: 10.1080/02619768.2021.1920921

Nykvist, S., and Mukherjee, M. (2016). Who am i? Developing pre-service teacher identity in a digital world. *Procedia Soc. Behav. Sci.* 217, 851–857. doi: 10.1016/j.sbspro.2016.02.012

Olsen, B., Buchanan, R., and Hewko, C. (2023). "Recent trends in teacher identity research and pedagogy" in *The Palgrave handbook of teacher education research*, 867–890.

Peterman, F. (2017). "Identity making at the intersections of teacher and subject matter expertise," in *The SAGE handbook of research on teacher education*. eds. D. J. Clandinin and J. Husu (London: SAGE Publications Ltd). 2, 193–209.

Peters, V. (2017). "The impact of technologies on society, schools, and music learning," in *The Oxford handbook of technology and music education*. eds. S. A. Ruthmann and R. Mantie (New York: Oxford Handbooks).

Phillips, M. (2016). Re-contextualising TPACK: exploring teachers' (non-)use of digital technologies. *Technol. Pedagog. Educ.* 25, 555–571. doi: 10.1080/1475939X.2015.1124803

Rosenberg, J. M., and Koehler, M. J. (2015). "Context and teaching with technology in the digital age," *Handbook of research on teacher education in the digital age*. eds. M. Niess, and H. Gillow-Wiles (New York: IGI Global Scientific Publishing), 440–465.

Saubern, R., Henderson, M., Heinrich, E., and Redmond, P. (2020). TPACK–time to reboot? *Australas. J. Educ. Technol.* 36, 1–9. doi: 10.14742/ajet.6378

Savage, J. (2017). "Authentic approaches to music education with technology," in *The Oxford handbook of technology and music education*. eds. S. A. Ruthmann and R. Mantie (New York: Oxford Handbooks).

Scherer, R., Howard, S. K., Tondeur, J., and Siddiq, F. (2021). Profiling teachers' readiness for online teaching and learning in higher education: Who's ready? *Comput. Hum. Behav.* 118:106675.

Schmid, M., Brianza, E., and Petko, D. (2020). Developing a short assessment instrument for technological pedagogical content knowledge (TPACK.Xs) and comparing the factor structure of an integrative and a transformative model. *Comput. Educ.* 157:103967. doi: 10.1016/j.compedu.2020.103967

Shibazaki, K., and Marshall, N. A. (2013). Gender differences in computer- and instrumental-based musical composition. *Educ. Res.* 55, 347–360. doi: 10.1080/00131881.2013.844937

Simmonds, A. H., and Dicks, A. P. (2018). Mentoring and professional identity formation for teaching stream faculty: a case study of a university peer-to-peer mentorship program. *Int. J. Mentoring Coach. Educ.* 7, 282–295. doi: 10.1108/IJMCE-02-2018-0012

Stephens-Himonides, C., and Hilley, M. (2017). "Beyond the classroom," in *Routledge companion to music, technology, and education*. eds. A. King, E. Himonides, and S. A. Ruthmann (New York: Routledge), 441–450.

Stephens-Himonides, C., and Young, M. (2023). Exploring teacher self-perceptions of technology, pedagogy, and content knowledge, identity, and adaptability. In: RIME 2023: The 13th international conference for research in music education.

Strong, C., and Raine, S. (2019). "Towards gender equality in the music industry: An introduction," in *Towards gender equality in the music industry: Education, practice and strategies for change*. eds. C. Strong and S. Raine (New York: Bloomsbury Academic).

Suarez, V., and McGrath, J.. (2022). Teacher professional identity: How to develop and support it in times of change. OECD Education Working Papers, (267), 0_1–0_45.

Thompson, I. (2023). "Subject disciplines and the construction of teachers' identities," in *The Palgrave handbook of teacher education research*. ed. I. Mentor (Cham: Springer International Publishing), 851–866.

Tobias, E. S. (2017). "Re-situating technology in music education" in *The Oxford handbook of technology and music education*. eds. S. A. Ruthmann and R. Mantie (New York: Oxford Handbooks).

Upitis, R., Abrami, P. C., Brook, J., Boese, K., and King, M. (2017). Characteristics of independent music teachers. *Music. Educ. Res.* 19, 169–194. doi: 10.1080/14613808.2016.1204277

Waddell, G., and Williamon, A. (2019). Technology use and attitudes in music learning. *Front. ICT* 6:374160. doi: 10.3389/fict.2019.00011

Wenger, E. (1998). Communities of practice: learning as a social system. *Systems Thinker* 9, 2–3.

Zou, D., Huang, X., Kohnke, L., Chen, X., Cheng, G., and Xie, H. (2022). A bibliometric analysis of the trends and research topics of empirical research on TPACK. *Educ. Inf. Technol.* 27, 10585–10609. doi: 10.1007/s10639-022-10991-z