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Preschool teachers' perspectives on (haptic) technology in the classroom

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One particularly exciting platform with the potential to teach science, technology, engineering, and math (STEM) in early childhood classrooms is the tablet. However, one challenge in using these devices for STEM learning is that traditional tablets lack important sensory information. The emerging technology of haptic (or tactile) feedback touch-screen displays might reduce this barrier. In order to better understand pre-school teachers' attitudes toward haptic feedback technology for teaching STEM concepts, we conducted three focus groups. From the focus group data, researchers identified themes around current classroom practices with technology for STEM learning, teachers' reactions to the haptic feedback tablet, and their impression of the implications of its use in early childhood education. These themes provide insight on teachers' attitudes and could influence the design of future STEM apps created for haptic feedback tablets.

KEYWORDS

focus groups, haptics, preschoolers, STEM—science technology engineering mathematics, tablets, teacher-education

Introduction

With the increasing number of jobs in science, technology, engineering, and math (STEM) fields exceeding the people available to fill them, the United States is more focused on STEM education than ever before (Committee on Stem Education, 2018). This focus has trickled down to the very earliest learners, coalescing on the data that demonstrates that entry into the STEM pipeline should begin as early as preschool (Early childhood Stem working group, 2017). Research on early childhood education and its long-term impacts has found that it is, in fact, important to promote math and science skills in children from an early age (e.g., Brenneman et al., 2009).

One platform with the potential to teach STEM in early childhood classrooms is mobile media. The latest National Association for the Education of Young Children

(NAEYC) survey reports that 71% of early childhood educators have access to tablet computers in their classrooms (Pila et al., 2019). Not only are mobile devices ubiquitous for young children in the classroom (Dore and Dynia, 2020) and at home (Rideout and Robb, 2020), but they are also believed to offer the active, physical contingency that more passive media (e.g., television) lack (Hirsh-Pasek et al., 2015). Indeed, users have agency to choose what appears on the tablet or smartphone simply by touching, swiping, or dragging items across the screen to the extent afforded by the technology (e.g., Russo-Johnson et al., 2017; Piotrowski and Broekman, 2022).

One challenge with using these devices for early STEM learning is that traditional tablets, while encouraging agency, can lack other important sensory information. Haptic feedback technology within the tablet—felt in the form of vibration in response to specific touch—may offer a solution to this challenge. Furthermore, although the use of tablet devices is increasing in classrooms (Blackwell et al., 2015; Pila et al., 2019; Dore and Dynia, 2020; Liu and Hwang, 2021), we know little about teachers' use of and attitudes toward these devices for STEM learning and nothing about their expectations nor attitudes toward haptic technology in the classroom. Therefore, the purpose of the current project is to identify preschool teachers' perspectives on the use of these haptic feedback machines (and other forms of media) for STEM learning.

Literature review

Technology in early childhood education

More than 60% of United States 3–5-year-old children are enrolled in some type of preschool program (National Center for Education Statistics, 2022b) and almost 50% (48.7%) of these preschoolers are enrolled in center-based programs (National Center for Education Statistics, 2022a). Early childhood education centers have largely embraced the digital world in tandem with the proliferation of young preschoolers' use of mobile devices in the home, but this adoption is often dependent on the resources of the school. In two national surveys of early childhood educators done in 2012 and 2014, Blackwell et al. (2015) found that the majority of educators (more than 50%) had access to several different technologies (i.e., TV/DVDs, computers, digital cameras, and tablet computers) in their classrooms, but only a small minority of teachers had access to more niche educational technologies like interactive whiteboards and e-readers (26 and 20%, respectively in 2014).

The greatest difference from the survey done in 2012 to the one in 2014 is that 55% of educators mentioned that they had access to tablet computers (up 26% from 2012). This increase was largely due to the increase in tablet computer ownership by teachers who work with lower-income populations. The researchers remark that despite income level, all children in preschool programs have more access to the newest interaction and communication technologies (ICT), and especially increased access to tablet computers in the classroom. The researchers also found that although access increased for all educators, time spent using these devices did not. In fact, educators in 2014 reported using some technologies, like TV/DVDs and digital cameras, less than respondents in 2012 did. Further, fewer teachers mentioned using technology like computers and tablets for instruction and learning purposes. Instead, most educators recorded using these tools primarily for documentation purposes. The use of computers and mobile devices for documentation is not problematic in and of itself, but it does pose the question of educators' willingness and ability to incorporate technology in other potentially meaningful ways.

Preschool teachers

Given the unprecedented pace of new technological advancements, the conversation around their utilization in early childhood classrooms continues. The Naeyc, Fred Rogers Center (2012) joint position statement was published 10 years ago now. The statement, however, continues to be relevant for teachers to consult as it outlines the best practices for incorporating technology in the preschool classroom according to the frameworks of developmentally appropriate practice (Copple and Bredekamp, 2009; National Association for the Education of Young Children, 2022).

Since the position statement was written, many teachers have mentioned their excitement about the opportunity to implement technology in the classroom (Blackwell et al., 2015; Nikolopoulou, 2021), but often say they lack the confidence to employ the technology appropriately. There are a variety of factors contributing to teachers' overall technology use and potential lack of confidence (Blackwell et al., 2014; Sheehan and Rothschild, 2020). First, teachers themselves have anxiety around teaching STEM material, especially surrounding technology and engineering (Pendergast et al., 2017). Second, few, if any teachers, have had meaningful technology practice embedded in their teacher education programs (Kara and Cagiltay, 2017; Nikolopoulou, 2021). While pre-service programs are working to integrate early education technology use into their own curricula, such training programs have not kept up with the increase in and quickly changing technology. Finally, teachers are wary of supplanting traditional experiences with technology (e.g., Dong, 2018).

Young children's learning from tablets

Despite teachers' concerns with media in the classroom, research has demonstrated that preschoolers can and do learn from high-quality educational media and many studies have revealed such positive effects are possible even in the very earliest years (e.g., Herodotou, 2017). While mobile devices like smartphones, tablets, and other touch-screen technology have most of the same affordances as the television set when it comes to watching video content, the largest difference between the two platforms is mobile technology's ability to incorporate physical interaction and provide a contingent reaction to a child's behavior on the touch-screen (Kirkorian and Pempek, 2013; Roseberry et al., 2014; Cristia and Seidl, 2015). Not only do young children seem to quickly learn that their physical touch makes something happen on the device, but even very young children's fine motor skills are adept enough to swipe and click (Cristia and Seidl, 2015). Such movements are intuitive enough to even the youngest users and it is no longer surprising to see a child who can barely sit up fluently swipe across an iPad or other large tablet device to get to a favorite app (Rosin, 2013; Glatter, 2014). Based on research in the infant cognition literature that suggests infants' own action on objects help them understand others' actions (Sommerville et al., 2008; Gerson and Woodward, 2014), it is theorized that the contingency and interactivity that touch-screen technology affords could help young children better process and comprehend the activities they are doing on these mobile devices.

Science, technology, engineering, and math

Considering the promise of interactive touch-screen devices for young children's learning, initial research on this topic provides encouraging findings. It appears that children's can transfer learning from tablet games designed to teach STEM concepts to specific real-world tasks. Huber et al. (2016) found that preschoolers, 4–6-year-olds, were indeed able to transfer instructions on a challenging cognitive task (i.e., Tower of Hanoi) from a touch-screen to the physical version. In fact, regardless of the original modality children practiced the task on (2D or 3D), all children improved in the final problem-solving task (Huber et al., 2016). Further, evaluations of specific math apps have also found mostly positive results (e.g., Stiles and Louie, 2016; Disney et al., 2019). For example, Schacter and Jo (2016) demonstrated that preschoolers can learn math concepts from a math-oriented game (Math Shelf) on a tablet. Compared to children who were in the control group (business-as-usual in their classrooms), the experimental group (who played this tablet game for 20 min weekly for 15 weeks) learned significantly more mathematics concepts. Not only that, but it is clear that teacher professional development can impact learning from touch-screen tablets as well. For instance, Lewis Presser et al. (2015) found that a treatment group of preschoolers' whose teachers received dedicated professional development tools and implemented a high-quality digital math app in their classrooms outperformed a control condition on post-test measures.

Despite these hopeful findings, it is not entirely clear that playing tablet applications on a 2D screen improves learning outcomes for every STEM content area, in every situation, and for every child. Aladé et al. (2016) found that children exposed to a measuring tablet game (either by playing or watching a pre-recorded video of the game) did better on a measuring transfer task than the control group who played a comparable non-measuring game. The participants who had the opportunity to interact with the tablet performed better on near transfer tasks, meaning that they were able to replicate transfer when the task was nearly identical to the tablet game. However, those in the non-interactive condition watching a pre-recorded version of someone else playing the game actually performed better on far transfer tasks. That is, when the task was similar, but NOT identical to the original game, these participants were able to transfer the knowledge from the video they watched. The researchers suggested that while children can practice approximate measuring skills from either watching or play a game meant to teach that topic, perhaps the interactive nature of playing distracts from the conceptual learning, hence why the two groups performed differently. Other research echoes these findings, suggesting that exposure to high-quality educational apps, but not necessarily interacting with them, supports desirable STEM learning outcomes (e.g., Schroeder and Kirkorian, 2016; Herodotou, 2018; Herodotou et al., 2022). As these researchers note, it is also possible that such differences may also be a function of child age (younger vs. older preschool children in these samples).

Haptic technology

Haptic feedback technology—which may also be known as "kinesthetic communication" or "3D touch"—is any technology that has the ability to create a touch experience through force, vibrations, or motion for the user. It is common to have vibrotactile feedback in modern cellular devices. For example, Android users may notice this vibration in response to selecting icons on their smartphones or those who have an iPhone 8+ can tell when they use the home "button." That is, the button is not actually a button at all, but rather a piece of glass provides the sensation of pressing a button for users when the phone is on. There are two main types of haptic feedback: friction and vibrotactile. For reference, we explore both in our literature review but use a friction-based haptic technology exclusively in the current study.

Haptic impact on learning

Given the tactile nature of haptic feedback, many posit that it could be most helpful for STEM learning because it provides the hands-on, kinesthetic experience necessary for profound and "sticky" STEM learning (e.g., Shams and Seitz, 2008). Research evaluating the effectiveness of haptics for teaching

STEM subjects generally supports this phenomenon. In fact, research on learning STEM concepts like force fields (e.g., Brooks et al., 1990), viruses (e.g., Jones et al., 2003), and levers (e.g., Wiebe et al., 2009) finds it conducive. Further, haptic feedback technology has also been used with middle schoolers who are blind, low vision, or otherwise visually impaired to support their STEM learning (Darrah et al., 2015). In a recent study of nineteen visually impaired primary school students and their educators, children themselves facilitated the design of a prototype LETSMath which was a tangible system for support in working with math concepts. All children understood the composition of the interface and could use it alone.

Although the research suggests a potentially positive effect of haptic feedback experiences on learning, most studies of this nature focus exclusively on young adult, adolescent, or grade school populations. The technology has become quite embedded in undergraduate engineering education specifically (Hamza-Lup, 2019). However, there is considerably less research on haptic feedback use in teaching elementary STEM concepts. Han and Black (2011) did find that, compared to peers who were not exposed to haptic feedback, fifth graders who learned about gears using force and kinesthetic simulations (haptics) improved in their conception of gears and were better able to transfer this knowledge to a novel environment. This study measured only effectiveness of haptic simulation in transfer—the ability to apply information learned in one context to a novel one—and not student's experience with haptic devices. Other research has found a general appeal of haptic experiences among grade school children (and their educators) using haptic phones. For example, Hightower et al. (2019) found that children who used the haptic device for science inquiry were very engaged and had a slightly more favorable opinion of the journaling task even if it wasn't statistically significant. Sadly, there is even less known about haptic experiences with young children. Only one study of preschoolers found no effect of haptic feedback on comprehension or transfer of STEM material but did note that young children in their sample enjoyed the game they played on the tablet (Pila et al., 2020). Experiences with haptic feedback technology seem to be extremely engaging for youth of all ages (Hightower et al., 2019). Indeed, Williams et al. (2003) found that elementary students thought that the haptic software the team developed for learning about simple machines was effective or very effective in teaching such concepts. Both students and teachers in this study also responded to open-ended questions about the software and many said that using it "[sic] was FUN" (Williams et al., 2003).

While research has shown haptics to improve STEM learning for middle school, high school, and undergraduate students, there is still a dearth of research on how haptics may support other types of STEM learning for younger children; a primary argument for understanding its purpose (or lack thereof) in early childhood education.

Theoretical framework

Considering haptic feedback technology in early childhood education could possibly be understood through a technology, pedagogy, and content knowledge (TPACK) frame. TPACK is a framework developed and made popular by Matthew Koehler and Punya Mishra over the last decade (e.g., Mishra and Koehler, 2006; Koehler and Mishra, 2009). Based on insights from Shulman's (1986, 1987) Pedagogical Content Knowledge (PCK) framework, TPACK describes the interaction between educators' knowledge of technology, pedagogy, and content that shapes teachers' integration of educational technology in the classroom (Koehler and Mishra, 2009; Koehler et al., 2013). Visually depicted as a Venn diagram with three overlapping circles, each of the main elements—technological knowledge, content knowledge, and pedagogical knowledge—are represented in their own circle. See **Figure 1** for a representation. Each circle shares some space with the other two such that the interactions between and among the three circles are equally as important. These intersecting spaces are noted as the pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge areas, respectively. In the middle, the intersection of all three circles is TPACK, the culmination of successful integration of technology for learning purposes. More than just the sum of its parts, TPACK is the unique combination of all three components. Altogether, the TPACK framework suggests that considering each piece of knowledge (e.g., technology, pedagogy, and content) individually is not enough for teachers to effectively integrate technology into the preschool classroom. Instead, educators must take great care to use technology in ways that supports the specific content and follow already well-known pedagogy on children's thinking and learning. Thus, lack of knowledge about technology, confusion around desired learning content, and/or misuse of pedagogical practices would not contribute to effective teaching with technology and, in fact, would be an inappropriate use of technology in the classroom. Of course, the researchers also note that there is not one right way to implement technology use, but rather, the best integration will reflect considerable thought around "particular subject matter ideas in specific classroom contexts" (Koehler and Mishra, 2009; Koehler et al., 2013).

The present study

Given the literature above, the present study seeks to explore how pre-school teachers incorporate technology into their classrooms and identify their perspectives on implementing haptic feedback devices in their classrooms. Specifically, we ask:

RQ1: How do preschool teachers incorporate technology into their classrooms?

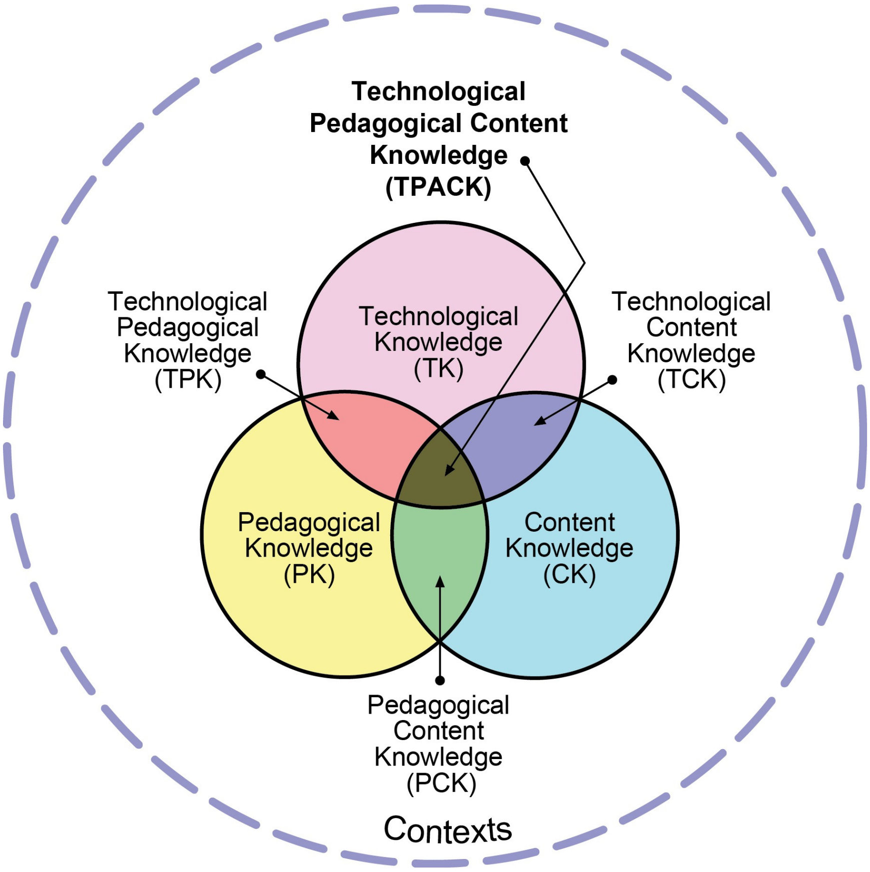

FIGURE 1
Representation of TPACK.

RQ2: What are preschool teachers' attitudes towards haptic feedback technology in teaching STEM?

Method

In order to better explore pre-school teachers' attitudes toward technology—particularly haptic feedback technology—in teaching STEM concepts, we conducted focus groups with preschool teachers. We performed two of these groups in a suburban Midwestern city and one in a suburban Southern city. These two locations were chosen as a convenience sample of teachers. Focus groups allow for "discover[y of] collective perspective, 'synthesis and validation of ideas and concepts,' involvement of diverse group of people, and access to a potentially large number of participants" (Gibbs, 2017), while also capturing nuanced perceptions of the devices and haptic feedback technology directly from the user. This method was necessary because we were not only interested in what teachers individually considered useful, but also how teachers differ from one another even at otherwise seemingly similar sites. Focus groups were audio and video recorded for later analysis. All study procedures were approved by the sponsoring university's Institutional Review Board.

Participants and setting

Focus group participants were recruited using e-mail and printed advertisements targeted towards local preschools. Participants (N = 13) were all females between the ages of 25 and 66 (M_{age} = 44.2), worked primarily with children between the ages of 0 and 5, were predominately middle income (average reported household incomes were between \$50,000 and \$59,000), and identified mostly as Caucasian (n = 10, 76.9%). Participants were compensated \$50 in cash for their time.

Procedure

Each participant completed an informed consent form and a short survey that asked about demographic information (e.g., age, race, gender, household income, and education) when they first arrived at the focus group location. See **Supplementary material** for complete questionnaire. Each group was approximately 90 min, and all participants were encouraged to speak openly and honestly about their experiences. They were told that they were participating in a research study and there were no right or wrong answers. They were also told that the moderator did not work for the company or university conducting research so participants could be honest with their feedback. A trained moderator led the focus group discussion with a semi-structured interview guide. The interview guide addressed four main categories: (1) discussion on classroom practices, (2) testing haptic enabled application, (3) feedback on test application, and (4) implications of haptic technology in the classroom (see **Supplementary material** for full interview guide).

Haptic feedback tablet

All participants were introduced and given time to explore a Tanvas TPaD tablet. The TPaD tablet (see Cingel et al., 2015 for a review of the technology) uses TanvasTouch technology embedded in a standard Android tablet. This technology allows for programmatically varying the friction between the users' fingertip and the flat glass display surface, creating the sensation of tactile patterns.

Measures

Classroom practices

To understand participants' current technology use in the classroom and their feelings toward using technology to teach STEM, the moderator asked questions like "How often do you use technology in your classroom? What do you use?" "Are there any specific technology resources—apps or activities—that you love?" and "What are some specific science topics that you cover with your students? What topics or activities or approaches seem to engage them the most? Are there topics or methods that are especially tough to learn for kids this age?" Participants were asked to elaborate on these responses.

Experience with test applications

Participants then had the opportunity to test out the haptic feedback device using an introduction app that already existed on the tablet as well as a target STEM game that the research team designed. The demo app allows users to test out different textures by unzipping a zipper, following a maze, and feeling moleskin and corduroy pants. The target STEM game that the research team design had embedded haptic feedback that was chosen to introduce the concepts of weight and balance. As described in Pila et al. (2020), the research team modified a freely available application, WGBH's *Peep and the Big Wide World* Bunny Balance game. Using three bunnies of increasing size and a seesaw on the screen, participants could test what happened to the seesaw as they dragged and placed one bunny on each end. In the haptic feedback condition "as bunnies increase in size, they also increased in the tactile feedback associated with dragging them across the screen. Each bunny differed in its oscillation pattern such that the largest bunny at high friction was the most difficult to move, while the smallest bunny was at low friction, the easiest to move. The other bunny was on the pattern somewhere in between. We also chose to associate particular textures with the bunnies" (Pila et al., 2020). While the participants were engaging with the apps, the moderator and researcher circulated among the groups and recorded the group's initial reactions.

Feedback on test applications

After they had a chance to use the demo application and the STEM game made by the research team, the moderator asked participants to identify "How might you envision using this type of tool [haptics] in your science teaching?" They were also asked to consider their own students, probing more explanation to questions like "How do you think 3–5 yos would use this? Would anything confuse them? What would they do with the different features? Do you think that they'd be able to use it relatively independently?"

Implications

Finally, participants were asked culminating questions such as "Which uses of haptics for science learning make the most sense to you?" and "Do you have any concerns about using this type of technology [haptics] in your classroom?"

Analysis

All interviews were transcribed verbatim by research assistants. Participants were anonymized throughout results. In line with Thomas (2006), we used general inductive analysis to determine themes throughout the interviews. Data analysis for this project was driven by TPACK as a frame of reference. After multiple readings of the focus group transcripts, the first and second authors met to develop a coding frame that best reflected the theoretical aims of the project. After the initial meeting, we used this coding frame to code the first focus group transcript. Then, we assessed the coding frame as well as new codes and any disagreements were discussed and agreed upon by the researchers. With these categories in mind, we then coded the remaining interviews.

Results

We discovered three major themes with sub-themes within the following areas: classroom practices, reactions to the haptic technology, and teachers' perceptions of the positive and negative implications of incorporating haptic feedback technology in the early childhood education space. These themes are discussed separately below.

Classroom practices

Because teachers in our focus groups came from a variety of early childhood centers, classroom practices around science and technology differed considerably. In all of the focus groups, however, one similarity emerged for each educator—intentionally varying methods for different learners. Educators would purposefully provide science and technology content either in the large group (whole classroom), small groups, or one-on-one (individualized instruction) based on any given child's unique needs, experiences, etc. Educators in our focus groups were mixed about the implementation of technology in the classroom. About half of the educators were excited about the possibility of technology to improve young children's learning especially because they recognize today's young children as digital natives who are quite adept at using technology already. Despite this excitement, we also heard from educators who feared technology would begin to supplant hands-on learning which they believe is necessary for most topics that are being taught at this young age, and especially science.

We noticed a clear tension between these camps of ideas, and such differences were not necessarily due to the age of the educator. In fact, contrary to popular belief, some of the younger educators were the most worried about technology in early childhood bemoaning that it was replacing physical learning while some older educators were ecstatic about the potential of technology to support learning. We also heard some moderate opinions on technology in the classroom, for example that technology can be used appropriately as a supplement or reinforcement for other methods of teaching. One teacher remarked that "children can practice, they can relate it [iPad play] to their study in some way." This middle-of-the-road opinion was a possible compromise between the two different ideologies.

Although all participants in one focus group worked at the same center and four of the five educators in another focus group worked for the same umbrella organization at different centers, technology practices in the classroom varied greatly. With the exception of one participant who worked in a tech-free classroom, all participants had some experience with technology in the classroom. The majority of the technology mentioned was tablets and smartphones. Of those whose students had access, almost all reported that students were allowed to use these technologies most often during free choice time. When children used technology independently or in small groups during this time, there is still considerable oversight by programs. Participants told us that students can use iPads that are pre-loaded with specific applications. One participant said, "each classroom has maybe four iPads for teacher use and child use, so they do get some time to use it. It's part of their free choice time. They can use an educational app, things like that" while another in a different focus group mentioned "[students] don't have like, unlimited choice of apps. We have them use one app, for example, when they use the iPads during big room time it's Starfall." It is clear that student use is limited and still needs to somehow fit a prescriptive curriculum in order to be seen as effective.

Although student use was limited in scope, teachers' use of technology was much more varied and centered around documentation, building stronger home-school connections, and looking up information. Indeed, teachers were eager to discuss their own use of tablets and smartphones for these purposes. In terms of documentation, teachers noted that tablets are used for "recording information for our paperwork" for one, and "they can share all the documentation, observations that teachers enter with them," for another. Both tablets and smartphones are used for strengthening the home-school connection. At one center, they use a service called Teaching Strategies Gold that includes a communication portal between teachers and parents. The administrator described it as:

Parents can make their own observations at home. Sometimes they're learning at home, and the teachers can have a conversation with it. And they can actually go onto [teaching strategies gold] TSG and enter their own observations. And teachers can be able to see that, so they can see, do a comparison-home and school, and see if they're missing anything. Parents can do their observation at home, if they participate in it. Has not been real successful, but they have access and the option if they realize it.

In the same focus group, others mentioned that they use services like Class Dojo and Tadpole to "... send photos, videos, put it on your classroom story, and every time I upload it, I can privately message them [parents]...It helps parents feel really connected to what we're doing in our classroom." At another center, teachers and staff also communicate directly with parents by text and email. In addition to documentation and connecting school to home, tablets and smartphones are also used for looking up information. In each focus group, participants described using technology to address children's spontaneous questions in the classroom. For example, one participant said:

I think where technology can come in for me is when they ask a question I don't know the answer to. Here's a way we can look it up. I don't have a book right now, but let's find the iPad, and we can find that information. We often pull out our phones for that.

Another offered, "[technology offers] The freedom to say I don't know... Now we can look it up or we can look at this video."

Occasionally we heard other uses for technology in the classroom. For the most part, these language, literacy, and physical activities were done on Smartboards (interactive whiteboards) that are essentially giant touch-screen tablets. Although only one participant in the Midwestern focus groups mentioned having access to interactive whiteboards, the participants in the Southern focus group significantly described using their smartboards for these alternate purposes. Of course, some of this use was in line with information seeking, but not all.

We have a SmartBoard in our Kindergarten room, and that has been really helpful for those types of questions when the teacher doesn't know. And it helps them get more a visual, and it's interactive, so they can use the SmartBoard, especially when they're talking about geographics and where they are or when they're doing a study within a classroom. They can go right into the SmartBoard, they can search it, they can see it. They can pinpoint the place right on the map.

In addition to this information seeking, the Southern focus group educators said that they use their smartboards for "music and movement," showing pictures and video on the big screen, and "[watching] YouTubes of Eric Carle reading some of his books and then showing how he makes his art." Language, literacy, and physical movement activities are obviously not entirely excluded from classroom technology use.

Reactions

Haptic feedback

When participants had the chance to interact with the Tanvas demo application, most of the reaction we heard was "interesting," and "oh yeah that's cool." Indeed, most participants had something positive to say about the technology and how it could be used, at least for adults. It was not all positive, however. When one participant in our Midwestern group felt a test application for moleskin pants during the introductory time with tablet, she said that "I don't think it's accurate... It doesn't feel like moleskin." Another participant seconded her reaction by noting "I didn't feel it very well, and I thought the corduroy was interesting. When you get down to it, still, I think those experiences have to be in person. But it is helpful, in a way. It's more information." Educators in these groups were thinking about the differences between their own adult perceptions and young children. They often considered the size and sensitivity of children's fingers, asking if children would be able to notice the difference when "they have smaller fingers . . . their touch might be a little more." Participants also wondered if "should their hands be clean when they play?" and if the "oiliness" of hands would impact the feeling of the feedback for adults and children.

Science, technology, engineering, and math application

Only one theme came out of our participants' reactions to the test application in question. This was the STEM application that we designed to help preschoolers explore concepts of weight and size. It was clear that participants liked the look of the game and some of its features. The participants commented that the look of the app was very child friendly and visually appealing.

Importantly, however, most of the educators did not understand what the haptic feedback was supposed to add to the learning outcomes until we explicitly told them. In this case, the size/weight of the bunny mapped onto to the friction of the tablet such that the heaviest bunny was the most difficult to drag. Our participants said things like "I didn't notice it until, the third or fourth time maybe" and "I didn't catch that, it wasn't clear at first, that the heavier bunnies were supposed to be harder to drag." If our educated adults did not notice the haptics' intended purpose, perhaps it could be lost on preschoolers as well.

Implications

After having the chance to experience the haptic feedback in the demo app and our test STEM app, it was clear that participants could see our developed game as one more way to reinforce the concepts of weight and balance. It did not intend to take away from hands-on, kinesthetic experiences, but rather act as another medium in which to practice those same skills. Many mentioned using a 3D scale and weights in addition to the test application, either using the app as the pre- or post-exposure to this activity. Most said it could be a good way to supplement and reinforce other concepts that students are already practicing in different modalities; that it would be used to enhance "real-world" learning, not to replace it. One participant summed it up when she said, "Yeah I think it's like, what [observer] was saying. Just more reinforcement and more tactile experience." It was also described as a tool for teaching vocabulary. "A lot of the items that you can teach them for vocabulary because that's what you want to do – extend their vocabulary. They can actually see and touch and then they can know what it is." Another implication of haptic feedback technology that educators discussed would be to use it to introduce concepts that are traditionally difficult to teach because they are more abstract OR otherwise dangerous to touch and experiment with (e.g., bugs, electricity, etc.).

The thing we heard the most during the focus groups was the benefit of haptic feedback use for special populations; particularly children with sensory processing disorders, individuals who are blind or low vision, and children with Autism Spectrum Disorders (ASD). "Sensory kids" and people who are blind were regularly brought up as populations that could benefit from this technology, saying that "it almost seems like it would be more essential or valuable for kids with disabilities first, because it might really fill that need." However, it was unclear how individuals in these populations would react to the technology. One participant mentioned that they're either gonna run from it, and it's the worst thing ever. Or they're gonna really love and it and use it, be engaged in it. It can help them focus their attention too because they're feeling, they're actually getting a real sensation of what they're doing as they're doing it.

Overall, educators were on the fence with how their own classroom students would react to the technology and we heard mixed feelings based on the individual differences of their students.

Discussion

This study provides detailed information about early childhood teachers' attitudes and practices using technology in their classroom and explores their reactions to a novel haptic device in the context of STEM learning. Despite there being a decade since the NAEYC position statement was published, a clear divide still exists between teachers who see the potential benefits of technology use in the classroom and those that fear the consequences of use. Importantly, even those teachers who expressed fear when discussing technology use in their own classroom, saw the potential use of haptic technology particularly with regards to differentiation and supporting all learners in the classroom.

Educators reported use of technology in their classroom were consistent with results found in NAEYC survey data (Wartella et al., 2012; Blackwell et al., 2015; Pila et al., 2019). Access was generally similar amongst participants and mobile media was the most used form of technology. Niche electronics like smartboards and interactive whiteboards were only discussed by a small portion of our participants which is also in line with the NAEYC survey findings. Finally, teachers shared that they predominately use technology for documentation, a similar trend as reported in the NAEYC surveys. It also appears that better resourced schools with higher income families likely had more access to and comfort with technology. Although our moderator did not press on these subjects, it is possible that this difference is related to the centers' ability to provide more professional development, time, and financial support with these resources.

Technology, pedagogy, and content knowledge framework suggests there is still a way to go towards successfully integrating technology for teaching STEM in the classroom. Even if educators are integrating technology meaningfully (technological knowledge) and engaging in applicable pedagogy, if they are not able to identify science appropriately (lack of content knowledge), such disconnect will mean little for students' overall learning outcomes. Indeed, Koehler et al. (2013) would likely consider these circumstances a misuse of technology. On the plus side, it is clear that teachers are thinking about the developmental appropriateness of technology in their classrooms. When they described using technology to look up information, there was great care in considering the developmental appropriateness of the answers they received. They might screen a video or at the very least, read through the answer that the internet provided before disseminating that information. They also thought about the different students in their classrooms and how they envision using the haptic feedback technology differently to best support individual learning, a core tenet of developmentally appropriate practice (Copple and Bredekamp, 2009) and basis of TPACK. These findings are in line with Otterborn and Schönborn (2022) who describe the use of tablets in Finnish preschool classrooms as opportunities for rich, meaningful, and impactful activities. Although this study is not the first to use TPACK as a method of analysis, it does support previous research that considers TPACK in light of particular technological devices (Blackwell et al., 2016; Lauricella and Jacobson, 2022).

Further, our focus group participants could see haptic feedback devices being valuable for supplementing other, more hands-on approaches to learning. Hightower et al. (2019) also found that haptic feedback devices were best for "learning activities that involve concrete observation and when tactile sensory information aids in making descriptive comparisons." Participants' reactions to the tablet device are in line with current research on the Tanvas TPad in that they were concerned that their adult perception of the haptic feedback might differ from young children's given the size of their fingers and more mature sensory systems. Such reactions are empirically supported by research with children and their parents from Beheshti et al. (2019) who found that parents and children sometimes differed in their perception of the presence of haptic feedback. Beheshti et al. (2019) report at least two scenarios in which the child notes a stronger haptic feedback current, but it feels the same to the parent both times. It appears to be the case that not everyone perceives the haptic feedback in the same way (Mullenbach et al., 2013a,b; Mullenbach et al., 2014) and this phenomenon was also demonstrated with our focus group participants.

Relatedly, all of our participants believed that the haptic tablets would be best for special populations: blind/low vision, sensory processing disorders, and/or ASD. Our educators are well in line with other researchers who have studied haptic technology with users who are blind/low vision (Darrah, 2012; Darrah et al., 2014; Twyman et al., 2015; Marichal et al., 2022), individuals with ASD (Pérusseau-Lambert, 2016), and users with other disabilities (Jin et al., 2014). We must acknowledge there is also the possibility that because the device is so sensitive and feedback differs person-to-person, the implications of using the device suggested by our participants may have been misinterpreted.

Limitations

Of course, this study is not without its limitations. For one thing, with a small sample size, it is impossible to make any generalizable claims about all early childhood educators' attitudes towards this new technology. Secondly, as a new technology, many of our findings highlight a novel activity that educators may never actually experience in the classroom. It is difficult to know exactly how educators would feel if these devices were embedded in their curricula rather than just getting to try it out for 1 day. Additionally, the haptic feedback technology we use is friction, but future research would do well to consider vibrotactile feedback devices as well. Comparing the reactions after using both types would be a great contribution to the literature. Finally, although the moderator and observer in these sessions asked participants to be honest about their reactions, it is possible that there was some social desirability bias, especially for teachers who worked for the same organizations.

Conclusion

By soliciting focus group interviews to understand teachers' attitudes towards haptic feedback technology in the classroom, this work is an important step in identifying how haptic technology may be able to support STEM learning in early childhood education. Though preliminary in scale, results from this study can help provide the foundation for future researchers to examine learning outcomes associated with this new media as it grows in availability and becomes further integrated into early childhood classrooms. Ideally, if these technologies can be realized to improve STEM learning and engagement, the young children using these devices today may become our next scientists, mathematicians, engineers, and technology experts in the future.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Northwestern University Institutional Review Board Office. The patients/participants provided their written informed consent to participate in this study.

Author contributions

SP observed focus groups, led the analysis of data, and wrote the first draft of the manuscript. All authors contributed equally to conception and design of the study, manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2022.981935/full#supplementary-material

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