MODESTUM
OPEN ACCESS
EURASIA Journal of Mathematics, Science and Technology Education, 2019, 15(12), em1784
ISSN:1305-8223 (online)
Research Paper https://doi.org/10.29333/ejmste/109949

Preschool Teachers' Beliefs and Pedagogical Practices in the Integration of Technology: A Case for Engaging Young Children in Scientific Inquiry

Sarika Kewalramani [1*], Sari Havu-Nuutinen [2]

[1] Monash University, AUSTRALIA
[2] University of Eastern Finland, FINLAND

Received 25 April 2019 ▪ Revised 26 May 2019 ▪ Accepted 10 June 2019

ABSTRACT

This paper presents findings from an on-going international study (Australia and Finland) of preschool teachers' beliefs and pedagogical practices in the integration of technology to engage young children in learning science. Scarcely used in early childhood education research, this study is framed using Mishra and Koehler's (2006) Technological Pedagogical and Content Knowledge (TPACK) theory. Case studies presented in this paper are undertaken with data collected from three preschools in Australia. Participant observation of teachers' (N = 7) and children's play experiences, and semi-structured interviews, revealed that teachers occasionally used iPads and some apps within their intentionally constructed science investigations, both for teacher-initiated research and for communicating with parents via children's journals. Teachers were not adverse to, but rather accepting of embedding technology as a pedagogical affordance and keen on planning for multimodal science-based experiences. The findings of this study imply the need for a pedagogical shift, wherein teachers' technological pedagogical knowledge improves in how and when to sensibly integrate technology for children's engagement in scientific inquiry, rather than relying on hands-on experiences alone. Implications lie in more closely aligning teachers' TPK and related practices with science content knowledge by co-researching together with children and foregrounding both teachers' and children's perspectives.

Keywords: children's inquiry skills, early childhood pedagogical practices, teacher technological pedagogical knowledge, technology integration, young children's science engagement

INTRODUCTION

In the last decade, a shift to greater societal reliance on technology has mandated that young children's educators emphasise the use of technology as a play-based tool to tune into children's learning and cognitive engagement (Arnott, Palaiologou, & Gray, 2018; DeCoito & Richardson, 2018; Fleer, 2018). The inescapable fact that digital technology is increasingly present within family life, and the reality that many young children are interacting with apps and high-tech toys, has driven early childhood education policy and research to unpack this for preschool teachers (Early Childhood Australia [ECA], 2018). Many researchers worldwide have begun to articulate that, because of the immersed role of technology in young children's everyday life and the rapid changes in technology, there is an urgent need to take into account teachers' technology knowledge as a precursor to understanding how they can engage young children's cognitive engagement, for example, scientific thinking (Ailincai & Gabillon, 2018; Hsu, Liang, Tsai, & Chai, 2014; Voogt, Fisser, Roblin Pareja, Tondeur, & van Braak, 2013).

However, given the preschool context of the current study, amidst the varying play-based pedagogical practices in young children's education, the use of technology for preschoolers' science engagement remains rarely undertaken. Moreover, Marsh et al. (2018) have recently suggested that early childhood professionals need to be

✉ sarika.kewalramani@monash.edu **(*Correspondence)** ✉ sari.havu-nuutinen@uef.fi

Contribution of this paper to the literature

- This study is unique in utilising Mishra and Koehler's (2006) TPACK framework in an early childhood science education context and assists in the understanding of the complex connection between technology and preschool teachers' pedagogical practices for engaging young children in scientific inquiry.
- Teachers are not adverse to, but rather accepting of embedding technology as a pedagogical affordance and keen on planning for multimodal science-based experiences.
- This paper provides a nuanced understanding of teachers' technological and pedagogical beliefs and science instructional practices, with the view to enhance children's problem solving and inquiry skills.

aware of the growing interest young children have in the use of apps that may relate to having similar fun as they experience with physical toys. Ailincai and Gabillon's (2018) French Polynesian study, although pertaining to elementary school teachers' beliefs about digital technology postulated how internal factors such as interest in technology, teachers' technological skills and extrinsic factors such as support from administrators and technical maintenance play key roles in shaping teachers' practices. Consequently, this creates significant implications for how preschool teachers can meaningfully use technology as an educational tool that will benefit (or even encourage children) in engaging in science experiences.

With this agenda in mind, the present study explores preschool teachers' beliefs and pedagogical practices relating to the use of technology in the context of engaging children in science learning. It draws upon Mishra and Koehler's (2006) Technological, Pedagogical, and Content Knowledge (TPACK) framework, which assists in the understanding of the complex connection between technology and pedagogy for effective teaching of science concepts to preschool children.

Current Trends and Benefits of Technology Integration for Science Instruction

This study is of particular importance in light of the recent Organisation for Economic and Collaboration Development (OECD) research report, which highlights how children's higher-order thinking, above and beyond content learning, can be fostered by specific technology-supported pedagogical models (Kärkkäinen & Vincent-Lancrin, 2013). The last two decades of educational research has seen considerable effort invested either in understanding science teaching or only the use of technology to cater for 21st century learners (Ailincai & Gabillon, 2018; Fleer, 2010, 2015, 2018; Sandoval, Sodian, Koerber, & Wong, 2014), which mainly concerned contexts other than the preschool education. There has not been much research attention on examining teachers' beliefs and the technologically-constructed teaching and learning that can be articulated to aid in preschool children's science engagement. As such, the current study is fairly new in understanding technology integration for science instruction.

Considering the Australian early childhood context, the current Australian science and digital technology curriculum (towards Foundation and up to Grade 2) (Department of Education and Training [DET], 2017) requires young children to intentionally participate in investigations that can build their independence in observing and sharing their discoveries. In line with this, the Early Years Learning Framework of Australia (EYLFA, 2018) has recently proposed that the planning cycle structure supports teachers' understanding of the continuity of learning in science concept areas.

However, despite these policy initiatives, little is known about the extent to which preschool teachers, together with children, partake in technology as multimodal learning platforms. For instance, exploring apps or making digital stories about particular scientific concepts can promote scientific inquiry (Marsh et al., 2018; Yelland, 2018). When teachers have clear aims for planning science activities and accordingly make pedagogical decisions to integrate technology, it becomes possible for the teacher to assess whether, and to what extent, the learning aims can be achieved (Mishra & Koehler, 2006). Simultaneously, when children share and demonstrate their understanding of objects and everyday events, make and evaluate claims, and engage in argumentation through images, pictures, alternative and augmentative communication in addition to simple statements, technology then becomes a crucial educational tool within a multimodal learning platform (Edwards, Straker, & Oakey, 2018; Sandoval et al., 2014; Yelland, 2018).

In relation to the affordances offered by technology for science instruction, studies have shown how integrating the use of digital devices (iPad applications) can have potential benefits in increasing children's motivation to explore scientific concepts, expanding the pedagogical resources available to science teachers (DeCoito & Richardson, 2018; Havu-Nuutinen, D. Sporea, & Sporea, 2017), promoting cognitive development, and highlighting the relevance of abstract scientific concepts to children's real-life experiences (Kärkkäinen & Vincent-Lancrin, 2013). Research in both science and play-based exploration indicates that digital technology can afford opportunities to develop children's curiosity and scientific inquiry skills. In particular, technology use can foster science creativity

(Craft, 2011), and fascination, wonder and interest can prompt aesthetic engagement, spark curiosity and lead to the use of scientific inquiry to develop children's explanations of phenomena (Milne, 2010; Kermani & Aldemir, 2015; Wang, Kinzie, & Pan, 2010). Whilst a constructionist teaching approach in early childhood science teaching and children's science engagement has received less research attention, Highfield (2010) argues it is not merely a catalyst, but also presents unique opportunities for promoting children's sustained engagement with challenging scientific concepts. For example, robotic toys such as Bee-bots, Pro-bots and Micro:Bit, when programmed and viewed on the computer screen together with the teacher, provide a visual process for children as they observe the robot moving and performing problem-solving tasks. The dynamic nature of such toys assists children to reflect on their program, thus creating shared and engaged moments for trial and error and simultaneously reflecting on the scientific concepts under exploration (Havu-Nuutinen et al., 2017; Highfield, 2010).

Despite the affordances offered by technology in science instruction, little is known about preschool teachers' beliefs and pedagogical practices in using technology. Therefore, it is important to understand teachers' knowledge base for teaching with technology and how this can inform their pedagogical practices; these factors can either assist or impede their willingness to engage children in science learning. The next section explores the barriers to integrating technology.

Barriers to Using Technology in Preschool Science Teaching

It can be argued that keeping abreast of fast-paced technological advances can potentially pose a barrier to preschool teachers' adaptation to technology and instructional practices. Aldhafeeria, Palaiologou and Folorunsho (2016) demonstrated that although the Kuwaiti teachers in their study were competent users of digital technologies in their personal lives and the Kuwaiti classrooms had largely been digitalised, the teachers were still hesitant in embedding digital technologies in their early childhood curriculum and teaching practices due to lack of confidence and adaptability. In Palaiologou's (2016) study, teachers were anxious that digital devices did not allow children to initiate activities and may impede their imagination and creativity. The concerns were around how children could be stimulated because most of the electronic toys just offered directions for use, with no space for children's imagination, and no richness in language.

According to Donohue (2015), when technology and digital media are integrated into early childhood classroom practices, educators need to think about technology across the curriculum throughout the day, not of technology as a separate activity. In relation to science instruction, Parette, Quesenberry and Blum (2010) argue that the discussion of technology integration should move beyond whether technology use is appropriate, and rather focus on how to integrate this medium in early childhood science education in a developmentally appropriate manner. While research has also suggested that technology can present several positive teaching moments, there is still literature that highlights teachers' lack of confidence as well as a slow and cautious pace of integrating technology during play-based practices (Havu-Nuutinen et al., 2017).

A number of researchers (Marsh et al., 2018; Palaiologou, 2016) have argued further that, since children from a very young age have access to digital technologies, parents and educators have a responsibility to prepare them for the society in which they will live and work by helping them gain appropriate skills. The fact that the preschool learning environment has many unresolved issues regarding the use of technology, and that research on technology use in early childhood science education is still in its infancy, makes the current study apt and timely. The increasing use of audio-visual media and technology in children's everyday learning environment calls for attention as to how teachers can prudently use technology for purposeful science teaching. Although the unintended influence of technology on innocent minds cannot be ruled out, striking a sensible balance is the key. It is important to examine the learning environment in terms of preschool teachers' beliefs and what pedagogical practices exist, if and when teachers try to integrate technology during intentional teaching. This can be pivotal in shaping young children's science engagement from preschool onwards. The current study sheds light on preschool teachers' beliefs and pedagogical practices in the context of integrating technology to engage young children in learning science, which few other have addressed. Another innovative aspect of this study is the use of Mishra and Koehler's (2006) TPACK framework, which has rarely been applied to explore preschool teachers' technological pedagogical beliefs and practices. This framework is explained in the next section.

CONCEPTUAL FRAMEWORK

Expanding Shulman's (1986) concept of Pedagogical and Content Knowledge (PCK), Mishra and Koehler (2006) added an additional domain of technological knowledge into PCK and created the TPACK framework in order to teach effectively. This study looks at the complex interplay and interaction between teachers' Pedagogical Knowledge (PK) and Technological Knowledge (TK) when teaching science concepts. Teachers' Technological Pedagogical Knowledge (TPK) is considered to be the basis of effective teaching with the integration of technology, especially in the context of play-based pedagogical practices in preschool settings. Chuang and Ho (2011, p.101-

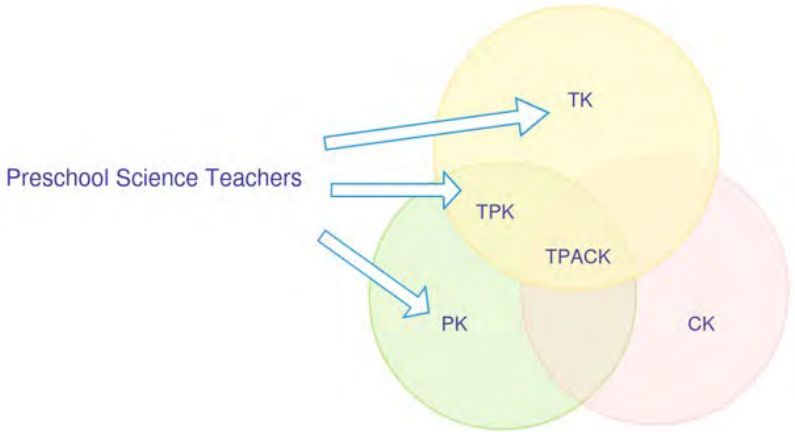

Figure 1. TPACK conceptual framework in a preschool context for science teaching

102) define TPK as "the knowledge of how technology can create new representations for specific content and can impact the practices and knowledge of a given discipline". The authors suggest that when teachers understand, by utilising a specific technology as a teaching and learning tool, they can change the way in which learners practise and comprehend concepts in a specific content area; scientific concepts, in the case of the current study. This includes the knowledge of pedagogical affordances and constraints of different technological tools.

This study considers TPK as a sub-strand of TPACK, where technology can be integrated by teachers as a useful pedagogical tool for promoting children's science learning and inquiry, when its use is well-rationalised. Although teachers' development begins with being equipped with professional knowledge about the scientific content to be taught, preschool teachers' TPK is equally important. For example, TPACK for preschool teachers may include knowledge regarding representations of abstract (non-observable) scientific concepts using voki.com; this can spark children's design thinking process for physical scientific concepts by use of simulations and encouragement of peer-peer interactions, while collecting survey responses as a problem-solving task, and all alongside teachers' own pedagogical reasoning of integration of ICT tools (Chuang & Ho, 2011).

To understand how preschool teachers integrate technology in their pedagogical practices to promote scientific inquiry, this study developed an initial conceptual framework (**Figure 1**) which is predicated on the TPACK concepts (Mishra & Koehler, 2006). Since the studied knowledge primarily focuses on teachers' effective pedagogical practices in a technology-enhanced learning environment, only the TPACK subcategory elements of TPK (TK and PK) were included in the conceptual framework. The current study considers that when teachers believe and demonstrate how pedagogy and technology can be infused in their instructional practices, these can jointly support children's science engagement.

METHODOLOGY

Context of the Study

In Australia, preschool education is provided by both private and public sectors, which include long day care centres, sessional and community kindergartens, and Early Learning Centres (ELC) affiliated with private primary and secondary schools. The EYLFA supports all professionals who work with children aged 0-8. Given the qualitative nature of the research focus, the line of inquiry favoured a case study approach, which is particularly useful when looking at a certain process, that is, how teachers embed technology as a learning tool to engage children in learning science (Yin, 2003). Furthermore, the case study design allows classroom activities to be examined in detail and deeply (Yin, 2014).

In the context of this study, it was crucial to be in proximity to reality, observe the teachers' pedagogical practices and also hear the viewpoints of the teachers' use of technology in their planning of children's activities and teaching practices. Ethical procedures were ensured to seek teachers' consent, being mindful that the observation sessions were not intrusive, and the interview questions suited the teachers' pedagogical needs, opinions and respected their professional knowledge and experiences. Parental consent was sought for their children to participate in the project. Pseudonyms have been used for the ELC classrooms and their respective teachers and children.

Table 1. Teacher observational protocol

Essential features of teachers' Technological Pedagogical Knowledge (TPK) for developing children's science engagement	Indicators	Elements of TPACK conceptual framework
1. Teacher planning	- Curriculum goals aligned to the intentionally planned activity - Learning intentions clearly defined, displayed, and reviewed with children - **Well planned selection of technological tool** that aligns with the learning objective/child's interest taken into account - Meaningful activities that integrate science concepts (e.g. simulations, constructing models that promote science vocabulary opportunities while drawing, reading, listening, and/or speaking)	PK
2. Scaffolding children's prior knowledge	- Concepts linked to children's background experiences and science concepts - Teachers make **specific links to children's use of technology** or media entertainment within home contexts	PK
3. Building children's inquiry skills	- **Using the appropriate technological tool**, a variety of questions asked that promote children's inquiry skills (e.g. what do you think, what if, why did, how did, what might happen if, how would you?) - Teachers promote creative thinking skills by asking scientific oriented questions - **Selection of technology-based tool** helps in visualizing abstract science concepts and building creative models	TK
4. Teacher-child and peer-peer interactions	- **Using the technological tool** poses opportunities for interaction and discussion between the teacher/child and among children about science concepts - Ample opportunities for children to clarify key science concepts from the learning objectives - Teacher's questioning spark children's creative thinking	PK
5. Engaging children in science learning	- **Teachers' selection of technological tool** stimulates children's imaginative thinking - Children research science oriented questions using technology together with the teacher - Children generating hypothesis or making predictions - Children engage in problem solving and come up with new imaginary ideas/innovative solutions - Children produce an artefact as a result of this activity using technology	TPK
6. Teacher Assessment/Review of children's science understanding	- Comprehensive review of the key science concepts - **Use technology** to provide regular feedback to children on their output (language, content, work, drawing)	PK

Participants and Data Collection

The participants in this project included three ELC 3 (three-year-old kinder) and four ELC 4 (four-year-old kinder) classroom teachers along with their children. A total of seven teachers (six females and one male) from three different ELCs participated. All the teachers had a Bachelor of Early Childhood qualification and were early- to mid-career teachers. The ELCs were affiliated with independent International Baccalaureate (IB) primary-secondary schools situated in culturally diverse communities in the metropolitan suburbs of Australia. The schools were characterised by a parental community of middle-to-high socioeconomic status.

The researcher visited each of the ELCs for two days a week over a fortnight to observe how the teachers used technology to engage the children in science-based activities. All the teaching episodes and children's experiences over the two days in each ELC were observed using the teacher observational protocol (**Table 1**).

The observation protocol comprised the essential features of teachers' TPK and related indicators for developing children's science engagement. These pedagogical features were adapted from the Effective Early Education Experiences for Kids (E4Kids) study (Tayler, 2016). E4Kids is Australia's largest four-year longitudinal study, conducted in 2010-2013, suggesting that early childhood professionals use intentional teaching strategies that are always purposeful, and may be pre-planned or spontaneous, to support achievement of well-considered and identified goals. The current study extended the E4Kids study's intentional teaching strategies and identified six essential features of teachers' planning and integration of technology to teach science within the TPACK approach:

teacher planning; scaffolding children's prior scientific knowledge; building children's inquiry skills, teacher-child and peer-peer interactions; engaging children in science learning; and, teacher assessment/review of children's science understanding. In addition, **Table 1** shows how the elements of the TPACK framework (TK, PK and TPK) are linked to the essential features and the related observed indicators. This observational protocol was crucial in analysing the data.

In addition, to document the amount of children's exposure to science experiences along with the integration of technology, the researcher collected teachers' weekly plans across the school terms. These documents helped identify how often science lessons were being intentionally incorporated into teachers' planning. A total of nineteen weekly plans (from the three ELC 3 and four ELC 4 teachers) were collected. These weekly plans incorporated sampled activities/experiences that the teachers had conducted across two school terms (approximately 20 weeks of school), prior to the beginning of the current project. In addition, the documentation included photographs of children's samples of work, artefacts, children's constructed models and teachers' reflection notes.

After the observational period, the seven teachers were interviewed. The teacher interview protocol included questions such as "how do you see the importance of using technology in teaching science?", "can you provide examples of using technology for children's science learning", "how do you plan to use technology for science activities" and "how do you feel the children respond to the learning of science and using the technology resource?".

Data Analysis

Data analysis was conducted in two stages. Firstly, the teacher observations and documentation were analysed using the teacher observational protocol (**Table 1**) underpinning the study's TPACK conceptual framework (**Figure 1**). This protocol helped in mapping teachers' TPK, TK, PK to understand how the essential features and the related observed indicators were evident in the teachers' pedagogical practices. For example, as seen in **Table 1**, teachers' PK was mapped through indicators such as planning documents, reflection journals, pedagogical reasoning for their choice of technology being used, and so on. Teachers' TK was mapped through indicators such as how they considered and used an appropriate technological tool to provoke children's questioning and inquiry, using technology to produce creative models or artefacts, and so on.

In the second stage of data analysis, for the seven teachers' interviews, thematic analysis was conducted by drawing on the elements of the TPACK framework (TPK, TK, PK). This revealed teacher's beliefs, perceptions and related experiences of using technology while planning and engaging children in learning science. Initial data analysis involved identifying themes within each case followed by a cross-case analysis of all teacher interviews (Yin, 2013). In summary, the following two steps were performed to analyse the seven teacher cases and deduce the themes (Bryman, 2012).

1. Development of specific codes: The codes were generated based on participants' responses, past literature and that were pertinent to the study's research question. Example codes derived from teacher responses included "beliefs", "practices", "use of technology", "experiences and pedagogical knowledge", "planning" and "children's scientific inquiry".

2. Deducing themes from codes by examination of similar and contrasting patterns between the teachers' responses: The identified codes that represented segments of an individual teacher case were inspected and compared to elucidate how differently or similarly the concept was perceived and discussed by other teachers. This allowed aggregation of the data into meaningful themes. For example, repeated codes such as "knowledge of iPad apps", "choice of technology resource", "introducing technology and science", and "ideas to use technology" were clustered into the theme "Teachers' technological beliefs and practices in science instruction". Codes such as "planning to use technology", "learning to use apps and robots", "research and investigate on internet", and "incorporate science and technology to help children" were mainly about teachers' beliefs, experiences and related technological pedagogical practices and thus were clustered into the theme "Teachers' technological and pedagogical beliefs and practices in science instruction".

In order to maintain the qualitative rigor of the study, member checking was employed. Member checking is considered a reflexive mode of knowledge production that establishes rigor by completing triangulation (Cho & Trent, 2006). In the present study, member checks involved showing the interview transcripts to the preschool teachers to ensure that what they actually mentioned had been coded and written. This, in turn, aimed to enhance the reliability of the data collected by empowering the parent participants and reorienting the focus of the research.

FINDINGS

The findings are presented as two themes of "Teachers' technological beliefs and practices in science instruction" and "Teachers' technological and pedagogical beliefs in science instruction". In reporting the data from

Figure 2. Example of Digestive system model in ELC 3 room

these themes, exemplars from teachers' planning documents and interview responses provide an interpretive view of their beliefs and practices in using technology for children's science engagement (Campbell & Jobling, 2010).

Teachers' Technological Beliefs and Practices in Science Instruction

Tina's (ELC 3 teacher) document analysis and observations of integration of technology showed that she mainly planned for hands-on science activities through which the children investigated and participated in inquiry-based experiences. Examples included making a snow dome, sand and water play, exploring the naturalist environment, growing seeds, rainbow colours experiment, season changes, and incursions such as a visit from the doctor. In terms of the use of technology and her TK, Tina documented children's experiences and interactions through digital photography that made up children's portfolios. She also used the classroom projector to showcase children's work from their portfolios, where the children communicated with their peers to share their insights about what they had learned from the activity. Tina's reflection journal also documented how children found sharing the similarities and differences each other's artefacts as visuals on the overhead projector. In one unit of inquiry on 'Changes', Tina used iPad apps to display changes in body and facial expressions as a provocation in one of the activities, where she had planned to demonstrate causation and change.

Similarly, Maya's (ELC 4 teacher) integration of technology included using an overhead projector. She perceived that the use of refracted light to produce images, reflections, and shadows was considered as a technology tool, besides using iPads. Her planning documents portrayed that she considered science and technology as a transdisciplinary program, relied mainly on everyday concepts, and browsed information using iPads with children to indulge in scientific inquiry. Maya also used visible thinking routines such as 'See Think Wonder', where children took images of objects under investigation such as growing seeds, engaged in conversations with their peers about what they found and communicated their thinking. While there were notable instances in Tina's and Maya's PK where they intentionally planned for exposing children to meaningful scientific everyday concepts, their TK was only evident through the occasional use of iPads – and this was more for research-based purposes rather than using them as an instructional tool. This demonstrated that their TK needed further support and insights into the types of technological pedagogical affordances available. Figure 2 provides two photos of how the children and Tina together researched and gathered information, downloaded a printable of the human body structure and depicted what changes happen to food when it goes inside the body. Subsequently, they developed a model of the digestive system, thus blending the use of internet research and hands-on materials.

With respect to teachers' technological beliefs, there was a consensus amongst all the teachers that engaging children in learning science was seen as a focus in their ELC. ELC 4 teacher Emma shared her perceptions that "There's a time and a place for using technology. I probably use it as more of a research tool. You have to be interested as a teacher in teaching science and to make sure it is incorporated into your classroom. If I know which apps, just to learn a little bit about what's out there". When asked about the use of any form of technology in their

ELC classes, the teachers stated that they do not use it much but definitely saw the value of integrating technology, particularly for teaching unobservable science concepts. Likewise, Allie (ELC 4 teacher) admitted, "We use the iPads a lot actually for research sorts of things but definitely this is an area to move for sure. Again what is that benefit of having the higher technology with the iPads is also the sort of thing". It seemed there were some confounded perceptions about whether iPads were to be considered as higher-rated technology resource, and, as such, how teachers could justify their use of iPads was a confusing belief.

On the other hand, out of the seven teachers Kenny, an ELC 4 teacher, perceived himself to be most confident in using technology to engage children in scientific concepts. "We have a big screen where you can plug your iPad and children come up one at a time and they have their turns, and we can do a discussion backwards and forwards. We talk about functionality when we were investigating the bones of the body using iPads". Kenny seemed to make judicious use of well-chosen iPad apps as a resource to provide pedagogical solutions and generate curiosity in children's minds about the parts of the body and functions of the bones. Moreover, he saw technology as a tool for children to share their thinking through peer interactions.

Indeed, it appeared that the teachers were adept at integrating technology in the teaching of relevant science concepts when there was a time and opportunity for it. Nonetheless, some were cautious because of their ELC's policy regarding willingness to promote the integration of technology into pedagogical practices. Teachers' perceptions portrayed mixed feelings about the use of technology versus traditional hands-on activities with preschool children in teaching science concepts. Although the teachers generally possessed some TK, how they could sensibly translate such TK into their instructional strategies (TPK) needed some further pedagogical support.

Teachers' Technological and Pedagogical Beliefs in Science Instruction

Document analysis and observations of Emma's teaching practices (ELC 4 teacher) showed evidence of purposeful planning for play-based experiences within the scientific units of inquiry such as 'Living and Non-living', 'Water', 'Patterns' and 'Space'. Interestingly, due to the proximity of the junior and senior school campuses, Emma planned for the children to visit the senior school laboratories to use technology resources in their investigation of the 'Living and Non-living' unit. This allowed children to observe and interact with their peers when they indulged in using technology in the laboratories, for example, digital microscopes to view plant and animal cells. Although Emma engaged the children in using scientific language such as 'building blocks of life', 'cells', 'particles', and use of microscopes, she did not integrate technological resources either independently or in conjunction with the children.

Another exemplar included where, within the unit of inquiry 'Space', the ELC 4 children visited their Grade 3 senior peers to participate in the making of 3D models of the solar system using computer software. This was a great platform for senior peers to share their learning with the ELC 4 children. Emma further developed children's knowledge of the solar system and planets by engaging in reflective inquiry from the 3D models that the children had seen. For example, on one occasion during the creative movement session, children were asked open-ended questions to reflect on what they had observed and apply this in problem-solving; for example, "What do you need to visit the Moon?", "What would you like to know about the solar system?" Emma concluded this unit of inquiry by inviting the children to design their own representation of the solar system and planets through art and craft, but not by any use of technological tools.

In summary, Emma, in a similar manner to Tina, predominantly planned for traditional hands-on science experiences for the children. However, she more frequently used collaborative strategies to engage children in technologically constructed scientific thinking and reflective inquiry and made use of technology resources as demonstrated by senior peers rather than using technology herself with the ELC children. The senior school laboratories seemed to be predominantly used as a segue to expose children to technologically constructed learning of science concepts, with occasional use of the internet as an educational resource. Emma's TPK (similar to Tina's) in "sensibly" planning for an appropriate technological resource and getting children to indulge in scientific inquiry and exploration of the topic at hand, seemed to be at a nuanced pedagogical stage.

In Kenny's ELC 4 classroom, observations showed that he judiciously planned for technology-constructed experiences. Kenny provided opportunities for children to discuss their scientific explorations and understandings with their peers as well as the teacher using iPad apps. His choice of technology and his TPK seemed instrumental in stimulating children's curiosity and problem solving. For example, as seen in **Figure 3**, using technology-based toys such as Bee-bots for coding, children learned to program the Bee-bot to reach a certain target. Kenny used questions such as "How many times do you think it will need to go forward, estimate". Children were invited to take turns and encouraged to achieve their target using trial and error. Document analysis showed the rationale behind this activity was to instigate children's creative thinking skills and be able to exercise control over tech-toys such as Bee-bots, while also practising coding. He had clear learning objectives in his planning for technology-based experiences, where children learned to persist in problem-solving challenges.

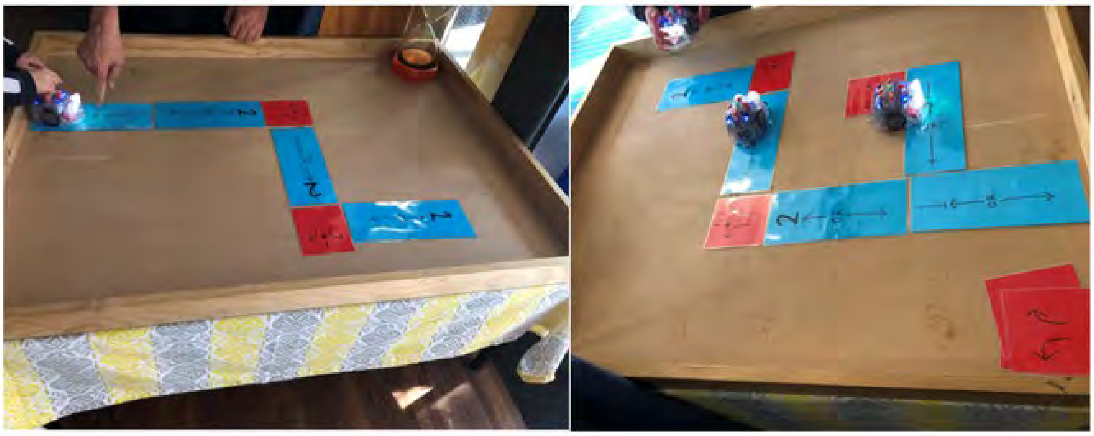

Figure 3. Use of Bee-bots in ELC 4 room

Kenny also demonstrated his use of tech-toys such as Bee-bots in planning experiences that stimulated children's mathematical inquiry, although these experiences were not typical science-based ones. In relation to integrating technology for science experiences, there were occasional opportunities where Kenny engaged the children in research type activities using iPads. Within the 'Bones and Bodies' investigation unit, during the extended research process, Kenny exposed children to iPad apps with bone structure depictions that were of great interest to the children. This inquiry unit appeared to open up frequent opportunities for children to raise questions within the technologically driven play process and using the iPad apps led to the discovery of new scientific knowledge. In summary, Kenny's TPK seemed to be prudent and this was consistently shown in his planning and allowing children to indulge in tinkering with technological resources and inquiring along the way.

In their interviews, teachers shared their technological and pedagogical practices. For example, many used projectors in the classroom to showcase the children's work: "When children made star constellations and did pinprick drawings on paper and then we transferred it to the projector to project onto the wall". Similarly, Kenny shared his perceptions of how children engaged well when he integrated iPads in inquiry projects: "We have a couple of iPad apps, one called Swallows Playground, where children make a little creature go over a maze, which they absolutely adore". It seemed the teachers were generally proactive in providing engaging learning environments where children were actually having fun whilst also being creative, for example by giving instructions to a Bee-bot to perform tasks and collaborating to problem solve. Although, the teachers were in agreement regarding the appropriateness and usefulness of integrating technology in their pedagogical practices, they all still flagged the need for the "how" to do things, not about ''what'' is required. As Emma stated, "There's definitely great apps that you can use for different things. I've never used a little robot or anything like that, but I know that another teacher [in the neighbouring primary school] has shown a robot". It was apparent that teachers did express the need to develop their TPK in being able to competently and sensibly plan an appropriate technology resource in providing opportunities for children's scientific inquiry.

In one instance, while reflecting on her past teaching experiences with six-year olds, ELC 3 teacher Tina admitted using animated videos from BrainPop, a popular source in junior school. She commented: "We have the big TV so you can show children video footage or photos or science facts. But it's used a lot more in junior school than ELC". It seemed that, due to the school's focus being more on the use of technology from primary school onwards, this was somewhat problematic in allowing teachers to be creative in their pedagogies while integrating technologically constructed science experiences for ELC children. The question was then whether or not the teachers were given the flexibility to be risk-takers in their technological pedagogical practices in order to engage the ELC children in learning science.

The teachers highlighted that another use of technology was to maintain two-way communication with parents and share children's learning experiences at the preschool. "If we've done an experiment in the class, we'll always put a link to a science webpage that we've got the idea from into the children's journals". By using technology apps to connect with parents and sharing children's digital portfolios, the teachers seemed to have a greater sense of children's levels of experience relating to science at home. Nevertheless, although the ELC teachers were keen to integrate technology to communicate with parents, there were still issues with their intentional use of technology as a pedagogical resource (TPK) and how to translate this into authentic, technology-based inquiry experiences suitable for ELC children's science learning.

DISCUSSION

In this study, the teachers demonstrated positive perceptions of integrating technology and comfortably planned for traditional science experiences for young children. Teachers' believed that, by integrating technology as an instructional strategy, children were able to see and enquire about everyday scientific concepts. Such beliefs facilitated their pedagogical decisions of wanting to plan more; however, many did not know how and which affordances would be most appropriate. The fact that teachers acknowledged that infusing technology can be a value-add to support children's inquiry and procedural knowledge, as in the case of using Bee-bots, contrasts with studies that have suggested otherwise (Aldhafeeri et al., 2016). Teachers were keen to incorporate iPad apps and coding robots as they believed such technological experiences can spark children's interest in inquiry and problem solving.

Teachers' use of technology as a pedagogical resource was predominantly used to involve parents and understand children's prior experiences about scientific concepts taught at the preschool. Extending Kermani and Aldemir's (2015) and Ailincai and Gabillon's (2018) findings, this study highlights the point that, when teachers intentionally plan and deliver technologically constructed science experiences for preschoolers, this is believed to present authentic science learning opportunities for children. When teachers' TPK and related teaching practises formulate the cornerstone of developing children's science experiences, this serves as a platform for building children's science engagement.

In contrast to those in the study of Aldhafeeri et al. (2016), the teachers in the current study acknowledged the importance of giving young children opportunities to experience digital technologies alongside hands-on experiences. Teachers were not deterred, but rather accepted the thought of embedding technology in their planning of science-based experiences. As some of the teachers used programmable robots and were keen to continue using such robots as a multimodal learning experience for children, this suggested that teachers' PK was sound enough to engage children in collaborating for problem-solving challenges.

However, the findings also flagged the need for supporting preschool teachers' progression in TK and TPK, especially to make them confident in "how" to implement age-appropriate technologically devised activities in their scientific pedagogical practices (Chuang & Ho, 2011; Marsh et al., 2018). There is a need to develop a robust integrated pedagogical approach for preschool teachers' implementation of technology-constructed practices in enhancing children's science inquiry and procedural knowledge (Havu-Nuutinen et al., 2017). In order for children to gain deeper and more lasting understandings in science, teachers need to rationalise when and why to introduce technology in their day-to-day teaching. Teachers need to know when to be deliberate, purposeful and thoughtful in their pedagogical decisions and actions (Edwards & Bird, 2017; Edwards et al., 2018). Teachers need to be aware of the affordances that can achieve technology integration within their TPACK and mindfully use such knowledge for teaching, assessing and subsequent children's science learning.

The limitations of this study may possibly lead to future studies that quantitatively explore the TPACK framework within the context of preschool science education. Additionally, further examination of whether teachers' affective knowledge, as well as science-content knowledge (CK), might be an important factor contributing to their technological pedagogical knowledge in teaching science is needed. It is critical that children receive authentic and varied inquiry-based experiences in preschool, stimulating them to question and become curious about the science around them (Fleer, 2015, 2018). Using an appropriate technological tool while exposing children to scientific concepts, teachers can generate a variety of questions to build children's scientific inquiry. Given that early exposure to science-based experiences are important for children to become innovative, agile and creative thinkers ready to meet present and future challenges (ECA, 2018), teachers' TPACK can serve as a continuum for children's scientific thinking and inquiry building in the early years as they transition into primary school. This study is an important contribution to early childhood research underpinning the TPACK framework where the added value is in understanding teachers' positive conception of integration of technology in their pedagogy to support children's science learning and procedural knowledge (Hsu et al., 2014; Jen, Yeh, Hsu, Wu, & Chen, 2016; Mishra & Koehler, 2006).

Implications and Further Plans for Teachers' TPACK Development

This study identifies how teachers use technology in their pedagogical practices to engage children in learning science. One key finding is that this is easier said than done. Further research should be undertaken to assist in the development of preschool teachers' technological pedagogical knowledge and skills to enhance children's scientific inquiry. Additionally, Arnott et al. (2018) have suggested that engaging children as collaborators in processes such as pedagogical innovation and subsequent documentation highlights the potential of teachers' integration of technology-constructed practices. Further research is recommended to more closely align teachers' TPK and related practices with science content knowledge by co-researching together with children and foregrounding both teachers' and children's perspectives. For some teachers, this will require a pedagogical shift; specifically, one that incorporates technology in constructing inquiry-based opportunities for children rather than hands-on experiences alone, thus enabling multimodal learning platforms (Yelland, 2018). This pedagogical shift will require access to professional development focusing on ICT use (Aldhafeeri et al., 2016; Edwards et al., 2018). The focus should be on contextualising, introducing and adapting technology integration in teaching preschool science. This will simultaneously build confidence in and highlight the impact on children's creativity and inquiry skills, rather than just focusing on professional development and skills.

Statement on Open Data, Ethics and Conflict of Interest

The research project was approved by the Monash University Human Research Ethics Committee (Project Number: 13307) and followed all the protocols inherent to the conduct of research in an ethical manner. The data are not available due to the protocols established by the ethics committee, and thus are kept in a secure location on campus. The authors acknowledge they have no financial interest or benefit arising from the direct applications of their research.

ACKNOWLEDGEMENT

The authors thank the research committee of Monash University's Faculty of Education for the Seeding grant funding for this project.

REFERENCES

Ailincai, R., & Gabillon, Z. (2018). Analysing teachers' representations of digital technology using a Grounded Theory approach. *Eurasia Journal of Mathematics, Science and Technology Education, 14*(10), https://doi.org/10.29333/ejmste/93380

Aldhafeeri, F., Palaiologou, I., & Folorunsho, A. (2016). Integration of digital technologies into play-based pedagogy in Kuwaiti early childhood education: Teachers' views, attitudes and aptitudes. *International Journal of Early Years Education, 24*(3), 342-360. https://doi.org/10.1080/09669760.2016.1172477

Arnott, L., Palaiologou, I., & Gray, C. (2018). Digital devices, internet-enabled toys and digital games: The changing nature of young children's learning ecologies, experiences and pedagogies. *British Journal of Educational Technology, 49*(5), 803-806. https://doi.org/10.1111/bjet.12676

Bryman, A. (2012). *Social research methods* (4th ed.). New York: Oxford University Press.

Campbell, C., & Jobling, W. (2010). *Science in early childhood.* Port Melbourne, Vic: Cambridge University Press.

Cho, J., & Trent, A. (2006). Validity in qualitative research revisited. *Qualitative Research, 6*(3), 319–340. https://doi.org/10.1177/1468794106065006

Chuang, H., & Ho, C. (2011). An investigation of early childhood teachers' technological pedagogical content knowledge (TPACK) in Taiwan. *Journal of Kirsehir Education Faculty, 12*(2), 99–117. Retrieved from https://www.researchgate.net/publication/228457330_An_Investigation_of_Early_Childhood_Teachers'_Technological_Pedagogical_Content_Knowledge_TPACK_in_Taiwan

Craft, A. (2011). *Creativity and Education Futures.* Stoke on Trent: Trentham Books.

DeCoito, I., & Richardson, T. (2018). Teachers and technology: Present practice and future directions. *Contemporary Issues in Technology and Teacher Education, 18*(2), Retrieved from https://www.citejournal.org/volume-18/issue-2-18/science/teachers-and-technology-present-practice-and-future-directions/

Department of Education and Training. (2017). *Illustrative maps from the VEYLDF to the Victorian Curriculum F–10.* Retrieved from http://www.vcaa.vic.edu.au/Pages/earlyyears/vfldoutcomes/index.aspx

Donohue, C. (2015). *Technology and digital media in the early years: Tools for teaching and learning*. New York, NY: Routledge. https://doi.org/10.4324/9781315856575

Early Childhood Australia. (2018). *Statement on young children and digital technologies*. Retrieved September 8, 2018 from http://www.earlychildhoodaustralia.org.au/our-work/submissions-statements/eca-statement-young-children-digital-technologies/

Early Years Learning Framework (2018, July 8). *Learning outcome planning cycle resource: Children are confident and involved learners*. Retrieved from https://www.vcaa.vic.edu.au/Documents/earlyyears/Planning-Cycle-Resource_LearningMay2018.pdf

Edwards, S., & Bird, J. (2017). Observing and assessing young children's digital play in the Early Years: Using the Digital Play Framework. *Journal of Early Childhood Research, 15*(2), 158-173. https://doi.org/10.1177/1476718X15579746

Edwards, S., Straker, L., & Oakey, H. (2018, September 8). *Early Childhood Australia: Statement on young children and digital technologies.* Retrieved from http://www.earlychildhoodaustralia.org.au/wp-content/uploads/2018/10/Digital-policy-statement.pdf

Fleer, M. (2010). *Early learning and development: Cultural historical concepts in play.* Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511844836

Fleer, M. (2015). *Science for children*. Cambridge: Cambridge University Press. https://doi.org/10.1111/chso.12095

Fleer, M. (2018). Digital animation: New conditions for children's development in play-based setting. *British Journal of Educational Technology, 49*(5), 943-958. https://doi.org/10.1111/bjet.12637

Havu-Nuutinen, S., Sporea, D., & Sporea, A. (2017). Inquiry and creativity approaches in early years science education. A comparative analysis of Finland and Romania. In E. Kimonen & R. Nevalainen (Eds.), *Reforming teaching and teacher education: Bright prospects for active schools* (pp. 89-116). Rotterdam, The Netherlands: Sense Publishers. https://doi.org/10.1007/978-94-6300-917-1

Highfield, K. (2010). Robotic toys as a catalyst for mathematical problem solving. *Australian Primary Mathematics Classroom, 15*(2), 22-27. Retrieved from https://files.eric.ed.gov/fulltext/EJ891802.pdf

Hsu, C. Y., Liang, J. C., Tsai, C. S., & Chai, C. (2014). Exploring preschool teachers' technological pedagogical content knowledge of educational games. *Journal of Educational Computing Research, 49*(4), 461-479. https://doi.org/10.2190/EC.49.4.c

Jen, T., Yeh, Y., Hsu, Y., Wu, H., & Chen, K. (2016). Science teachers' TPACK-Practical: Standard-setting using an evidence-based approach. *Computers & Education, 95*(C), 45-62. https://doi.org/10.1016/j.compedu.2015.12.009

Kärkkäinen, K., & Vincent-Lancrin, S. (2013). Sparking innovation in STEM education with technology and collaboration: A case study of the HP Catalyst Initiative. *OECD Education Working Papers, No. 91*. OECD Publishing. https://doi.org/10.1787/5k480sj9k442-en

Kermani, H., & Aldemir, J. (2015). Preparing children for success: Integrating science, math, and technology in early childhood classroom. *Early Child Development and Care, 185*(9), pp. 1504–1527. https://doi.org/10.1080/03004430.2015.1007371

Marsh, J., Plowman, L., Yamada-Rice, D., Bishop, J., Lahmar, J., & Scott, F. (2018). Play and creativity in young children's use of apps. *British Journal of Educational Technology, 49*(5), 870-882. https://doi.org/10.1111/bjet.12622

Milne, I. (2010). A sense of wonder arising from aesthetic experiences should be the starting point for inquiry in primary science. *Science Education International, 212,* 102-115. Retrieved from http://www.icaseonline.net/sei/june2010/p4_ian.pdf

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A Framework for Teacher Knowledge. *Teachers College Record, 108*(6), 1017-1054. Retrieved from http://one2oneheights.pbworks.com/f/MISHRA_PUNYA.pdf

Palaiologou, I. (2016). Children under five and digital technologies: Implication for early years pedagogy. *The European Early Childhood Research Journal, 24*(1), 5-24. https://doi.org/10.1080/1350293X.2014.929876

Parette, H. P., Quesenberry, A. C., & Blum, C. (2010). Missing the boat with technology usage in early childhood settings: A 21st century view of developmentally appropriate practice. *Early Childhood Education Journal, 37,* 335-343. https://doi.org/10.1007/s10643-009-0352-x

Sandoval, W. A., Sodian, B., Koerber, S., & Wong. J. (2014) Developing children's early competencies to engage with science. *Educational Psychologist, 49*(2), 139-152. https://doi.org/10.1080/00461520.2014.917589

Shulman, L. S. (1986). Paradigms and research programs for the study of teaching. In M.C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed.). New York: Macmillan.

Tayler, C. (2016). E4Kids. Retrieved March 4, 2019, from https://www.education.vic.gov.au/about/research/Pages/E4kids.aspx

Voogt, J., Fisser, P., Roblin Pareja, N., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge - A review of the Literature. *Journal of Computer Assisted Learning, 29*(2), 109-121. https://doi.org/10.1111/j.1365-2729.2012.00487.x

Wang, F., Kinzie, M. B., McGuire, P. & Pan, E. (2010). Applying technology to inquiry-based learning in Early Childhood Education. *Early Childhood Education, 37*(5), 381-389. https://doi.org/10.1007/s10643-009-0364-6

Yelland, N. (2018). A pedagogy of multiliteracies: Young children and multimodal learning with tablets. *British Journal of Educational Technology*, *49*(5), 847-858. https://doi.org/10.1111/bjet.12635

Yin, R. K. (2003). Case study research: *Design and methods* (3rd ed.). Thousand Oaks, CA: Sage.

Yin, R. K. (2014). *Case study research: Design and methods* (4th ed.). California: Sage Publications.

http://www.ejmste.com