Mobile learning in pre-service teacher education: Examining the use of professional learning networks

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Interest in how to use mobile devices to support teaching and learning has increased as technologies have become more sophisticated and ubiquitous. A recent focus in teacher education is the use of mobile devices to support teachers' professional learning networks (PLNs). This study investigates how pre-service teachers (PSTs) use mobile technologies to support different aspects of their PLN activities. The study uses a qualitative methodology, where data from focus group discussions, artefact collection, and participant journals kept by 11 final year PSTs provided nuanced insights into their mobile learning practices. A validated mobile pedagogical framework (Kearney, Schuck, Burden, & Aubusson, 2012) is used to analyse the data. Findings uncover a deeper understanding of exemplary mobile learning approaches in initial teacher education and have implications for effective preparation of PSTs for career-long professional learning.

Introduction

In the context of teacher education, professional learning networks (PLNs) are defined by Trust, Krutka, and Carpenter (2016) as "complex systems of interactions consisting of people, resources and digital tools that support ongoing learning and professional growth" (p. 28). Underpinned by a premise that learning is a social process (Vygotsky, 1978), teachers' use of technology-mediated PLNs, for example using social media, can supplement face-to-face (F2F) professional learning strategies to create a broader learning landscape for teachers' interactions, knowledge exchange, and negotiation of meaning with peers (Jenkins, Purushotma, Weigel, Clinton, & Robinson, 2009). Use of technology-mediated PLNs is becoming vital to teachers' ongoing learning and their use is increasingly seen as a legitimate and effective approach for their professional growth (Trust et al., 2016; Xerri, 2014). Research into use of technology-mediated PLNs as a professional learning tool has been conducted mostly with practising teachers, while research into pre-service teachers' (PSTs) use of PLNs is relatively limited (Carpenter, Krutka, & Trust, 2016).

Given the increasing functionality and frequency of the use of mobile devices (m-devices) and associated applications (apps) to support teachers' professional learning, for example using social media (Carpenter & Krutka, 2015; Carpenter et al., 2016; Visser, Evering, & Barrett, 2014), this study makes a timely examination of contemporary use of mobile technology-supported PLNs. Mobile learning (m-learning) is considered as learning mediated by mobile devices such as smartphones and tablet computers (Schuler, Winters, & West, 2012). In this study, we examine m-learning from the perspective of learners' experiences rather than the affordances of the m-devices or associated apps (Traxler, 2007), and we use a socio-cultural perspective to examine this phenomenon (Wersch, 1991).

There has recently been considerable interest in exploring the use of mobile technologies to support pedagogical practices in school education (Adams Becker, Freeman, Giesinger Hall, Cummins, & Yuhnke, 2016), and m-learning has also been espoused as an important part of contemporary teacher education (Baran, 2014; Herrington, Ostashewski, Reid, & Flintoff, 2014). This study aims to contribute to an emerging literature base on m-learning in initial teacher education, by providing a nuanced understanding of how use of mobile technologies supports PSTs' professional learning networking. This paper addresses the following research questions:

- How do PSTs use their mobile devices to mediate their PLN activities?
- What are PSTs' perceived challenges and concerns relating to mobile technology-supported PLN activities?

Background

Professional learning networks in teacher education

In response to growing evidence of ineffective formal professional learning strategies for teachers, especially traditional top-down approaches underpinned by transmissionist strategies, such as staged workshops led by external experts (Beauchamp, Burden, & Abbinett, 2015), teachers' use of less formal, typically self-initiated PLNs has been espoused as a more collaborative, autonomous option and worthy of further research (Kearney, Schuck, Aubusson, & Burke, 2017; Visser et al., 2014). Teachers' use of PLNs offers a more flexible approach for professional learning, in collaboration with (local and global) teacher peers and other experts, as well as key organisations within and beyond school education contexts, as depicted in Figure 1 (Kearney, Pressick-Kilborn, & Hunter, 2016).

Figure 1. PLNs from a teacher's perspective. (From Kearney et al., 2016, p. 31)

Teachers' professional learning interactions can be enacted through F2F strategies such as mentoring (Burke, Aubusson, Schuck, Buchanan, & Prescott, 2015), critical friendships (Kuh, 2016), action learning groups (Aubusson, Ewing, & Hoban, 2009), and more recently through *unconference* initiatives such as Teachmeets and Edcamps (Swanson, 2013). Unlike traditional courses and workshops, these more autonomous, self-directed strategies encourage teacher discussion and reflection, testing of new strategies, student feedback, and working with colleagues on targeted projects (Aubusson et al., 2009). These F2F strategies can be supplemented by technology-mediated approaches such as use of social network services (e.g., Facebook), microblogging tools like Twitter, and content curation tools like Pinterest. This study focuses on technology-mediated approaches to PSTs' PLN activities, enacted through a mobile device.

Research into use of technology-mediated PLNs has been conducted mostly with practising teachers, providing evidence of an effective approach for their self-regulated, professional learning (Visser et al., 2014). For example, Tour's (2017) study found that practising teachers enjoyed meaning and independence in their professional learning networks and concluded there was value to be gained by increasing teachers' awareness of such networks. While Biddolph and Curwood (2016) showed that having a global PLN allowed their language teacher participants to develop agency, accessibility, and reciprocity in their own learning in ways that can complement traditional school-based professional development methods. Key issues and challenges are emerging relating to teachers' use of PLNs. For instance, a critical issue is the recognition by employers and accreditation bodies of teachers' PLN activities as legitimate professional learning (Kearney et al., 2016). For Berry (2017), teachers' use of PLNs holds the promise of not only improved teaching but also policy changes that include "creating micro credentials that allow teachers to

drive their own high-quality professional learning – and be recognized and rewarded for it" (p. 54). Given the mounting evidence-base supporting the value of technology-mediated PLNs for practising teachers, including specific PLN platforms such as Twitter (Carpenter & Krutka, 2015; Visser et al., 2014), it is imperative for studies to fully explore PSTs' use of PLNs to prepare themselves for their teaching careers.

Researchers have recently focused on the potential of technology-mediated PLNs in pre-service teacher education, with Carpenter et al. (2016) suggesting: "PLNs can facilitate reciprocally beneficial interactions between pre-service and in-service teachers" (p. 1940). PST participants in Krutka's (2014) study used Twitter, Facebook, and Edmodo as part of their studies and found Twitter to be the most beneficial as a professional learning tool. While Carpenter's (2015) study found that PSTs' 'microblogging' (using Twitter) supported sharing of pertinent teaching resources, and communication with educators both inside and outside their university class. Other studies such as Wright (2011) have focused on professional experience contexts, showing the value of PSTs' networking through Twitter to enhance a sense of community and more purposeful reflections on their teaching. However, there is a need for further research into technology-mediated PLNs, particularly about PSTs' use of mobile apps for professional learning (Carpenter, 2015; Visser et al., 2014). Given these apps are used on mobile devices, an exploration of how the affordances of m-learning support these PLN activities is warranted.

Mobile learning practices in teacher education

M-learning practices in teacher education can be categorised into two areas: teacher training about and with mobile learning (Baran, 2014). Teacher education about m-learning involves PSTs learning how to integrate m-devices into their own prospective school teaching. Teacher education with m-learning involves the enhancement of PSTs' professional learning with m-devices; for example, the use of these devices to mediate their reflections on/in practice during their professional placements or using the camera on their device to capture evidence of their teaching practices. This study focuses on the latter category: PSTs' professional learning with m-devices.

A promising area of focus in teacher education has been the use of m-devices to support PSTs' learning during their school-based professional experience. For example, Maxfield and Romano (2013) explored PSTs' use of m-devices to video-record their observations on the first day of their school-based professional experience and examined the impact that peer review of these videos had on their professional learning. The PSTs' use of m-devices enhanced observation, and they could connect to a diverse group of peers and other educators, enabling reflection on both their own and their peers' experiences. More recently, Dann and Allen (2015) investigated how m-devices can be used by PSTs, supervising teachers and teacher educators to provide feedback, while Burden and Hopkins (2017) examined the perceptions, attitudes and beliefs of PSTs using m-devices for professional learning purposes, including during their professional experience. Finally, Pegrum, Howitt, and Striepe (2013) found that PSTs' use of m-devices helped them to stay connected and organised, and to develop a broader understanding of learning spaces and learning networks.

Despite this recent research, there is still a shortage of m-learning studies in teacher education exploring benefits and insights into PST learning (Baran, 2014). This paper specifically contributes to a deeper understanding of PSTs' technology-mediated PLN approaches, and how these activities intersect with their mobile learning practices.

Theoretical perspective

The theoretical underpinning for the paper is a validated mobile pedagogical framework (Kearney et al., 2012). Informed by sociocultural theory (Wertsch, 1991), it highlights three central and distinctive pedagogical features of m-learning: personalisation, authenticity and collaboration (iPAC). How learners experience these distinctive characteristics is influenced by their use of time-space (or context), as depicted in Figure 2.
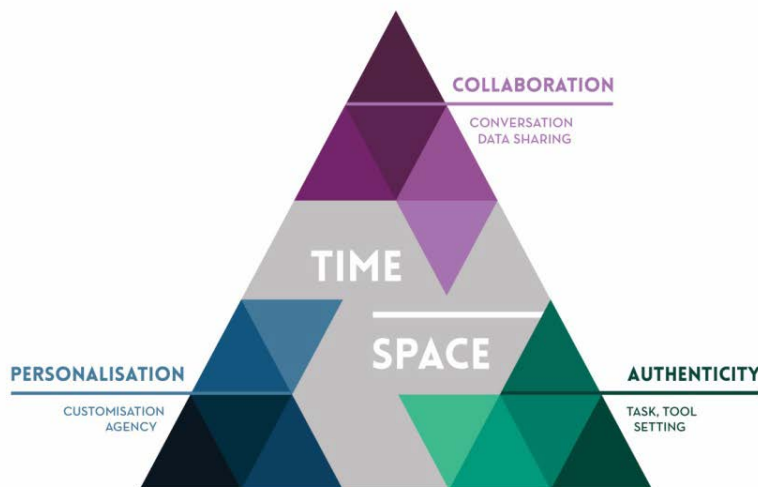
Figure 2. The Mobile Pedagogical (iPAC) Framework comprising three distinctive features of mobile learning experiences. (Adapted from Kearney et al., 2012, p. 8)

The personalisation construct consists of the sub-constructs of *customisation* and *agency*. High levels of personalisation would mean that learners can enjoy an enhanced degree of agency (Pachler, Bachmair, & Cook, 2009) and the flexibility to tailor both tools and activities, interacting with a strong sense of ownership of both the m-device (Traxler, 2007) and the learning process. The authenticity construct privileges opportunities for in-situ, participatory learning (Radinsky, Bouillion, Lento, & Gomez, 2001). The sub-constructs of *task*, *tool*, and *setting* focus on learners' involvement in rich, contextualised in-situ tasks, making use of tools in realistic, typically discipline-specific ways, and driven by relevant, real-life practices and processes (Burden & Kearney, 2016). The collaboration construct captures the conversational (Sharples, Taylor, & Vavoula, 2007), networked features of m-learning. It consists of *conversation* and *data sharing* sub-constructs, as learners engage in negotiated meaning-making, forging connections and interactions with peers, experts, and the environment (Wang & Shen, 2012).

The iPAC framework has been used to inform research on m-learning in school education (Kearney, Burden, & Rai, 2015), teacher education (Kearney & Maher, 2013) and other areas of higher education (Kinash, Brand, & Mathew, 2012). For example, Shuck (2016) explored ways in which the iPAC framework could enhance primary teacher education in Mathematics, using mobile technologies, including the challenging of PSTs' beliefs. The framework has recently been used to inform the development of a m-learning toolkit for educators (Burden & Kearney, 2018) aiming to help them diversify their mobile pedagogical practices; and to inform the design of an app evaluation instrument in science education (Green, Hechter, Tysinger, & Chassereau, 2014) to aid teachers' rigorous selection and evaluation of K-12 science apps. The theoretical underpinning of the iPAC framework fits with our socio-cultural views of learning with technology. The framework's constructs align well with the inherent personalised and networked aspects of learning with PLNs, providing a useful lens to fully interrogate the PSTs' m-learning experiences in a range of formal and informal settings and schedules (or time-space configurations).

Methodology

A qualitative research paradigm was used in this interpretive study (Erickson, 1986) drawing on case study methods to examine PSTs' mobile technology enhanced learning with PLNs. The aim of the research project was to gain a deeper understanding of contemporary mobile learning practices in pre-service teacher education, exploring the following research questions:

- How do PSTs use their mobile devices to mediate their PLN activities?
- What are PSTs' perceived challenges and concerns relating to mobile technology-supported PLN activities?

For this study, PLN activities are defined as PSTs' use of social media applications to foster interactions with people, resources and digital tools to support their learning as prospective teachers (see Table 1 for examples).

Table 1
PLN activities chosen by sample PST participants

PST participant	Apps mentioned by PSTs	PLN activities mentioned by PSTs (*activities during professional experience)
Rob (Business studies)	Twitter	Learning practical strategies for teaching*. Explored topics relating to innovation in education.
Ming (Science)	Twitter, Pinterest	Finding lesson plans and ideas for hands-on science activities and experiments*. Finding new in-class techniques for assessing science learners*. Archiving resources for teaching. Notes to self and memos. Sharing interesting science phenomena.
Guang (English)	Twitter, Pinterest; Facebook groups; LinkedIn	Browsing English teacher blogs; tweeting during professional development session at school* (run by a science organisation); tweeting with guest panelists during and after an early career teacher day at university. Sharing interesting class activities during and after university classes.
Pat (Maths)	Edutopia, Twitter, Facebook	Sharing photos of his classroom boardwork to elicit feedback on use of Interactive Whiteboard*. Communicating with American teachers.
Angela (Science)	Pinterest, Edmodo, Youtube community	Browsing to become aware of news and recent changes. Browsing, capturing, and saving interest threads and webinars. Finding interesting science experiments and ideas for lessons*.
Deirdre (Science)	Twitter, Facebook groups	Finding what is currently happening in Science and teaching. Finding chemistry teaching strategies* e.g., demonstration ideas, how to best explain topics. Learning about flipped learning. Searching for job opportunities via local science teachers' association. Discovering upcoming meetings and conferences.

Data were collected including; participants' individual journals, focus groups (two per semester), and artefact collection (e.g., self-selected social media posts, images, and annotations). Data were analysed according to emerging themes across all sources, categorised under the three mobile pedagogical constructs of the iPAC framework (Kearney et al., 2012): personalisation; authenticity and collaboration. These themes emerged through independent researcher analysis and subsequent intra-researcher checking. An interpretive approach was employed for this analysis, providing insight into how participants made sense of their experiences (Mason, 1996).

Participants were 11 final year Masters of Teaching (Secondary) PSTs at an Australian university. Six PSTs were specialising in science education, three in mathematics, one in English and one in business studies. Each participant volunteered for the project and either had an extensive, well-developed PLN or was interested in further developing one. After university ethics clearance, participants used their own m-device (either tablets or smart phones) to participate in their self-selected PLN activities in the context of their campus-based studies and school-based professional experience. They were encouraged to include links to their PLN as part of the e-portfolio they were developing in their capstone subject; and they were also encouraged to reflect on their learning in light of relevant Australian Institute for Teaching and School Leadership (AITSL) standards.

PLN activities were chosen by participants for their relevance to their individual professional learning needs in the context of their final year studies. Apart from two meetings with participants and a project Facebook group that was used for administrative purposes, there was minimal intervention or scaffolding by the researchers. PLN activities and apps mentioned by sample PST participants are shown in Table 1. Pseudonyms are used throughout the paper to protect participants' identities.

The PST participants' self-directed activities focused on a range of topics including lesson preparation, teaching strategies, assessment practices, classroom management, literature, feedback strategies, teacher resilience, and innovation. They researched and found resources for campus-based assignments; shared success stories and teaching resources from professional experience; captured and shared images of school students' work and other classroom artefacts on professional experience (in closed communities) and brainstormed teaching ideas. They also focused on recent changes in their own discipline area and explored new career opportunities.

Findings

The findings are organised around the three previously discussed m-learning constructs of the iPAC framework (Kearney et al., 2012): personalisation, authenticity and collaboration. Themes categorised under *personalisation* included features relating to learner choice, agency, and self-regulation, as well as customisation, where m-learning experiences were tailored in some way to individual learners (the PSTs). Themes categorised under *authenticity* included aspects linked to the use of realistic settings, tasks or use of tools (e.g., apps) in a similar way to real-world practitioners to provide relevance and personal meaning (as prospective teachers). Finally, findings categorised under *collaboration* related to PSTs' m-learning experiences involving peer conversations, sharing and rich interactions with others.

Personalisation

PSTs used their m-devices to support personalised learning in numerous ways. Their PLN activities were often emergent and unplanned, and they typically enjoyed high levels of agency. For increasingly time-poor PSTs with tight schedules, this flexibility was perceived as significant. They chose their own apps to suit their specific activities, controlled who and what organisations to network with, and they customised their network to their own professional interests and ways of working.

Exploiting the m-device's portability, the PSTs enjoyed high levels of agency over where and when they participated in their PLNs. They chose a range of settings and times to engage in their PLN, typically using their m-devices during in-between times, in both formal (e.g., university classrooms) but more typically informal contexts such as home and on public transport (Figure 3). For instance, Caroline mentioned in her focus group: "I find it really convenient. I've always got my phone on me. I am always using Facebook and Twitter and LinkedIn. I use it mainly on trains and at home."

Figure 3. Settings where study participants (*n* = 11) used their m-devices to participate in their PLNs. Note. The size of each word in this figure is commensurate with how often it was mentioned by PSTs in study data.

This agency over the scheduling of their PLN activities was perceived as important. Deirdre mentioned in her focus group that she mainly participated in her PLN while "on the go, on trains, dead-time. Between classes. Instances where I wouldn't open a laptop. To check in with what's happening. Just five to ten minutes, when I wouldn't have time to go in more formally". Ming agreed: "Whenever and wherever the urge strikes me. So, … in the classroom, on a train, on my way to and from places – wherever I'm going, at home, wherever." Other terms used by participants to describe this less formal scheduling of their PLN activities were "downtime", "procrastination time", "off-time", and "little moments".

PSTs also enjoyed agency over their choice of apps and control over their own specific PLN activities. There was a range of sef-selected apps used by the PSTs, ranging from more open platforms such as Twitter and Pinterest, to more private, closed spaces such as Google+ and private Facebook groups. More specifically, PSTs used between two and five app platforms (per participant) to form their PLNs, including Twitter (used by 8 participants), Pinterest (7), Facebook (6), LinkedIn (2), Google classroom (2), Edutopia (1), Edmodo (1), YouTube community (1), and Blogs (1). Angela appreciated the convenience of easily accessing these apps:

> In my off-time, my mobile device allowed me to browse Facebook, Pinterest and blogs for teaching activities ideas and to be aware of news and recent changes. The apps were easy to access and I could access my PLN network at almost anytime and anywhere.

A common theme in the data related to PSTs exploiting the immediacy of the moment, as well as the capabilities of their chosen apps to archive, organise and share newly discovered resources and to customise their learning. In her focus group, Angela talked about the organisational benefits of apps such as Facebook and Pinterest: "One of the realities for being on the go is that I'll often get interrupted and want to save ideas for my lessons". She subsequently saved Facebook threads and archived Pinterest pins to refer to later. Angela also wrote about her use of these same apps in her journal, including how her chosen apps' in-built facilities helped her to customise the way she works: "The apps are very flexible and adaptive as they contain features that allow me to browse, capture, save and upload interest threads". While Rebecca believed that the careful organisation of her PLN allowed her to more effectively take advantage of these in-between times:

> Sometimes use of my PLN could turn that procrastination time into productive time. Like if you came across something which is a matter of chance depending on how carefully you orchestrate your PLN, then that could sometimes make you go "yea I better get onto that!"

Use of the m-device offered the PSTs the benefit of immediacy and convenience for their professional networking, and helped their learning to become more accessible, organised and tailored to their own preferred ways of working. Rob appreciated this autonomy, as mentioned in his journal: "It's a different kind of learning to university. And always self-regulated. The learning comes to me, instead of me to it."

Challenges and concerns
The main perceived challenges relevant to the m-learning construct of personalisation were developing effective strategies to initiate, build and tailor their PLNs to their own preferences, and finding the optimum scope of their emerging networks. A range of strategies was mentioned by participants, ranging from using their professional experience contacts, to following up on people and organisations associated with interesting resources they had discovered.

A challenge for PSTs was choosing apps suited their own activities and customising their initial connections to people and organisations in their PLN, tailored to their own ways of working. Some PSTs chose to wait until they started their professional experience to link up to carefully selected practising teacher colleagues. For instance, Ming described in her focus group how she initially networked with a leading teacher at her professional experience school. She looked at his Twitter followers and the people he followed, and slowly built up her own network to include mainly Science educators and academics. Alternatively, Rebecca and Deirdre used newly discovered, interesting teaching resources as a conduit to finding and following educators when using apps such as Pinterest and Twitter. Other participants were guided by specific chosen themes for their PLNs. For example, Rob commented in his focus group on how he customised and developed his PLN mindful of his focus on innovation in Education. In his focus group, he said that he uses

Twitter "to direct my own thoughts as an upcoming teacher, to follow up on areas that might be the next wave where Education is moving. I've really directed my Twitter platform and tailored it to this type of use".

Another challenge discussed by participants was choosing the ideal maximum size of their networks. What is the ideal optimum scope of a PLN for busy PSTs to manage? Rob addressed this problem in a journal entry discussing how he needed to tailor his network to his own ways of working: "The greater the growth of my PLN, the more diluted and less focused my PLN becomes. It's frustrating because it becomes less productive and relevant." Some PSTs commented that at the culminating stage of their university degree, and after an initial period when they would just follow, follow, follow, that their networks had reached an optimum size in spaces like Twitter and LinkedIn. They now wanted to contain and trim these networks to keep them manageable.

Authenticity

Authentic learning was evident in the participants' mobile practices in various ways. Their chosen PLN apps were used in-situ (in realistic professional contexts) in similar ways to teacher practitioners. They were using their m-device to find and connect with outside experts and organisations of relevance to their careers, and to interact with real-world (practising) teachers about meaningful, current topics of interest. The PSTs' use of m-devices supported their situated professional learning experiences in authentic settings relevant to the teaching profession, including school classrooms, playgrounds and school halls. PSTs used their m-devices to capture and share 'evidence of learning' during their professional experience lessons, both in and outside the classroom, usually through smaller closed networks such as Facebook groups. Rebecca explained in her journal how she captured and shared images of her school students' work:

> The mobile technology allowed me to take images of student work or any other resources I wanted to share through my PLN. I could upload my pictures to my PLNs immediately, which was really convenient while I was busy on practicum; or wait to share it at a later time when I can refine it by adding a more detailed description, or making the image more appealing.

In her focus group, Caroline mentioned a multi-disciplinary science, technology, engineering and maths (STEM) lesson in the playground that she and two teacher colleagues were filming to capture and share moments with colleagues within a (closed) PLN platform: "We were doing STEM classes and we launched a rocket that the students designed. We were all holding our mobile devices to capture the moments."

The PSTs in-situ and spontaneous use of their m-devices to participate in their PLNs could be seen as an authentic way of using their m-device, in a similar way to practising teachers' PLN practices (Carpenter & Krutka, 2015), for example at professional conferences and other teacher meetings (Lu, 2011). For instance, Guang described her live tweeting at a staff development session in the school hall during her professional experience:

> We had a staff development day run by a science organisation so I took a photo of that and tweeted that session. That was extending the PLN with the teachers I was working with, as well as the wider audience of the people who do the research. They had a twitter feed and I connected with them on that feed.

A further example of this authentic tool use was the PSTs' use of apps such as LinkedIn and Facebook to seek future employment and to market themselves to potential employers. Deirdre mentioned job networking in her focus group as one of her key PLN activities: "Being on practicum, I haven't had a lot of time, it's been good being on the go and being able to check into some of my PLNs, especially networking around jobs." When describing a learning episode in her journal, she elaborated on this theme:

> An aha moment for me was the importance of Facebook groups for career opportunities. I was on the train coming back from a client site for work when I went on to Facebook and on to the NSW Science Teachers' Association. They had a posted a number of job opportunities and I went and had a look at a range of them. I also found out about an upcoming 'meet the markers' conference that I will attend.

As mentioned in the previous sub-sections, PSTs used their m-devices to make meaningful and relevant connections with educators of interest from their professional experience schools, from other schools and teacher communities, typically in their own discipline areas. For example, Guang described how she made connections with other English teachers through her use of the Twitter app during her professional experience: "I use Twitter to connect with other educators. There are a lot of really great English teachers on Twitter who share a lot of their resources." While Rebecca appreciated how her PLN led to more rich connections, essentially acting as a conduit to liaising with other enthusiastic practising teachers, and ultimately as a source of fresh, relevant teaching ideas: "PLNs allow teachers to connect with fellow educators who are passionate about developing creative resources and help educators stay updated with new ideas that are applicable to the real world."

Challenges and concerns
An important issue for PSTs was the management of both personal and professional networks and their associated digital footprints. Some participants' PLNs emerged in spaces already used in their personal lives, for example Facebook, though others preferred to keep them separate. PSTs such as Rob chose one platform for his personal use and a separate one for professional learning: "I have a personal network on Facebook but Twitter for me is strictly professional." A similar challenge for an increasing number of mid-career changing, mature-age PSTs, is the challenge of adapting their PLN from their previous career to their emerging teacher-focused PLN.

Collaboration

PSTs' use of m-devices in their PLN activities evidently supported spontaneity of communications, currency of exchanged data and sharing of multimodal resources. They reported on enhanced collaboration in their m-learning practices through their rich connections to other people, resources, and organisations. They used LinkedIn, Twitter, Facebook, and Edmodo apps to share their interpretations with peers inside their university cohort, and with professional colleagues and other experts globally. Their PLNs became a less formal but safe place to ask questions and receive feedback, and collaborate with peers and more experienced teachers to develop new knowledge and enhanced teaching practices.

Apps were used by PSTs to access global networks, and "a resource to ask for advice and to share and learn from experiences" (Rebecca, journal). One city-based PST, for example, mentioned her conversation with rural teachers: "I can speak to teachers who are working in vastly different contexts such as rural Australia" (Guang, focus group). Many PSTs were confident with global platforms such as Twitter, and could see the benefits of connecting to a wider range of educators:

> I think Twitter is a huge asset in terms of connecting to a wider audience. The ideas you get on there are of much greater diversity than you would if you were just speaking to the immediate people you have contact with. (Guang, focus group)

A feature of the PSTs' collaborative m-learning practices was the spontaneity and sharing of multi-modal resources. For instance, Pat described how he used his m-device to capture images of his classroom board work. He then shared these artefacts "on the fly" to elicit feedback from peers via his PLN. In his focus group, he reported on this use of his m-device and how it "made it a lot easier to not just take the photo but share the photos amongst the people in our [university] maths group." He later reported how feedback from his peers via his PLN "motivated me to improve my whiteboard technique and flow of lesson."

The PSTs' m-devices were also used as a conduit to extend conversations from F2F to more flexible, online conversational spaces. Pat believed that the blend of physical (F2F) and digital spaces helped him to promote ongoing professional learning conversations amongst his peers: "The PLN and the physical interactions combined into a continuous integrated discussion throughout the day. I think we should make more of this." Twitter was used in this way to extend local dialogue to a virtual conversation. For example, Guang discussed a scenario emerging from a campus-based class with guest speakers discussing the topic of early career teachers (ECTs). She tweeted with the guest panelists, initially during the session, and then afterwards on the train home. In this way, she enjoyed a valuable follow-up dialogue with them via Twitter: "The panelists replied and tweeted, liked my tweets and initiated a dialogue with me."

Many PSTs reported their use of more private, smaller networks to communicate with and support each other both for campus-based work and during professional experience. These exchanges were enacted in spaces such as Facebook groups and Google Classroom and were often extensions of their own (F2F) peer networks within their university course, typically within their discipline areas.

> We have a Facebook group and we talk through there about things that were coming up [while on professional experience]. My first day back at university we had an assessment due so we were using google docs and Facebook to complete the assessment from a distance. (Tracey, focus group)

They shared content via these more private PLN platforms with their peers at university and/or staff in their professional experience school community. For example, Angela spoke about her use of Google classroom in collaboration with other PSTs and ECTs at her school. The main theme was to discuss challenging school students and appropriate classroom management strategies. She stated:

> In our school, we have a lot of PSTs and ECTs. We would share our experiences in class where we are challenged by the students. How would you come up with strategies to help you cope and help us to get ideas?

Angela appreciated the immediate feedback she received from this group while still on her school-based campus, stating later in her focus group that it "helps you feel much better, especially if you have another [professional experience] class." In this way, the m-device mediated immediate and valuable collaborative learning conversations.

Challenges and concerns

The main issue relevant to the m-learning construct of collaboration that was reported by participants concerned the pros and cons of smaller more intimate group spaces, and larger, public networks. They also emphasised the importance of relevant digital literacies in supporting online learning conversations in their PLN platforms. Some PSTs struggled to find their voice in more public PLN platforms, or what were described as "sophisticated and intimidating global platforms". Deirdre, for instance, was reluctant to collaborate in larger, public spaces (like Twitter), describing herself in the focus group as a "lurker and voyeur". She felt pressure "to be perfect" and was conscious of a wider, more experienced education audience who might potentially be "judging her" as a naive PST: "A barrier for me sharing my PLN more broadly is that on mobile devices I feel I am putting something very publicly on Twitter so it has to be perfect." Angela agreed:

> We're not very confident in being able to speak to the wider public … a benefit and disadvantage of PLNs is that it is such a broad network … our boss and supervisors might see what we shared! We are scared of being judged, especially by our [university] teachers and supervisors.

Many participants were comfortable working in more private PLN spaces, such as closed Facebook groups, and were self-conscious and reluctant to participate in public spaces. In using a more private, closed group, these PTS felt more comfortable that they could share mistakes they had made and learn from and with each other without being judged. In this way, they could more effectively support each other, "sharing challenging experiences and coping strategies" (Tracey, focus group).

However, PSTs who were confident and more experienced in public spaces emphasised the importance of relevant digital literacies to support online learning conversations in their PLN. In her focus group, Guang emphasised that using the right tag was critical in initiating and sustaining further online peer conversations. She mentioned the need to be fluent and digitally literate with apps such as Twitter, for example knowing what tags to include in posts to support more dialogue. Ming also emphasised hash tags as a useful way for her to join and sustain conversations on topics of interest.

Discussion and future research directions

This study provides insights into PSTs' technology-mediated PLN activities, particularly their m-learning experiences of personalisation, authenticity, and collaboration. It also elicited their perceptions of related challenges and concerns. Given that PLN activities are inherently collaborative and personalised

endeavours (Trust, 2017), with or without technology-mediation, the study aims to provide nuanced understandings of how the use of mobile technologies mediates these practices in a PST learning context.

The level of agency in these m-learning activities was noteworthy. PSTs exploited the portability of their m-devices to choose where and when to engage in their PLNs, akin to practising teachers in the study by Trust et al. (2016) who appreciated the "anytime, anywhere availability" of their PLNs (p. 15). They participated in these activities in the 'in-between' times and places—both formal and informal, physical and virtual—that are characteristic of mobile learning (Schuck, Kearney, & Burden, 2017). They controlled what apps they used and what connections they made through these apps, and they customised their apps to tailor their learning to their own preferred ways of working.

PSTs were using apps that are increasingly seen as legitimate professional learning tools by practising teachers and other discipline experts from outside of education (Trust et al., 2016; Xerri, 2014). They often used these apps in situ and with spontaneity, akin to the way practising teachers use their PLNs in conferences and teacher meetings. Importantly, PSTs were interacting through their devices with real practitioners and other experts, and participating in genuine conversations of high relevance and meaning to their prospective career (Burden & Kearney, 2016). In this way, there were high levels of participatory authenticity (Radinsky et al., 2001) evident in the data.

A feature of the PSTs' mobile collaborative practices in this study was the immediacy of communications and convenience of using their m-device to capture and share multimodal resources, especially during professional experience. The portability of the m-device was exploited by the PSTs for seamless learning (Wong, 2015) across contextual boundaries, extending learning conversations beyond the physical spaces used for staff meetings and campus-based classes, to virtual spaces. Many PSTs reported on the benefits of more customised, closed networks for peer collaboration. These protected spaces (such as Facebook groups) were associated with increased confidence and more critical and timely peer feedback. For example, PSTs used these PLN spaces during their professional experience to share ideas and negotiate solutions to pertinent problems, such as behaviour management issues. Immediate peer feedback allowed them to take this fresh advice into subsequent lessons, as outlined by Angela and Tracey. In this way, having ready access to these spaces using their mobile devices facilitated valuable collaborative learning conversations. PSTs who were confident and digitally fluent with PLN apps, participated in more public networks to support their collaborative activities. Further research is needed to explore how specific digital literacies, such as *Twitter literacy* (Greenhow & Gleeson, 2012) and *mobile literacy* (Pegrum, 2014), can affect PSTs' engagement with their mobile technology-mediated PLNs (particularly collaborative processes), and to identify strategies for developing these critical skills.

Limitations

A limitation of this study was the small sample of 11 (Masters level) PST participants, who were all studying to be secondary school teachers. Further studies are needed in this area using a wider participant sample, including undergraduate students and prospective primary teachers. Discipline-specific foci in further studies (e.g., focusing just on maths teacher participants) may reveal further nuanced patterns of behavior that are characteristic of specific domains. This study was of limited duration (one semester) and longitudinal studies are needed to more extensively track PSTs' journeys over a longer period to see how their PLNs evolve and how this development intersects with their m-learning practices. This type of longitudinal study is needed to cover PSTs' whole candidature and possibly their transition into early career teaching.

Implications

Research undertaken recently suggests that teacher educators are not confident in modelling the use of mobile technologies with their PSTs and are struggling to adopt effective mobile pedagogical approaches (Burden & Hopkins, 2017; Burden & Kearney, 2017). There is a similar problem with school teachers' adoption of effective m-learning practices (Kearney et al., 2015), emphasising the imperative for initial teacher education programs to develop best-practice m-learning approaches (Herrington et al., 2015; Pegrum et al., 2013). The study provides insights into practices self-directed by PSTs that evidently exploit the distinctive pedagogical affordances of mobile technologies, providing a timely spotlight on effective contemporary m-learning in teacher education. Findings in this study indicated that use of technology-supported PLNs provided a rich m-learning experience for PSTs, although further research is needed to

gauge the effect of these experiences on their own adoption of mobile pedagogies in school teaching contexts.

The study uncovers understandings of challenges that provide teacher-educators with increased clarity about the guidance needed to assist PSTs in managing their mobile technology-mediated PLNs. PST participants identified a range of challenges, including finding effective ways to initiate and develop their PLNs; tailoring their PLNs to their own interests and customising apps to their own ways of working— including choosing the optimum size of their networks and the levels of privacy; management of personal and professional boundaries, and (for mid-career changers) transitioning their PLNs from previous careers. To optimise these mobile collaborative practices both on campus and during their professional experience, teacher educators may need to advise PSTs with respect to the privacy levels of their chosen PLN platforms, and help them to become confident participants in intimidating public platforms. Guidance may also be needed to help PSTs in the initial stages of developing their PLNs, for example providing strategies for choosing and customising apps to forge appropriate links with 'credible and trusted' peers, teacher colleagues and professional organisations. Although some of these issues have been highlighted in similar studies of practising teachers, for example, the blurring of boundaries between personal and professional identities (Fox & Bird, 2015), and finding a voice in more public spaces (Biddolph & Curwood, 2016), this study highlights the specific needs and behaviours of PSTs in their initial teacher education context, particularly relating to their m-learning practices. Further research is needed into the types and levels of guidance needed by PSTs to help address these challenges, as well as how teacher educators might model best-practice through their own PLN activities. More research into the design and development of supportive resources, such as Burden and Kearney's (2018) mobile learning toolkit for educators, and the PLN enrichment framework (Krutka, Carpenter, & Trust, 2016), will offer teacher educators valuable assistance when addressing these issues.

Conclusion

This study highlights the efficacy of mobile technology-mediated PLNs in pre-service teacher education. It explores how PSTs' use of m-devices in their PLN activities can support the distinctive m-learning features of personalisation, authenticity, and collaboration, and in this way, contributes to the literature on m-learning in teacher education contexts. The study also provides teacher educators and researchers with new understandings of challenges experienced by PSTs when participating in these potentially career-long PLN practices.

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