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Abstract: This exploratory research project characterised the degree of adoption of mobile learning devices among 149 fourth year pre-service teachers (PST) studying education. It also examined the impact of perceptions about possibilities and constraints in the adoption of mobile devices in schools. The findings reveal that pre-service teachers were generally at the fourth of a six-stage continuum of technological adoption that can be characterized as familiarity and confidence which was one level higher than academic staff. Some of those constraints appear to reside on equity issues, lack of mobile learning support resources, pedagogically unproductive use of mobile tools and student distractedness. Gender did not have a major impact on participants' opinions but access to a mobile tablet did.

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Learning About Mobile Learning: Pre-Service Teachers' Perspectives

This exploratory research project characterised the degree of adoption of mobile learning devices among 149 fourth year pre-service teachers (PST) studying education. It also examined the impact of perceptions about possibilities and constraints in the adoption of mobile devices in schools. The findings reveal that pre-service teachers were generally at the fourth of a six-stage continuum of technological adoption that can be characterized as familiarity and confidence which was one level higher than academic staff. Some of those constraints appear to reside on equity issues, lack of mobile learning support resources, pedagogically unproductive use of mobile tools and student distractedness. Gender did not have a major impact on participants' opinions but access to a mobile tablet did.

Keywords: mobile learning; pre-service teachers; zone of free movement, K-12 education; initial teacher education

Introduction

This study focused on fourth year pre-service teachers (PST) studying a mathematics education course where one of the outcomes of the course was to teach students skills in using mobile learning tools in the mathematics classroom for when they are teachers in the future.

The study examined the impact of the PST perceptions about the possibilities and constraints in the adoption of mobile devices in schools. A technology adoption scale, based on Russell's (1995) work was adapted for the study and the Zone of Free Movement (ZFM) scales (Valsiner, 1987; Valsiner, 1997) were also used. This study is important as teachers increasingly are required to use technology inside (Twyman & Heward, 2018) and outside the classroom (Whalley, Mauchline, France, Park & Welsh, 2018) with high technology solutions important in teaching as they can improve student learning.

This study used an instrument that was adapted from a previous study (Handal, MacNish & Petocz, 2013) which used an instrument with academic staff that consisted of three major scales, originally based on Russell's (1985) work on how teachers in post graduate study learned to use technologies and then applied to their teaching.

Literature review

Mobile learning

For the purpose of this study, mobile devices are portable handheld devices providing computing, information storage and retrieval functionalities as well as multimedia and communication capabilities (Handal, 2015). Mobile devices are available on the market and also known as smart phones as well as 'mobiles.' These devices also include 'tablets'.

Mobile technologies have increasingly been used in an ubiquitous way in the past few years (Hwang & Tsai, 2011) and have also opened the way to a more seamless approach to learning and teaching. This is not only for the ubiquitous nature of mobile devices but also for their portability and includes devices like tablets and smartphones (Sharples, Taylor & Vavoula, 2007). Mobile technologies allow users to access these devices and to simultaneously access various teaching and learning tools (Wong, 2012). Smartphones and tablets permit learners to integrate computational, productivity, simulation, exploration and information retrieval tools in a central hub (Handal, MacNish & Petocz, 2013). Furthermore, learners and instructors are able to immerse themselves dynamically in their learning and teaching tasks and in the virtual world 'anywhere, anytime' with research suggesting that using mobile technologies in the classroom can improve student learning (Campbell, 2013). Additionally mobile phones used in the classroom can actually create a more positive learning environment (Handal,

2015), however it is important to remember that technology use in the classroom should always have a purpose (Ng, 2012).

Teaching and learning have thus been extended beyond the university bricks-and-mortar surroundings, opening new academic vistas to tertiary education in the early 21st century. From the learners' perspective, students are bringing their own devices (BYOD), and are moving away from university proprietary software and hardware, for example, university owned computers, and becoming more independent in their digital choices (Wong, 2012). This is increasingly happening with Wi-Fi now available across most university campuses so that students can connect at any time when on campus.

Baran (2014) made the case that there has not been much theoretical development about integrating mobile learning into teacher education programs. Much has been written about using mobile devices at the school level in the context of various technology-based teaching and learning frameworks such as the technological pedagogical content knowledge (TPACK) and the Substitution-Augmentation-Modification-Redefinition (SAMR) models, among others. However, the teacher educator is a critical variable that has not yet properly articulated within the context of curriculum development and course delivery. Normally, school students, teachers, manufacturers, parents and school executives are considered the main mobile learning stakeholders in the educational environment (Handal, 2015). Certainly, the inclusion of the teacher educator as an important dimension of the educational ecology would enrich the current discussion exploring new theoretical possibilities.

Stages of adoption

It has been said that teachers adopt technology progressively as they come across pedagogical and technical challenges (Christensen, 1997; Handal, Chinnappan, & Herrington, 2004; Handal & Cavanagh, 2011; Handal, MacNish & Petocz, 2013) and

develop various instructional strategies as they implement them (Vazquez, Vargas, Ezkauriatza, Juarros, Corral, Espinoza & Doolan, 2018). Some are likely to advance those skills faster than others or reach higher levels of integrating technology into their teaching practice. For some using technology in the learning space, either inside or outside a classroom, will require going through a more hierarchized linearly pathway while others would be able to do the journey intuitively and naturally. In general teachers seem to follow various stages of adoption as they grow professionally integrating technology in the curriculum.

The stages of the technology adoption scale is one that describes the types of phases that teachers can pass through while learning a new technology. Teachers can go through these various stages in their own time and can actually begin in any phase as this is very dependent on the teachers' background and previous life experiences (Russell, 1995). This scale has been adopted for the present study to represent the take-up of learning technologies and uses six developmental phases which are (a) awareness, (b) learning the process, (c) understanding and application of the process, (d) familiarity and confidence, (e) adaptation to other contexts, and (f) creative applications to new contexts. Previously, the six stages have been used in various formats according to learning technologies in previous studies (Christensen, 1997; Handal, Chinnappan, & Herrington, 2004; Handal & Cavanagh, 2011).

The stages of the technology adoption scale are represented in Table 1 in terms of mobile learning:

Table 1. Stages of adoption

	Stage	Item description
1	Awareness	I am aware that mobile devices exist but have not used them - perhaps I'm even avoiding them. I am anxious about the prospect of using mobile devices.
2	Learning the process	I am currently trying to learn the basics. I am sometimes frustrated using mobile devices. I lack confidence when using mobile devices.
3	Understanding and application of the process	I am beginning to understand the process of using mobile devices and can think of specific tasks in which they might be useful.
4	Familiarity and confidence	I am gaining a sense of confidence in using mobile devices for specific tasks. I am starting to feel comfortable using mobile devices.
5	Adaptation to other contexts	I think about mobile devices as a tool to help me and am no longer concerned about them as technology. I can use them in many applications and as instructional aids.
6	Creative application to new contexts	I can apply what I know about mobile devices in teaching and learning. I will be able to use them as an instructional tool and integrate them into the curriculum.

Zone theories

The Zone of Proximal Development (ZPD) was initially conceptualised by Vygotsky (1978) and is considered the gap between a learner's present capabilities and the higher level of performance that could be achieved with some appropriate assistance. ZPD defines functions that have not yet matured but are in a process of maturing, which are currently developing with these functions "called the buds of development, the flowers of development, rather than the fruits of development, that is, what is only just maturing" (Vygotsky, 1935, p. 33). Applied to the field of learning technologies, ZPD refers to those capabilities endowing the teacher with the capacity to effectively deploy ICT to advance teaching and learning. It explains academics' ability to efficiently integrate pedagogy, technology and discipline content at various developmental stages of adoption to progressively enhance students' learning experiences.

Valsiner (1987, 1997) added that such dynamics are also influenced by facilitating and hindering factors operating within the same learning environment. The Zone of Free Movement (ZFM) was outlined as the enclosed environment in which the individual interacts for teaching and learning purposes. ZFM represents both the processes and structures that condition the circumstances in which the learning and teaching are enacted. ZFM includes students' characteristics, perceptions about the role of technology in education, and curriculum and assessment requirements. For Goos and Bennison (2008, p. 103):

> The ZFM structures an individual's access to different areas of the environment, the availability of different objects within an accessible area, and the ways the individual is permitted or enabled to act with accessible objects in accessible areas.

In turn, the Zone of Promoted Action (ZPA) represented the opportunities for professional growth that the individual can access to advance his/her professional learning in order to achieve students' academic progress (Goos & Bennison, 2007). ZPA stands for those empowering factors aiming at skill development in ICT in education. It also includes participation opportunities in professional development, either external or internal to the university, and chances for collaboration and peer professional learning, including informal individual learning or assistance from colleagues. In general, ZPA corresponds to openings for becoming familiar with ICT and their pedagogies.

If effective teaching and learning is to happen, then the ZPD needs to synchronise with the academic's opportunities for continuous progress (ZPA), as well as operating within the doable working space delineated by the ZFM. This study focused only on the ZFM as perceived by pre-service teachers with regards to

possibilities and constraints related to using mobile devices in teaching and learning. It also looked at the interaction of those perceptions with the pre-service teachers stages of adoption.

Aim of the study

In order to characterise mobile learning stages of adoption and their relationship with related educational variables in PST, the research questions were formulated as follows:

(1) At which stage of adoption of mobile learning technology do pre-service teachers (PSTs) perceive themselves?
(2) How are these stages of adoption related to pre-service teachers in terms of:
    (a) Gender?
    (b) Personal involvement with mobile learning?
    (c) Access to mobile technology?
    (e) Perceptions of self-competence on mobile learning?

These research questions are important as this can affect PST mobile device use once they are teachers. It added to the literature in this area and can assist academics when teaching both PST and practicing teachers in the future.

Methodology

Participants

The research involved PSTs in their last year of their teacher education program. They were enrolled in the unit ED3005 ‘Mathematics, ICT and the Curriculum’ at The University of Notre Dame Australia. Maths education was chosen as the context of the study because of the discipline’s close reliance on learning technologies within a

Science, Technology, Engineering and Mathematics (STEM) primary education context (Burnard, Dragovic, Jasilek, Biddulph, Fenyvesi, Durning & Rolls, 2018). For example, during the course of the unit, students learned to explore, classify and systematically evaluate mathematics educational apps through a checklist. They also created and delivered a numeracy based lesson plan using mobile technology.

The ED3005 unit is taught in the first semester of the fourth and final year of their studies. By the end of that semester, the PSTs had completed 20 weeks of professional experience in schools and therefore acquired a strong knowledge of the teaching environment. By the end of the second semester they would have completed 30 weeks of professional experience and be eligible for graduation.

The study took place in the last week of the ED3005 unit after obtaining ethics approval from the Human Research Ethics Committee. The online questionnaire was totally anonymous and participants were told that there were no right or wrong answers.

The instrument

The online questionnaire used in this project was drawn from a previous instrument on the perceptions of mobile devices among 177 academic staff (Handal, MacNish & Petocz, 2013) from across all faculties of the same university. It consisted of three major scales.

The stages of adoption scale represent a continuum of six consecutive levels of integrating mobile devices in teaching and learning. They were originally based on Russell's (1985) conceptualisation of how school teachers enrolled in a postgraduate course learned to use technology and apply it in their teaching and learning. Table 1 above shows the six stages and their descriptors. The first scale ranks stages of adoption, while the second scale refers to the Zone of Free Movement (ZFM) that teachers encounter in terms of possibilities and constraints during the implementation of

mobile learning. It is divided into four sub-scales composed of items whose responses are arranged from agree to neutral and disagree. The four sub-scales are: pedagogical and operational possibilities showing the potential of mobile learning and pedagogical, and operational constraints indicating their technical and logistic challenges. The wording of the ZFM scale items for this study was slightly modified to reflect a school rather than a university environment. Items were previously piloted with ten teacher and school educators. For practical purposes these 32 items are presented later in the next section along with their descriptive statistics.

The third scale assisted in measuring the degree of individual involvement and interest in mobile learning. The scale is an adaptation of Zaichkowsky's (1985) *Modified Personal Involvement (PII)* which seeks to characterize a "person's perceived relevance of the object based on in inherent needs, values, and interests" (Zaichkowsly, 1985; p. 342; Bei & Simpson, 1995; Handal & Cavanagh, 2011). The ten scale items are: Interesting, Exciting, Appealing, Fascinating, Relevant, Valuable, Involving, Important, Means a Lot and Needed. Responses were presented on a 3-point Likert scale ranging from agree to disagree.

Limitations of the study

The questionnaire survey measured characterized beliefs, attitudes and opinions through items presented in Likert scales. Likert scales are written to offer a range of options, from agreement to disagreement, and make subsequent statistical analysis possible. However, this technique induces participants to choose the option that looks coherent with an ideal belief and do not offer them the possibility of expressing their own views (Cohen, Manion & Morrison, 2007). A second limitation of this study is the fact that the beliefs and practices in the questionnaire are self-reported, and as such cannot be immediately verified. Hence, the need for further studies through interviews

to explore PSTs perspectives in depth as well as the use of observations to examine practices within a context.

Quantitative results

Demographics

The link to the online questionnaire was sent via the university email system to all 247 primary methods students taking the unit ED3005 'Mathematics, ICT and the Curriculum' in semester one. A hundred and sixty-one of these PSTs students responded, making it a 66% response rate. Eighty-nine percent of the respondents were female. In the total cohort the percentage of females was 88%t.

The results show that 99% of the participants owned a mobile phone. However, only two-thirds of them had access to a tablet. The most popular smartphone brand owned by the participants was an iPhone (Apple) followed by Samsung. The most popular tablet was an iPad followed by a Samsung Galaxy. The latter can be categorized as a tool that in various sizes combines the electronic features of a smartphone and a tablet. There were no significant differences between females and males with regards to accessing either a smartphone or a tablet.

Stages of adoption

The median stage of adoption of mobile devices for teaching and learning was found to be Stage 4 "Familiarity and confidence" (Table 2). The mean was 4.5 showing a midpoint between Stage 4 and Stage 5 "Adaptation to other contexts". There were no significant differences between females and males in regard to stages of adoption.

Table 2. Stages of adoption

Stage	Frequencies	Cumulative Frequency	Percent
Stage 1: Awareness	3	3	2
Stage 2: Learning the process	8	11	5
Stage 3: Understanding and application of the process	30	41	20
Stage 4: Familiarity and confidence	41	82	28
Stage 5: Adaptation to other contexts	43	125	29
Stage 6: Creative application to new contexts	24	149	16
Total	149		100

Eighty percent of the PSTs chose the strongly agree and agree responses to the item "I feel very competent in using a tablet" as shown in Table 3. There was no significant gender difference to the self-confidence item.

Table 3. Responses to self-confidence item

Response	Percent
Strongly Agree	37
Agree	43
Neutral	14
Disagree	4
Strongly Disagree	2

Personal involvement for mobile learning

Each of the 10 items to the question "Indicate how do you feel about teaching and learning using mobile devices in schools" showed high levels of personal involvement towards mobile learning. Scores were coded in a 3-point Likert scale arrangement from agree, neutral to disagree. The maximum and minimum scores were 3 and 1, respectively. In general, scores of 2.0 would indicate an orientation that lies midway between agree and disagree. A score less than 2 would represent a lower level of personal involvement while a score higher than 2 would mean the opposite. Results are shown in Table 4 revealing that the items "Interesting" and "Exciting" scored at the top of the scale while "Means a Lot" and "Needed" stay at the bottom.

Table 4. Personal involvement for mobile learning

Item	Mean	SD
Interesting	2.84	0.387
Exciting	2.81	0.397
Appealing	2.79	0.441
Fascinating	2.66	0.514
Relevant	2.66	0.502
Valuable	2.63	0.523
Involving	2.54	0.626
Important	2.54	0.512
Means a lot	2.21	0.655
Needed	2.19	0.662

Likewise, the above ten Personal Involvement items were entered into a multiple regression analysis for the selection of significant predictors of stages of adoption. The results in Table 5 show that two items predict adoption of mobile devices, namely, "Appealing" and "Fascinating" ($p < 0.05$).

Table 5. Multiple regression by personal involvement items

Variable	Beta	Std. Error	t	Sig.	95.0% Confidence Interval for B	
					Lower Bound	Upper Bound
Appealing	0.618	0.306	2.019	0.046	0.012	1.224
Fascinating	-0.546	0.274	-1.994	0.048	-1.087	-0.004

In general, an increase of one unit on those two items would cause approximately half a unit variation on the stages scale. For the item "Appealing" the effect will be positive (Beta = 0.618) while for the item "Fascinating" the effect will be negative (Beta – 0. -0.546). It is important to note that the Merriam-Webster Dictionary defines "Appealing" as having qualities that people like while "Fascinating" is conceptualized in a superlative form as very interesting or appealing (Merriam-Webster, 2015). The Macquarie Dictionary defines appealing as "having pleasing or attractive qualities (Macquarie Dictionary, 2004, p. 81) and fascinating as "a great interest or attraction (Macquarie Dictionary, 2004, p. 670).

It is also noteworthy that there was not a significant difference between females and males for the ten Personal Involvement items. The ten-item scale yielded a Cronbach's Alpha of 0.860 revealing a strong internal reliability.

Zone of Free Movement Sub-scales

Participants' responses to single ZFM scale items were analysed by mean scores. The analysis was grouped by each of the four sub-scales, namely, Pedagogical Possibilities (PC), Operational Possibilities (OP), Pedagogical Constraints (PC) and Operational constraints (OC). Similar to the analysis for the stages of adoption data the maximum and minimum scores were 3.0 and 1.0 with a score of 2.0 as the midway between agree and disagree.

In addition, the sub-scales scores underwent a *t*-test of independent samples comparing the means of two groups whether they were female/male or having access to a tablet. When significant differences were found these have been indicated on each of the four sub-sections below.

Pedagogical Possibilities Sub-scale

All the Pedagogical Possibilities (PP) items received positive approval as shown on Table 6. The PP top-scored item acknowledged the statement that mobile learning in schools "Offers greater possibilities for distance/remote learning and individualised instruction" which somehow is related to the third top-item PP7 "Facilitates independence in learning anywhere and at any time". It appears then that the focus on the individual in terms of autonomous learning along with its components of independence and individualisation, draws PSTs to identify the role of mobile learning role in enhancing teaching and learning. Both statements can be linked to the second-top item PP6 supporting mobile learning as tools to empower students to explore new

concepts, simulate real-life situations, collect data or practice content. Finally, the three remaining items seem to support the idea of communication and collaboration because mobile learning "permits real-time interactions in class" (PP5), "facilitates collaboration and interaction among students" (PP2) and "increases communication among students and teachers" (PP3). In particular, these three last items have a larger standard deviation showing a great variability of responses.

Table 6. Pedagogical possibilities (PC)

Variable	Pedagogical Possibilities	Mean	SD
PP4	Offers greater possibilities for distance/remote learning and individualised instruction	2.73	0.488
PP6	Educational apps empower students to explore new concepts, simulate real-life situations, collect data or practice content	2.68	0.536
PP7	Facilitates independence in learning anywhere and at anytime	2.68	0.481
PP1	Enhances student-teacher communication beyond class time (e.g., email, SMS, file sharing, quizzes, feedback, updates, discussion forums, social networking)	2.65	0.569
PP5	Permits real-time learning interactions in class (e.g., resource sharing, surveys, questions)	2.64	0.628
PP2	Facilitates collaboration and interaction among students	2.44	0.701
PP3	Increases communication among students and teachers	2.39	0.658

Operational Possibilities Sub-scale

As shown in Table 7, the two top scores supporting the operational capabilities of mobile devices were items OP1 and OP4. The OP1 item acknowledges that students can 'electronically' carry their learning resources which previously had to be carried physically, such as books or personal notes. In turn, the OP4 item recognises that students can now produce their learning products not just with paper and pen but also using various multimodal formats that can include video, audio, animation and image. The respondents also strongly support the idea that mobile learning facilitates access to the online world rather than printed resources that were once confined to shelves, libraries or any other physical space. Indeed, there is an understanding that such ubiquity transcends the school walls and the concept of "library opening hours" making

learning a 24/7 experience. The other supported items in the OP scale provide evidence that PST's recognise the capacity mobile devices have to record learning and teaching experiences in schools and find them powerful tools for organising students' work and their learning experiences. Those items also exhibit, on average, a higher standard deviation.

Table 7. Operational possibilities (OP)

Variable	Operational possibilities	Mean	SD
OP1	Allows easy physical carrying of digital curriculum related files (e.g., PDF, Word, PowerPoint, course notes)	2.85	0.409
OP4	Empowers teachers and students in producing multimedia presentations through taking their own pictures or recording audio and video footage	2.85	0.374
OP2	Allows students and teachers working at and a location that suits them	2.84	0.369
OP5	Enables students to record teacher presentations or any other course learning experience	2.77	0.437
OP7	Improves access to online teaching resources (e.g., internet browsing, podcasting, online Library catalogue, virtual galleries)	2.72	0.509
OP6	Facilitates educational management of marks, attendance and students records.	2.69	0.491
OP9	Lets students write and save their own personal study notes	2.63	0.564
OP3	Assists teachers and students in organising their learning tasks (e.g., calendars, diaries, timetables, reminders)	2.59	0.569
OP8	Keeps students constantly connected to the curriculum	2.16	0.697

It is noteworthy that PSTs with tablet access ranked higher than those without such access on the OP3 statement "Assists teachers and students in organising their learning tasks (e.g., calendars, diaries, timetables, reminders)" ($t = 2.029$; $df = 89.602$; $p = 0.45$).

Possibilities Constraints Sub-scale

Results for the Possibilities Constraints (PC) sub-scale are shown in Table 8. Interestingly, items related to lack of preparation time (PC7) and professional development (PC6) were not validated as strong constraints as much as other factors were. For respondents, more pressing inhibiting factors were the need to access "Special curriculum tasks to support the use of mobile devices" and the thought that students "do not adequately know how to use them for their learning." In their minds, there were

classroom management concerns such as students being distracted in class and cheating during assessment which were of greater concern. The fourth top ranked item reflected fears that respondents' access to mobile tablets might reduce personal contact with students. The four last items showed a large variability in responses.

Table 8. Pedagogical constraints (PC)

Variable	Pedagogical constraints	Mean	SD
PC3	Special curriculum tasks to support the use of mobile devices are required	2.54	0.655
PC5	Students will be distracted in class	2.34	0.717
PC4	Students do not adequately know how to use them for their learning	2.29	0.695
PC2	Reduces teacher-student personal contact	2.27	0.775
PC1	Concerned that students will cheat using mobile devices	2.21	0.772
PC6	There are not many formal opportunities to learn about mobile learning	2.21	0.752
PC7	Lack of time to integrate mobile learning	1.98	0.728

Interestingly, PSTs without tablet access were more likely to assert than mobile devices "Reduces teacher-student personal contact" (PC2). Also, from all the 32 ZFM scale items, "Students do not adequately know how to use them for their learning" (PC4) was the only one where significant gender differences were observed with females scoring higher than males ($t = 2.449$; $df = 25.190$; $p = 0.22$).

Operational Constraints (OC) Sub-scale

As shown in Table 9, there was a high level of agreement on the issue of poor connectivity as a constraint factor in mobile learning adoption. This is followed by the item OP4 which referring to the widespread lack of mobile devices, particularly tablets as seen before, inhibiting students from participating fully in learning activities. Similarly, PSTs consider that personal budgets to pay for data plans and accessing Wi-Fi limit the utilisation of the devices. Another concern for respondents is the pace of technological innovation and design change. Responses also reflect concerns about mobile learning devices restrictions on screen size, their data capacity to store large

files, particularly those related to video and sound. Interestingly, comparing the media richness of mobile devices with a desk/laptop was not seen as a crucial issue. The only unsupported item was "Lack of a mouse and a keyboard makes usability difficult" which scored under the average although respondents without access to tablets were more likely to endorse such statements (t = -2.115; df = 83.816; p = 0.37). This was probably due to lack of familiarity with the tool.

Table 9: Operational constraints (OC)

Variable	Operational constraints	Mean	SD
OC7	Sometimes the connectivity is poor in some areas	2.82	0.437
OC8	Not all students or teachers have mobile devices or are not in the habit of using them	2.67	0.599
OC5	Internet connection outside the school and home network can be expensive lack of Wi-Fi in many locations	2.57	0.630
OC4	In a fast moving market, mobile products can be out-of-date very quickly	2.50	0.655
OC9	Has restrictions on screen size and resolution	2.36	0.709
OC2	Data storage capacity is limited	2.28	0.696
OC1	Apps do not work across main mobile platforms	2.23	0.574
OC3	Do not offer the same interface richness/immersiveness compared to a laptop/desktop	2.02	0.751
OC6	Lack of a mouse and a keyboard makes usability difficult	1.83	0.782

Finally, stepwise multiple regression was used to investigate the explanatory effect of each of the 32 scale items upon the dependent variable stages of adoption. A stepwise regression analysis was conducted to identify explanatory variables based on their contribution to the model. Table 10 shows multiple beta coefficients for two items what were found to significantly impact stages of adoption. These two items were the constraints items "Students do not adequately know how to use them for their learning" (PC4) and "Internet connection outside the school and home network can be expensive - lack of Wi-Fi in many locations" (OC5). Both items were found to be negative predictors of adoption of mobile devices ($p < 0.05$).

Table 10: Stepwise multiple regression by beliefs items

Variable	Beta	Std. Error	t	Sig.	95.0% Confidence Interval for B	
					Lower Bound	Upper Bound
Constant	6.034	.524	11.524	.000	4.998	7.070
PC4	-.407	.154	-2.650	.009	-.711	-.103
OC5	-.342	.170	-2.006	.047	-.679	-.005

Principal Component Analysis

A principal component analysis was applied in order to show how the instrument discriminated among PSTs' responses in regard to the two constructs, namely, possibilities and constraints.

The two-factor solution extracted 32.4% of the variance using Oblique rotation. A Cronbach's alpha of 0.796 was yielded showing a moderately high-internal consistency measure of the instrument. The results in Table 11 show that the instrument efficiently discriminated two distinct constructs in PSTs' responses when loadings between -0.4 and 0.4 were considered (Muijs, 2010).

Table 11: Rotated Component Matrix of ZFM Scale

Structure Matrix					
Item	Possibilities	Constraints	Item	Possibilities	Constraints
OC1	0.188	0.459	OP8	0.536	-0.085
OC2	-0.047	0.619	OP9	0.467	0.044
OC3	-0.162	0.568	PC1	-0.073	0.647
OC4	0.115	0.562	PC2	-0.190	0.600
OC5	0.072	0.416	PC3	0.202	0.344
OC6	-0.124	0.563	PC4	-0.104	0.591
OC7	0.112	0.432	PC5	-0.289	0.555
OC8	0.305	0.401	PC6	-0.115	0.581
OC9	-0.016	0.625	PC7	-0.221	0.636
OP1	0.186	-0.133	PP1	0.604	0.083
OP2	0.509	0.191	PP2	0.479	-0.041
OP3	0.501	0.000	PP3	0.601	-0.022
OP4	0.550	-0.024	PP4	0.779	0.027
OP5	0.663	-0.125	PP5	0.545	0.012
OP6	0.601	0.072	PP6	0.646	-0.227
OP7	0.497	-0.181	PP7	0.593	-0.088

The item OP1 "Allows easy physical carrying of digital curriculum related files" was the only factor that did not load satisfactorily into the matrix. When the item was

removed from the scale the Cronbach's alpha increased from 0.796 to 0.798 and the variance decreased from 52.241 to 52.109. Such marginal variations warrants the decision to safely remove the item from the scale although it is recommended to keep it because it obtained the highest mean score in the Operational Possibilities sub-scale ($\bar{x}$ = 2.85; s.d. = 0.409).

Qualitative Results

The open-ended comments in the questionnaire reflect much of the quantitative comments. They shed light in the transition they are making from Stage 4 of adoption "Familiarity and confidence" to Stage 5 "Adaptation to new contexts". As a respondent remarked: "When a teacher is confident with using technology then there is no limit with what can be achieved in the classroom."

Attitudes towards Mobile Learning

As seen above, the quantitative study reveals that all ten items of the attitude scale reflect a high level of personal involvement. Typical of these statements were:

> Mobile learning is a vehicle in which students can have their learning personalised and engage in learning experiences in which they will be challenged and motivated.

> The use of the iPad in the classroom is very resourceful and can be used in things like group work, to things like individualised learning plans.

> I love the idea of connecting with students from other grades/schools/globally around the world.

Although less supportive comments were occasionally expressed such as "real life experience, with tangible tactile interactions can be a far greater learning tool than a finger swipe on a game based educational app" or "I believe we rely on technology too

much these days in the classroom". Other comments suggest that students have a more realistic approach to the effectiveness of mobile devices rather than feeling totally captivated by their electronic glamour. Such an approach from PST's might be the result of having concerns in their minds about the effectiveness of mobile learning after balancing possibilities and constraints. The following comment reflects such a phenomenon:

> I understand that ICT and devices can be used to only enhance student learning but make life easier for teachers as well, however it does intimidate me so I tend to stick to the old fashion method. In saying this I really want to learn more about them because I know I will teach better using them.

Accessibility

Among those constraints is the issue of democratic accessibility to mobile devices, particularly tablets. Some PSTs consider this equity issue as a deterrent to an effective implementation working negatively for both school students and PSTs. As for the latter one PST wrote:

> Equity regarding access to mobile technology is often overlooked. Many people may not have up to date devices or fast and reliable Internet at home, and that must be addressed before activities outside of the classroom are set. I felt very disadvantaged [in this subject/unit] because I don't have access to a tablet or Apple products - it made the task difficult because I had no way of exploring the app store to find apps that were suitable.

Likewise, the lack of tool ownership by school students plays a negative role in this adoption: "Some students can't afford this technology; specially a problem in Bring Your Own Device schools". A side consequence of this disadvantage is that when these students come to school they will see the devices more as a toy than an instructional tool. Because these students do not have access to both the educational and the 'fun'

aspects of these tools at home, they may be inclined to treat them as play tools when given the opportunity to use them at school:

> The application of mobile learning in low socio-economic areas, in my experience, has been a hindrance. As the students have no access to them at home they are seen more as a toy than a learning device. While it may be suggested that regular exposure would change this outlook it is not financially viable.

Distractedness

The view of mobile devices for entertainment purposes appear to be very widespread posing classroom management issues:

> iPads should not be used too often but merely as a motivational tool. Too distracting and very hard to get every child on task.

> I would re-consider using personal mobile devices in the classroom, unless there was a very strict policy (e.g., no texting, no social media, parental consent, stays in the classroom at all times, and would only be introduced if all students had a device) in which students use them for educational purposes only, as they could and would definitely be used incorrectly, and could pose a threat to classroom safety.

In particular, the belief that mobile phones are for communication and not for learning is pervasive because "it is a personal device used for mainly communicating (social media) with others, rather than for educational purposes and could pose as a distraction in class".

When to use mobile devices

In order to make mobile learning a pedagogically productive endeavour, opinions were also expressed in favour of more professional learning and curriculum development. According to two PSTs, "Mobile devices are great to use in class,

however teachers need help on how to do this" and "quality apps need to be set for tasks just like how resources in the classroom need to be sourced".

In general, there is an agreement that technology should be the tool and not "the focus of the lesson". There were many caveats among the cohort about putting the pedagogy first and then the technology. They seem to realise that technology should be used in a way that conventional instruction cannot do otherwise, like the student who wrote: "I would strongly recommend that the use of such mobile learning technologies only occur in occasions when they are the absolute best resource to use."

Others expressed the opinion that mobile learning cannot overtake a whole lesson but can be utilised as a complement to teachers' direct instruction. Two of the respondents believed that "Mobile devices ought to be used as a supplement to teaching" and "I can use technology and will be able to integrate into classrooms [but] I just don't see the need for it to be constantly present." In regards to the need to keep a balance between inquiry and problem solving tasks and direct instruction, a participant commented:

> I think the way that mobile devices are introduced and used determines how successful they will be and that it is through allowing students opportunities to work in their own ways that applications benefit education. When students are restricted to basic ways of solving and creating tasks the benefit of technology is lost and students become disruptive losing the purpose and value of the lesson.

Another respondent added that the combination of digital and physical resources is desirable:

> I believe mobile learning can be useful, but no lesson should be solely focused on technology. Many students still need manipulative resources that they can pick up, move, feel and smell, with different sizes and shapes that they can physically feel. I do not believe mobile learning has a full time place in huge classrooms, it

> should still be an occasional thing, useful in maths, but counters and geo boards are just as useful.
>
> There needs to be a balance, for myself I need to write with a paper and a pen and reading from a screen is not ideal for me. Not all students would prefer iPads or mobile devices but if it is incorporated with a balance and not all the time then I think it can be effective.

Pedagogy before technology

While acknowledging that mobile learning is a positive endeavour some PSTs thought that "A lot of teachers will use mobile learning in a negative way, they will let it be the teacher while they do". The respondents appear very aware that the "the technology is only as good as the teacher incorporating it" and that process "needs to be done in a meaningful way". Another respondent remarked that "A lot depends on how the teacher interacts with technology in the classroom to whether it is used in a beneficial way for students." Testimony to this dilemma is the following statements:

> If mobile learning is done in the wrong way such as simply "fill in the gaps" as opposed to being a tool to reach a final learning goal then the meaningful learning cannot occur.

In general, it appears that PSTs are very appreciative of the power of mobile devices in teaching and learning but feel that some conditions must be met in order to realize their full potential. From the open-ended responses it is evident that equity in regard to the ownership of mobile devices is an issue that hinders full implementation. Likewise, PSTs are concerned about the distractedness that can occur as a result of students having those devices in the classroom resulting in poor classroom management scenarios. Furthermore, they look very aware that mobile learning is effective in

circumstances when the learning task is well designed, is placed in the context of a whole lesson, and when pedagogy leads technology and not the way around.

Discussion

There was strong support among respondents about their personal involvement with mobile devices when it comes to teaching and learning. They also appear to be very self-confident in using mobile tablets and appreciative of the instructional power that these tools can bring to the classroom.

The mobile learning zone of free movement (Handal, MacNish & Petocz, 2013), defined by the interaction of a space of constraints and possibilities and another of pedagogy and technology, emerged as a landscape with unique patterns for each of the four sub-scales. In brief, the Pedagogical Possibilities sub-scale shows that PSTs support mobile learning for its individualizing and collaborative capabilities. In turn, responses to the Operational Pedagogical items reveal a preference for handling and producing in digital formats rather than printed resources as well as the capacity for accessing those resources anywhere, anytime. There was also evidence that having access to tablets help teachers to organize their academic/work life more efficiently. Pedagogical Constraints items related to the scarce availability of mobile learning teaching resources, as well as on instructional concerns related to students' readiness and classroom management. Finally, Operational Constraints issues were related to poor Wi-Fi or a lack of Wi-Fi connectivity when needed. Students' and teachers' not having access to mobile devices was said to make a difference in terms of preparedness and familiarization.

Gender differences did not make a noticeable impact; however, tablet access made a stronger difference in terms of better knowledge of the tool itself, awareness of

its organizational benefits for both students and teachers as well as the realization that the tablet can enhance teacher-student communication. Two particular operational constraints stood up as predictors of adoption: one is the belief that students do not use mobile devices adequately for their learning, a sentiment that is stronger in female PSTs. The other is poor non-school Wi-Fi connectivity which also seems to be expensive. PSTs were also concerned about students and teachers lack of ownership of mobile devices.

Interestingly, these two concerns came out more strongly in the qualitative analysis of open-ended responses. In those comments, PSTs believed that an optimistic yet cautious view should be maintained. Not surprisingly, the highest scoring Pedagogical Constraint item was “Special curriculum tasks to support the use of mobile devices are required”.

PSTs saw mobile learning possibilities being tied to equity issues, minimizing distractedness, positioning mobile learning in the context of broader instruction, dissemination of mobile learning teaching resources, and teacher capacity to integrate technology.

Implications

It came up clearly that PSTs do not think in dichotomies but in a complex way, expressing concepts within a continuum of strengths and weaknesses, of possibilities and constraints, of advantages and disadvantages. For them, the pedagogical beliefs are heavily contextualized, which is an area warranting further exploration through qualitative studies.

Interestingly, the caution theme emerging from the descriptive analysis explains the probabilistic finding that the “Appealing” variable is a positive adoption predictor

while the “Fascinating” variable is a negative predictor. In the light of both quantitative and qualitative data it might be concluded that for PSTs a practical attitude to mobile learning is more effective than having a grandiose expectation around the tool. This is further corroborated by the fact that PSTs chose the item “Interested” as the top scoring personal involvement items while “Needed” was chosen at the bottom of the selections.

Recommendations

What is needed to move PSTs further on the adoption scale to the Stage 5 “Adaptation to other contexts” is perhaps more exposure to mobile learning practical applications in the form of real-life projects and cross disciplinary activities. An exposure to such an environment could create enough confidence in using tools to explore new knowledge, produce learning objects or using them as instructional tools (Handal, Campbell, Cavanagh & Dave, 2014). Stage 5 is characterized by the attainment level where teachers think about mobile devices as a tool to help them and where they are no longer concerned about it as a technology. At that level, teachers use mobile devices in many applications and as instructional aids.

Importantly, the scale used to characterize the space of possibilities and constraints represented by the zone of free movement proved to be statistically reliable for this particular study as it did for the academic study (Handal, MacNish & Petocz, 2013). Future research is recommended to explore through qualitative methods the interaction between the zone of free movement and the zone of promoted action (ZPA). Such research would provide valuable information as to how teacher education modules on mobile learning can enhance the multiple pedagogical opportunities that mobile devices can offer to enrich the student experience.

Conclusion

This study investigated PST students enrolled in a fourth year mathematics education course and their perceptions about the possibilities and constraints in the adoption of mobile devices in schools. Another limitation of this study is that PST perceptions about their use and familiarity with mobile technologies and mobile learning may not actually translate into technology adoption in their future classroom. Although students appear to be self-confident in using mobile tablets, further research including observations in class to ratify students' self-reported perceptions would be beneficial.

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