FINAL SUBMITTED VERSION

Price, S., Davies, P. & Farr W. (2013) Teachers' tools: Designing customizable applications for mlearning activities. In Z. Berge & L. Muilenburg (eds) *Routledge Handbook of Mobile Learning* Routledge p. 307-317

Teachers' tools: Designing customizable applications for mlearning activities

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Abstract: Mobile technologies are potentially important tools for teaching and learning, but their successful integration into educational contexts is currently limited. Teachers' beliefs play a crucial role in the adoption of new technologies and teaching approaches. Based on the design and development of a customizable smartphone application for supporting geospatial approaches to science teaching, this chapter explores how a participatory design approach and the end-product plays a role in belief change around smartphone technologies and geospatial science concepts. Issues around the design process, challenges for implementing customizable tools into teaching practice, and future research directions are discussed.

KEY WORDS: Teacher beliefs, smartphone applications, customizable, science teaching, geospatial, participatory design, design

Teachers' tools: Designing customizable applications for mlearning activities

The functionality of mobile technologies makes them potentially important tools in the current and future landscape of teaching and learning. While research has established learning opportunities that mobile technologies may provide for students (e.g. Franckel, Bonsignore, & Druin, 2010; Kanjo et al., 2009; Klopfer & Squire, 2007; Rogers & Price, 2008), successful integration into educational contexts requires a focus on teachers' use of technology. Although mobile tools to support classroom teaching for various purposes exist (e.g. Ratto, Shapiro, Truong, & Griswold, 2003), uptake in educational contexts remains limited. Previous work highlights a number of reasons for this, including concerns that technology does not reflect pedagogic approaches (Major, 1995), teachers' lack of training or familiarity with computers, and the time involved in learning a new tool (Mueller, Wood, Willoughby, Ross, & Specht, 2008). More importantly, teachers' beliefs about what and how they teach are instrumental in shaping their teaching practices (Luft, 2009).

With a continued shift in K12 education towards mobile and 1:1 computing, growth in on-line learning, and increased bandwidth (Brown & Green, 2008) the need to consider new ways to engage teachers with technologies and new approaches for teaching with them is essential. Traxler (2011) suggests five ways that m-learning offers new learning opportunities: contingent learning, situated learning, authentic learning, context aware learning, and personalized learning, which may apply equally to teachers and learners. Furthermore, increased accessibility to Geographical Information Systems (GIS), such as Google Earth, together with Global Positioning Systems (GPS) and Web 2.0 technologies broadens the potential to support innovative ways of enhancing teaching (e.g. Anand et al., 2010), and provides opportunities to leverage change in pedagogical approaches to teaching science. Modern smartphone interfaces lend themselves to developing customizable applications, supporting teachers' creativity through modification and tailoring of activities to student age, ability, and subject.

This chapter explores the role of engaging in the design process (of developing a customizable smartphone application to foster a new approach to teaching science) in changing teacher beliefs about the value of technology for teaching and learning, and how it mediates new approaches to science teaching. The chapter draws on the GeoSciTeach project, which designed and developed a customizable smartphone application to support a geospatial approach to science teaching. It aimed to enable teachers to customize a mobile application, by selecting and organizing various tools for data collection, information sharing, and information visualization, to tailor the learning experience to support different science questions, age groups, and abilities. A participatory design approach involving pre-service science teachers (PSTs) was taken. These are science graduates training to teach science at 11-16 years, but with a specialist subject to post 16 years (i.e. chemistry, physics, or biology). The design process is described illustrating its approach in fostering teachers' belief development. Finally the chapter outlines issues arising around the research process itself, challenges for implementing customizable tools such as these in teaching practice, and indicates research directions.

OVERALL DESIGN CONSIDERATIONS AND APPROACH

A design process that aims to change beliefs held by teachers requires an involved and intensive timescale in the region of months and years (Trautmann & MaKinster, 2010). During pre-service training, however, beliefs are challenged during a pressured nine-month period. Yet, exposure to new procedural outcomes for pre-service teachers (PSTs), such as geospatial integration in educational settings, can have lasting effects on teacher knowledge, continuing professional development, and student progress (Hagevik, 2011). This section outlines the overall design approach and rationale behind the development of the GeoSciTeach application in this context of PST training.

Providing opportunities for teachers to take an active role in their learning, as well as fostering a collaborative learning process, with a focus on content knowledge is central to successful teacher development (Constible, McWilliams, Soldo, Perry, & Lee, 2007). Taking a participatory design approach, the GeoSciTeach project worked with PSTs throughout the design and development process, involving them from the conceptualization of the application through to the final workable prototype. This approach has been shown to be effective in Human Computer Interaction (HCI), particularly when introducing new tools into current practices (e.g., Mueller, 2002). In the context of teacher professional development this is important in fostering new approaches to teaching familiar subject domains, developing clear links to the educational curriculum, engendering a sense of ownership with the technology, and enabling a deeper engagement with the motivation of the application. In so doing, this approach aimed to facilitate changes in ‘beliefs’ about technology and geospatial ideas in science.

In addition, it is equally important that teachers are given the opportunity to reflect on their beliefs and abilities (Hagevik, 2011). Supporting this through using a contextualized approach has been shown to be effective (Penuel, Fishman, Yamaguchi, & Gallagher, 2007). The design of the GeoSciTeach application centered around a real life example from The Royal Botanical Gardens, Kew, providing an authentic context for thinking about the design of the application interface and the tools needed to support appropriate learning activities. It also directly supported part of the training program, which required PSTs to undertake a fieldtrip at Kew Gardens with groups of 11-12 year old students. The application was therefore used in an authentic teaching activity to promote *in situ* engagement with geospatial concepts and representations in science.

The value of effective subject specific professional development in supporting both teachers’ subject knowledge and pedagogical subject knowledge is well documented (Desimore, Porter, Garet, Yoon, & Birman, 2002). As the project specifically embraced geospatially related concepts to support the development of geospatial skills and awareness, the need to explore and support the development of PSTs' understanding of what 'geospatial' means and its relationship to science was taken into consideration. Geospatial and spatial skills are used to understand and make sense of properties of space. This could be how we represent real things on maps, images and diagrams, including how we visualise and think about things in two- and three-dimensional representations. Understanding Science often requires students to use geospatial and spatial skills, for example, in ecological studies considering succession and habitat changes through time. Digital technologies such as geographical information systems (GIS) and global positioning systems (GPS), together with sensing equipment (e.g. temperature, carbon monoxide), allow students to collect data and manipulate them in new ways. For example, students take pictures of plants in specific habitats and environmental measurements, and tag them according to their location in the world. Pictures and information are automatically uploaded to Google Maps, where students can then examine the different plant and environment characteristics to reason about biological and ecological processes. Again the use of an exemplary concrete activity enabled discussion with PSTs around these aspects.

Developing customizable applications also requires particular design considerations. Previous work has developed authoring tools to be usable by teachers without programming skills (Ainsworth, 2006), and empower them to be designers of learning environments (Major, 1995). However, they lack clear evidence of effectiveness, and require time intensive effort in initial learning and preparation of new activities (Ainsworth & Flemming, 2006). They also focus on content manipulation, and foster a proliferation of activities such as quizzes (Hutchful, Mathur, Joshi, & Cutrell, 2010). Despite an ‘easy to use’ design, these environments are not innovative in terms of the pedagogical approaches they encourage, nor the learning activities created (Mueller et al, 2008). In contrast mobile applications foster more active learning experiences, empower student engagement, portability, instant communication, and flexible and timely access to learning resources (JISC, 2005). For teachers these tools, therefore, need to support customizable *orchestration* as well as customizable content. Again basing the design on a concrete example of student learning activity aims to ensure that the application ‘works’, and enables PSTs to think about the technology – where and why it might be functionally useful, whilst also linking this with geospatial concepts. Once the application functionality has been created for the exemplary activity, then the customizable aspect can be developed. In this way, development ensures the end product is useable by teachers, alongside better insight into the application functionality before having to think about different activities to customize. PSTs were fully involved in the whole design, that is, the customizable form and the functionality of the application.

Effective teacher development conceptualized by Clarke and Hollingsworth (2002) provides a useful way to consider how teacher development is most productive. They conceptualize teacher progression (or growth) occurring through the dynamic interaction between domains, namely external sources of support, for example involvement in the project described here; teacher beliefs, professional experimentation, and teacher values (described by them as “salient outcomes”). When professional development is most effective, “change sequences” are observed between one, or more, of these “domains” which leads to “growth development”. Of particular significance, is the observation that for change to be long-term, teacher beliefs are central but that teachers need time and extended opportunities to refine their practices if change is to be permanent, something echoed in Trautmann and Makinster (2010). The involvement in the GeoSciTeach project required long-term commitment from the PSTs (across and beyond their training program), as well as giving opportunities to reflect on their practice, through exploring the use of new tools (smartphones) and new approaches to the thinking about science learning (geospatial). The approach to the design taken here is thus a good example of the Clarke and Hollingsworth professional development model for long-term growth and change.

The project provides an exemplary context within which to explore and discuss the process and outcomes of a customizable mobile phone interface. In so doing we aimed to also draw out key issues for future research to explicitly support teachers in their use and application of mobile technologies as an integral part of their teaching.

DESIGN PROCESS: IMPLMENTATION

This section details the implementation of the design approach, illustrating how this approach sought to foster changes in teachers' beliefs, highlighting both practical and conceptual issues that arose during the process.

PSTs were introduced to the GeoSciTeach project, and were recruited to participate on a volunteer basis after six months into their ten-month teacher training course. This involvement aimed to ensure end-user input into the design and technical requirements of the application, and contribution to the pedagogical design of the learning activities. A series of four, two hour long, workshop sessions over a five-month period were conducted to steer the development of the application, and give participants the opportunity to feedback to designers over the progress of the application. A project blog was set up to encourage participants to generate ideas about science learning activities, discuss geospatial notions and to comment on the development of the application throughout the project.

During the first session, a fuller explanation of the project was given, an outline of expected participation in the planned program of work, and consent forms completed. Participants began by describing the kinds of science practices and activities their students would currently engage in 'in the field'. An introduction to mobile smartphones was given, together with some example scenarios (plant response to climate change, electrical noise) for their use generated by a science education lecturer. These were also available on the website for participants to look at and think about in preparation for the next workshop.

In the second session participants were divided into small groups according to specific subject specialization (biology, chemistry and physics) to brainstorm ideas about possible scientific activities collaboratively with tutors, computer scientists, and HCI researchers. Eight Android phones were distributed across groups of five to six participants to facilitate this process. Most PSTs in physics and chemistry subject groups found it difficult to link the capabilities of the phone to learning in science, while biology-based discussion centered around the use of data logging sensors, which would require add-ons to phones. Biology graduates typically have experience using technology to support ecological investigations and their focus on this use of technology in their discussions emphasized the importance that prior learning and experience plays in teachers thinking about pedagogical approaches (Luft, 2009; Trautmann & MaKinster, 2010). The combined expertise of the team and participants highlighted the need for PSTs to think more specifically about what they would want their students to do in a particular learning scenario or activity, for example, the kind of data they would need, what they would do with this data, and what they need to learn during the process. In so doing, we could help map smartphone potential and geospatial ideas more directly to teaching goals. This approach is essential if the teacher wants to go beyond thinking about the technology as simply an additional ‘add-on’ to learning but actually use it to improve learning, both in terms of geospatial skills and specific subject content (McClurg and Buss, 2007). PSTs’ lack of familiarity with and understanding of geospatial concepts emerged from this session. In the context of science, taking a geospatial perspective is fairly progressive, and as such not explicitly written into the curriculum. Supporting the mapping of geospatial ideas to science teaching and the curriculum thus became a central part of the development process.

The next session focused on geospatial skills: an online survey of geospatial skills and current technology usage was circulated to participants and the basic concept of layering of information was explained; a concept fundamental to geospatial thinking. It was found over the three sessions that PSTs struggled to comprehend science activities within the context of mobile learning, with the use of a smartphone and geospatial ideas. Building on Haklay's (2010) three levels of geospatial reasoning (descriptive, analytic, inferential), a framework was developed to help PSTs map geospatial theory to science. It offers a description for each level, identifies ways in which the GeoSciteach application supports these, and maps them to related geospatial skills. This also indicates how curriculum development and geospatial skills move from the ability to identify and capture data, to making patterns and routes, and finally to understanding relationships and interconnected processes.

[INSERT TABLE 1 ABOUT HERE]

Development of the smartphone application activity took place in parallel with these workshops. Similar to Trautmann and MaKinster (2010), our approach involved the introduction of geospatial tools and smartphone technologies through application to a specific exemplary activity to be employed in an authentic teaching context (Kew Gardens). An online web application, Mockingbird, was used to produce mock-up designs for the application. These prototypes were made available to the PSTs for comment on the blog, as they were remotely situated in teaching placements. Opportunities for communicating and discussing ideas increases participant involvement in the design, improving the likelihood of long-term change (Trautmann & McKinster, 2010).

A smartphone prototype was developed based on mock-ups, discussion amongst project team members, and feedback from PSTs. A number of data collection tools considered necessary to support science fieldwork activity were made available as part of the application, including a camera, video camera, and data logging of abiotic factors (e.g. temperature, humidity). Students were also given the facility to record taxonomic information about plants' characteristics (e.g. through a series of leaf silhouettes for matching entities in the environment), human uses, and plant significance within a certain ecosystem. This gives the opportunity to gather information that is then mapped onto broader science learning ideas, for example the importance of structure and function in biological thinking. The place of origin of a plant could also be tagged, and layered onto Google Earth. These potential layers enable students to see patterns of plant distribution and adaptation throughout the world.

A fourth session with PSTs presented a working prototype as described above, initially being guided through the application in mock-up, before trialling it in pairs in an inner-city park. Participants provided feedback on aspects of the design they found useful, which ones needed additional modification, and what was lacking. The prospective Kew field trial was used as a concrete instance to work toward, providing a contextualised approach (Penuel et al., 2007). The application was made freely downloadable from the Android marketplace with automatic update. Participants were each provided with Android phones, so that all iterations of development could be trialled. This was important as PSTs being on teaching placements could trial the application at any time. In so doing PSTs were "given time to practice using new tools and data sources while also considering how they could apply these resources within their curriculum and with what pedagogical approaches" (Trautmann & Makinster, 2010, p. 365).

One week prior to the field trip with 11-12 year old students, the PSTs had an introductory meeting and planning day at Kew gardens. During that time, logistics of teaching and planning activities were undertaken. Project participants were given time to explore the possibilities of using GeoSciTeach in their teaching with the pre-service tutor involved with GeoSciTeach. They were not obliged to use the smartphone application but could do so if, and when, they thought it would support the learning activity. However, all project participants involved in teaching chose to use the application as part of the learning experience. PSTs devised questions that they felt could best be supported by GeoSciTeach, ranging from "How do plants maximize photosynthesis?" to "How do humans use plants?" These questions enabled exploration of how geospatial aspects of science learning might be foregrounded, through enabling students to harvest data and compare, contrast, and interact with that data locally and globally. The content of these questions suggests that the PSTs were beginning to change their understanding about geospatial thinking and develop a deeper appreciation of pedagogical content knowledge. This change implies that the participants' beliefs about the use of geospatial thinking in their practice was developing and that they were starting to identify different "salient outcomes," as described by Clarke and Hollingsworth (2002). PSTs had one week to plan all activities for the student field trip, including their preparation of QR code links, and selected video links.

During the exemplary activity day at Kew, children worked in groups of 16-18 and came around to each activity in turn. Where groups included project participants as teachers, the smartphone application became one aspect of the learning activity. While teachers not directly involved in the project showed little interest in how the application worked, those who used the application reaped the rewards as their students focused more on the specifics of geospatial relationships. For example, the prompt to upload photographs to Google Maps guided students to think about plant location in the world and its related habitat features.

In terms of beliefs and practice, different teaching approaches manifested differing use of the application. For example, while explaining how to use the application to each group of students one teacher made clear reference to how the app can be used for both science (specifically in relation to the question they were asking) and for accessing geospatial concepts (focusing on where things are in the world). Analysis of this PSTs interaction and use of the tool demonstrates developed competence in applying the technology to support a geospatial approach to science teaching. Another example (where one PST adopted a didactic teaching approach while the other took a facilitative approach), illustrated how the application supported the facilitative approach to greater extent than the instructional approach. This suggests a design coherence with constructivist approaches, which are important in modifying underlying 'traditional' beliefs of many science teachers to teaching science (Mansour, 2009).

Interviews with teachers and students into how well they thought the application worked revealed that both groups found it easy to use in context (teachers (novices to the app) taking about 15 minutes, while students took five), and that they themselves perceived that the application helped them to think geospatially about science. In terms of application design, one element that arose from discussion was that the application needed to have the option of being more structured or guided. PSTs were also concerned that collected data and planned activities on the application would have to be gathered, stored, and able to be distributed to students.

This was addressed during the development of the parallel mobile application enabling teachers to change the learning activity and the tools provided to guide or support the activity. The customizable part of the application begins by allowing teachers to choose the starting location for the learning activity, for example, Kew Gardens, or the school grounds. In this way the activity starts with the map (location) foregrounding geospatial notions. The teacher then types in the question they want their students to explore, and selects from a tick box link which data collection tools they would like to be made available to students. Teachers can modify supporting information and related information sites (e.g. in the form of YouTube video clips, text, or through QR readers), allowing them to tailor the experience to specific learning topics in fieldwork settings. However, during this phase of development, PSTs had finished formal training, and further attempts to arrange meetings and phone interviews with participants led to poor up-take. Instead, through contact from the Kew field trial, teachers from a school science department enrolled to trial the customizable application through a series of In Service Training (known as INSET) sessions after school. However, due to teacher time constraints and management pressures this became increasingly difficult to implement. Real challenges to engaging in participant design are exemplified here. As in many training and workplace contexts time pressures, management approaches, and the opportunity for consistent long-term commitment is problematic.

However, eight PSTs from a different cohort of PSTs did volunteer to trial the application and its customizable interface. A workshop session provided the opportunity for trial and comment on the exemplary activity application, as well as the customizable part of the application. The PSTs took around 10 minutes to find their way around the different tools for the exemplary activity, and discussed how they thought it could be used to help students explore the question “How do plants maximize photosynthesis”. Several suggestions for modifications or additions to future iterations were given including a place for a guidance note on the question page (similar to a breadcrumb trail that guides the students through the task), and a timeline or a percent guide that showed how much of the activity is completed or how much time is left. One group wanted haptic feedback (hotter, colder, with the phone vibrating when you were near something of interest (Rogers & Price, 2008). Others observed that there were a lot of tools/choices to make. However, the customizable nature of the application is precisely designed to allow teachers to choose as few or as many tools as they think appropriate for their question and students.

To trial the customizable interface PSTs were asked to choose one of a set of science questions, and in pairs, to create a learning activity for their students using GeoSciTeach. This involved deciding what activities the students would need to undertake, for example running, and what tools they would need to collect record and store data, such as, measurement sensors, camera, Google maps. Instead of using a ‘set’ question, each pair formulated their own science activity question. This is interesting as it indicates that the exemplary activity provided an effective grounding for them to extend the application to new science contexts. For example one pair designed an activity around the question “How fit are you?” For this students would go on a run, use GPS tracking to see where they went, how far, how long it took; recordings of pulse and breathing rate (and in future iterations, carbon dioxide measurements to explore metabolic rate).

EMERGING ISSUES AND FUTURE RESEARCH DIRECTIONS

This section draws on findings from the project to highlight emerging issues from the design and development process, and its role in fostering change in teacher beliefs. Finally, key directions for future research are outlined, that will engage with both the emerging opportunities for mobile learning in teaching contexts, and the principle challenges for research and situated application.

Engaging pre-service teachers in the design, development and evaluation process proved fruitful in: (a) developing a prototype application that subsequent pre-service teachers were able to quickly grasp and begin to develop their own new ideas of how to use the application in their science teaching; (b) developing ways to support the integration of new teaching approaches (in this case geospatial skills) with the use of new technologies; and (c) indicating ways in which pre-service teachers views of mobile technologies and the associated geospatial concepts could be useful in their science teaching. PSTs experienced each of the new learning opportunities afforded by m-learning (Traxler, 2011) at varying levels. Contingent learning occurred during the process of understanding the role of the smartphone application and the relationship between geospatial and science. Engaging centrally in the design process highlighted PSTs response to their changing experiences, enabling dialogue around, for example, what geospatial in science means. Situated learning took place during trials in the urban park and Kew Gardens, consolidating their competence in context. The project fostered an authentic learning approach, by engaging PSTs to think about and generate real science questions related to the curriculum. In terms of personalized learning, the application's customizable feature offers PSTs opportunity to think about how to tailor learning for different age groups and abilities.

Trautmann and Makinster (2010) suggest that involvement in implementing new tools can mediate belief changes in teachers. However, their study comprised intensive technical and pedagogic support for teachers to implement geospatial approaches in their practice over the period of one year. In contrast our study focused on the development of a tool that could be used in school, but primarily explored PSTs development of geospatial awareness and competence with technology – an antecedent to full classroom implementation. This was considered an important part in the process of belief change, through the design process (technologically and pedagogically), and their developing understanding of the geospatial-science relationship. The design process offered access to a deeper level understanding of the pedagogical and technological foundations of the tool. Nevertheless across both studies long-term commitment from participants was a central issue.

However, Mansour (2009) identifies a number of important barriers that impede teachers from putting their beliefs into practice. Time availability is problematic for teachers and the pressure of working in a busy school environment often means they cannot commit sufficient time to both thinking about, and developing novel resources. However, of greater importance to the project reported here is that some of the teachers felt that external pressures, for example from school policies, would hinder their use of new technology in their practice. For example, during the interview one project participant noted how the school he was now working in was not keen on the use of mobile phones, and even stipulated the type of mobile phone allowable on school grounds. These types of problems are hard to overcome and, in part, rely on a case being built to support the benefits of using new technology. This move to want to change practice echoes the "salient outcomes" described by Clarke and Hollingsworth (2002), although they were discussing this in the context of individual development, this can be applied to the other levels of school organization, such as departmental or senior management. Being customizable, GeoSciTeach lends itself to teachers having autonomy over the 'tool' allowing them to design activities which are specific to their learning context, and this may go some way in helping teachers to convince others of the benefits and applications of this technology.

While future research continues to face challenges of long-term commitment from end-users, this project illustrates how the development of an application like GeoSciTeach in the context of pre-service teachers, offers the opportunity for continued use and evaluation across subsequent cohorts. One fruitful avenue for research is to examine ways in which these kinds of technologies or applications can be embedded into teacher training programs, and so be usefully employed in the support and development of new approaches to science teaching.

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