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Designing Fieldwork with Mobile Devices for Students of the Urban Environment

Dora Constantinidis
Computing and Information Systems (CIS)
University of Melbourne
Wally Smith
Computing and Information Systems (CIS)
University of Melbourne
Shanton Chang
Computing and Information Systems (CIS)
University of Melbourne
Hannah Lewi
Architecture, Building and Planning
University of Melbourne
Andrew Saniga
Architecture, Building and Planning
University of Melbourne
John Sadar
Architecture
Monash University

Fieldwork learning frees students from the usual confines of classroom teaching and allows them to undertake relatively independent exploration and reflection. This paper reports on three case studies of attempts to enhance and support student fieldwork through the use of mobile technologies. The studies were conducted with students of the built environment who accessed either specially customised multi-media self-guided directions or pre-existing downloadable apps. The focus in the paper is the design of mobile-supported field activities. Five dimensions that need to be considered are identified: volume of content delivery; extent of data capture; directedness of the learning activity; extent of student collaboration; and strength of link to assessment

Keywords: mobile devices, fieldwork, built environment, directed learning

Mobile devices and tertiary education

The potential value of mobile digital technologies for student education is widely realised and actively under development (e.g., Sharples et. al. 2005). There are now widespread efforts to use smart phones and tablets to enhance lecture theatre experience, to provide administrative support for teaching and learning, and to allow students more convenient access to learning resources at anytime and anywhere. However, there has been relatively little empirical investigation of how to design and use mobile technology to enhance learning activities that have traditionally occurred outside the classroom, namely field trips and other kinds of fieldwork. With notable exceptions (e.g., Dyson et. al. 2009; Bedall-Hill 2011) there have been few reported studies of designing mobile applications to enhance student learning in the field. In this paper, we describe a project with this aim, and report three studies of designing mobile support for students of urban environments, including architecture, landscape architecture and urban design. All three cases set out to situate student learning theory within the experience of what is usually a convoluted reality out in the field.

A review of current literature on the application of mobile devices for mobile learning or 'm-learning', indicates that successful adoption (e.g., Cochrane 2010) has been gradually increasing despite sceptics of this trend (e.g., Traxler 2010). Numerous researchers have advanced various adaptations of mobile technology for educational purposes over the past decade or so (e.g., Sharples 2000; Cochrane and Bateman 2010). These variations will continue to be adapted within the evolving tertiary education landscape, influenced by both new forms of technology and the new expectations and familiarity of successive student cohorts (Albion et. al. 2012; Murphy 2011). However, some researchers argue that mobile devices have so far been mainly used for unidirectional teaching as defined by Berger and Karabenick (2011). Most effort has gone into providing efficient delivery of course content, and to making it conveniently accessible to increasingly “mobile” students (Murphy, 2011). But alongside this practical goal, there is increasing awareness that mobile devices and applications need innovative designs and approaches if they are to genuinely stimulate and inspire active learning within a social collaborative context. To achieve this, it is recognised that more empirical evaluations are needed (McConatha et. al. 2008; Corlett et. al. 2005) including predominantly user reflections (Chang et. al. 2012; Bachfischer et. al. 2008), as to the benefits of the use of mobile devices.

To support traditional field trips and visits through the use of mobile technology can be considered as one part of this move towards m-learning. Fieldwork is valuable for students in many disciplines to develop a practical understanding of concepts and theory. If well-designed, field exercises present an ideal opportunity to create 'authentic' learning experiences of the sort advocated by Herrington and Herrington (2007). Students undertaking fieldwork are not limited by the formal confines of the classroom and can in principle reflect more independently about concepts and ideas, and their application to “messy” reality. Fieldwork-based exercises have been a traditional and fundamental part of learning in many disciplines such as geography (Welsh et. al. 2012; Simm et. al. 2011; Dunphy and Spellman 2009) and biology (Lee et. al. 2011). Dunphy and Spellman (2009) and Stokes et. al. (2011) consider fieldwork to be of intrinsic value and even of necessity to geography students, but at the same time provide cautionary remarks that it does not necessarily provide equal benefit to all students given that a disparate cohort of learners has differing learning styles (Kolb 1984; cited in Dunphy and Spellman 2009). More recently formed disciplines have made less use of fieldwork, although there are some exceptions, for example in information and communication technology (Dyson et. al. 2008).

In this paper, we present initial insights from three case studies of fieldwork supported by mobile technology. Each case study is centred around a particular taught subject, and the investigation covered the design, deployment and evaluation of students using mobile devices in the field. In all cases, students used mobile devices in learning spaces they were required to explore and investigate as part of their study. Although the fieldwork exercise was conducted beyond the fixed space of the classroom in all three cases students’ reflections were brought back to tutorials for post-field reflections and analyses within a classroom setting. To evaluate the effectiveness of these exercises students’ use of mobile devices was observed in the field and these observations were also supplemented by conducting surveys and interviewing students. While the scope of these case studies was broad, the aim of this paper is to identify the major dimensions that defined our design decision-making process as the exercises were constructed. We present these design dimensions as a resource for educators to consider and apply when they design or evaluate the potential use for mobile-supported fieldwork exercises.

Learning theories for mobile device use

Research into the use of mobile technology in learning has drawn on a variety of theoretical frameworks. These include: active learning (Dyson et. al. 2009), activity theory (Albion et. al. 2012), collaborative learning (Kahn and Chapel 2010; Abrantes and Gouveia 2011; Park 2011); constructivist approaches (e.g., Herrington 2009); and communities of practice (Cochrane and Bateman 2010).

These theoretical frameworks have informed the design of learning activities that utilise mobile devices, ranging from: the earlier PDAs (Alford and Ruocco 2001, Dyson et.al. 2009, Hafeez-Baig et. al. 2006); to the more the recent iPads (Murphy 2011; Kinash et. al. 2012), iPods (Albion et. al. 2012, Jarvis and Dickie 2010); and Smart phones (Cochrane and Bateman 2010, Lee et. al. 2011, Chang et. al. 2012). Wu et. al. (2012) have argued recently that the primary issues of concern when deploying mobile devices for teaching and learning purposes are: the appropriate *design* of the use of mobile devices (Goh et. al. 2012, Dimakopoulos and Magoulas 2009, Roschelle 2003, Sharples et. al. 2002, Vavoula 2010) and *support* for students using mobile devices (Lee et. al. 2011, Costabile et. al. 2008).

Drawing on these established theoretical frameworks brings continuity to the field of m-learning, by emphasising that the challenges for educators are, in part, the long-standing ones of understanding the nature of learning and designing tools to support it (Dyson et. al. 2008a). Equally, the adaptation of the established frameworks in the research cited demonstrates how mobile technologies bring a new terrain in which the traditional concerns of the educator and learner arise in new forms (Kearney et. al. 2012). Theorising allows to see that mobile technologies applied in conjunction with appropriate theoretical frameworks (Ng et. al. 2010) can potentially allow for mobile learning that goes beyond mere 'novelty and convenience value' (Herrington and Herrington 2007). In the case of designing for fieldwork activities, a particular kind of support for learning is needed when students are sent out to the field without supervisory teaching staff. It is this particular challenge that we begin to address in this paper.

The potential uses of mobile devices in fieldwork activities

Mobile technologies are now very versatile computing platforms that offer a range of functionalities to enhance and support fieldwork. Beyond content creation and uni-directional information dissemination in the field, they can, in principle, allow students to gather data and provide a medium for multi-directional interaction between student and teacher, and student to student. We will first briefly review the potentials of this functionality before turning to our project.

Firstly, fieldwork requires ongoing *guidance*, including navigational directions to explore the site, and also instructions on how to carry out learning activities. Existing maps and compass applications, including in-built GPS features, can support this to an extent. In addition, teachers can develop packages of task instructions that can be made available on mobile devices.

Secondly, as with the general approach of m-learning, mobile devices can be used for rich content delivery (e.g., Murphy 2011; Costabile et. al., 2008). However, this has special implications for fieldwork and requires a special form of content. For students to achieve a high level of engagement with their environment, mobile guides might promote greater *interaction* with the objects under observation. For example, the content presented on a mobile device *in situ* can help students to “look with intention” (Sanders 2007, p. 181; cited in Welsh et. al. 2012) to make better sense of the field situation. For the students of the Built Environment studied here, this might be elements of the landscape or buildings encountered.

Thirdly, a mobile device might be used by students for *data capture*: the measurement and recording of the environment, usually for later analyses (Lee et. al. 2011). That is, the mobile device might take the form of an instrument to make measurements of 'objects' under investigation. Fourthly, in a related potential use, the mobile might take the form of a field note-book for students to do *field recording* by logging their activities. Herrington (2009, p. 60) states that 'Fieldwork and excursions were seen as particular contexts in which the affordances for mobile technologies could be exploited. Gathering data in the form of pictures, videos and sound recordings and note taking all appeared valuable activities that supported constructivist based activities set in contexts outside the classroom and lecture theatre.'

A fifth kind of use of mobile technology is to support *collaboration* between students and/or teachers. This might be to share data and learning resources, or to coordinate activities with each other. Recording *in situ* naturally promotes all forms of collaboration, as students can more easily exchange data with their peers by using mobile devices. More collaborative learning activities become possible for the teacher to design. Peer to peer coordination and shared experience can be enhanced in the field through the full range of social media as suggested by Hamid et. al. (2010).

Three case studies of mobile-supported fieldwork

Three subjects formed the focus of the three case studies investigated here. It was recognised early on in the project that when adopting any mobile device for fieldwork teaching and learning, careful consideration must be made for the learning goals of the exercise in order to properly design the use of mobile devices for pedagogical purposes (Kearney et. al. 2012). The circumstances of the three field activities are now briefly described.

Case 1. Environmental site analysis

This study was developed and conducted for third year undergraduate students taking the subject 'Technologies and Environments 3' in the Bachelor of Architecture at Monash University. The intention of the field exercise was to have students work alone without staff present and to work reflectively through the tasks of collecting real data from a physical site. This involved student immersion in the physical experience of day lit spaces and their comparison with numerically expressed light levels and sun angles; reflection on the relationship between physical data and the psychological experience of the dimensions as affected by other variables like surface qualities; considering the use of spaces in the same moment as physical data; and considering the validity, reliability and value of data measurements. Three digital tools were provided to students for the fieldwork exercise: an instruction pack of images as a 'guided tour' through the designated spaces of the exercise; 'LuxMeter Pro' and 'Solmetric' both existing downloadable iPhone and iPad apps that measure light levels and sun path respectively. Sixty students completed the task over a two week period in their own time. During the exercise, observers conducted brief informal interviews with students. In a later tutorial, 31 students completed a questionnaire about their experience and perceived value of the fieldwork exercise.

Case 2. Comparative understanding of historic buildings

This study concerned an iPhone/iPad app walking tour of historic buildings, developed by two of the authors (Lewi and Smith), for second year undergraduate students taking the subject 'Formative Histories' as part of a Bachelor of Environments or a Bachelor of Arts at The University of Melbourne. The downloadable app presented audio and visual materials to in excess of 300 students who toured in small groups without staff. The learning activity was for students to look more intently at buildings *in situ* to make better sense of what they encountered, by overlaying an informed commentary of built features and design concepts and history. An evaluation questionnaire was completed by all students in a later tutorial. The questionnaire probed: the kinds of social interaction students experienced in the task and the perceived value of the exercise and of the different kinds of audio and visual content that was provided.

Case 3. The interpretation of urban landscapes

This study concerned a field site exploration carried out as part of a subject 'History of Landscape Architecture' taken as part of the Master of Landscape Architecture at the University of Melbourne. The students were provided with an in-built iPad app developed by three of the authors (Lewi, Smith and Saniga) which presented audio commentary, historic images and video about 12 designated stops, and a variety of generic resources including a map with GPS location guidance and detailed landform contour maps. A class of 32 students was divided into two groups of 16. Only one group of 16 was split into four groups of 4 students, and each of these groups conducted the field tour using the mobile iPad guide. The 4 groups used a map to find 12 locations in the park. At each location they listened to an audio account. The researchers carried out direct observations of the students conducting fieldwork with the mobile guide (one researcher followed and observed each group). Brief and informal but non-intrusive interviews were carried out with students during the exercise which lasted between 2 to 3 hours. Later, students were given a questionnaire which probed their understanding of the various the tasks, and the perceived value of the overall exercise.

The aim in this paper is to report on the design process that occurred through the design and delivery of the mobile device supported field exercises. The design thinking is captured as five key dimensions that motivated discussion and defined the key decisions made. These are shown in Table 1 which also shows how the three cases varied in terms of each of the dimensions. The dimensions identified are:

The *volume of content delivery*. Mobile devices offer the potential to present encyclopaedic volumes of information. The designer of the field activity must decide whether to provide a great depth and breadth of content or whether to serve more lean activity-oriented material. Great volumes of content may be valuable but also risk distraction and over-focus on the technology relative to the field environment.

Extent of student data capture. As noted, mobile devices can be turned into measuring instruments through specialised apps (as for Case 1). Also, students can gather photographs, videos and notes as field records. The extent of these activities that are demanded by the field activity is a key consideration.

Directedness of learning activity. Putting students into the field is an opportunity to give them a valuable open-ended exploration of a real world situation. However, there is also the risk that they become uncertain about what they are being asked to do, and why it is of value for learning. A key dimension, therefore, is the extent to which mobile guides for fieldwork are prescriptive in directing students in their activity. This dimension refers not to the field activity as a whole, but rather to the part of the activity where the focus of learning takes place.

Extent of student collaboration. Mobile apps may be used to support social interaction between students (as noted above) and also the activities designed into the field activity, and partly embedded in the technology, may demand collaboration between students to varying degrees. This dimension captures the decision of the fieldwork designer about the extent, and also the nature, that this collaboration is demanded or facilitated by the activity.

Strength of link to assessment. The field activity can be designed with varying degree of real or apparent links to students' assessment of their studies. Mobile technologies can play a role in establishing and confirming such links. A direct connection might be an assessable quiz presented on a device. More generally the way the field activity is framed and communicated through mobile tools can strengthen or relax a direct connection to assessment.

	Volume of content delivery	Extent of student data capture	Directedness of learning activity	Extent of student collaboration	Strength of links to assessment
Case1. Light and sun path analysis	Low	High	High	High	High
Case 2. Comparative understanding of historic buildings	High	Low	Medium	Low	Medium
Case 3. Interpretation of historic landscape	High	Medium	Medium	Medium	High

Table 1: The dimensions of designing mobile-supported field activities for each case study.

Having outlined the three cases, we now describe in greater detail how they were shaped by the five dimensions of mobile-supported fieldwork identified and summarised in Table 1.

Design dimensions for mobile device supported fieldwork case studies

Case 1: Environmental site analysis: Design dimensions

The learning context of this case study was environmental qualities, their measures, and their place of increasing importance, because of health concerns and the environmental crisis, within architectural design. The fieldwork required students to conduct intensive measurements of light conditions by using pre-existing apps that could be downloaded to either iPhones or iPads. This case study differed from the other two studies since the collected data were then used as input into a software simulation program for more extensive analyses of light conditions and how these may impact the environmental conditions of a building. Learning about these effects within a lecture context was not possible. Hence the use of the environmentally-aware sensors available on iPhones or iPads meant that students could measure environmental phenomena *in the field*, making the sensed light conditions more apparent. Students worked in groups of 2-4 to measure both the illumination levels and sun angle within 4 designated spaces in the chosen building. The intention of the exercise was to have students work alone without staff present and to work reflectively through the tasks of collecting real data from a physical site. The fieldwork exercise was designed to immerse students within the physical experience of day lit spaces and compare numerically expressed light levels and sun angles with their perception of the phenomena. Table 1 shows how we considered each of the five design dimensions when designing this field activity. Since the mobile devices were used primarily to support the task of *measuring* light levels and sun angles this field activity was considered as being high for the **data capture** design dimension. It was also considered high on the design dimensions of **directedness of learning**, **student collaboration** and **links to assessment** given the nature of the required tasks that were conducted as part of this fieldwork exercise. The level of **content delivery** was considered low. Apart from an instruction pack of images to guide students to the correct spaces under investigation, no other content was made available to support their interaction with the designated spaces.

This case study identified a need to design ways for students to avoid a mechanical completion of the field task and instead to encourage reflective consideration of data meaning and validity. Even though measuring units are essential for design, students were encouraged to better understand what the units mean in relation to bodily perception. This was intended to lead on to a better understanding of how that relationship impacts the way architects think about building design. Since the mobile devices were used primarily as tools to take measurements the need to support stronger interaction with the environment was identified. An aim for the use of devices to measure light levels in student groups was to induce more social and integrated reflection from the students about expected light level readings and how effective they were for the design of the rooms they were investigating. An unintended effect of the field task was that it became a test of understanding of some basic concepts of lighting measurement including luminance. This had been discussed in three of the lectures in the subject. The assignment revealed uncertainty amongst the students on this point and it was realised that stronger consideration is needed for ways of priming students in preceding lectures about the value of the exercise and its integration into lecture content.

Challenges: This case encountered the special difficulties around the use of mobile technologies to guide students to complete a field activity without the presence of a teacher. As with any use of a measuring instrument, the students needed to evaluate the reliability and validity of data collected *in situ* and to experiment with ways of improving these. This is complex for computational measuring tools where the inner workings of the software are opaque. There is currently a limitation to the use of the app chosen in this study for taking light readings. The app did not average the light falling on its surface, but rather analysed what the camera saw, and thus took into account colour and texture. For example pointing the mobile device camera at a black surface would give a different result from a white one and a matte surface would give a different result from a polished one. Without a teacher present to discuss issues of reliability and validity of measurement, many students carried out the tasks with ongoing uncertainty. Another issue encountered is that if hardware is limited, students have to be scheduled on the equipment. This then limits the possibilities of time of day/day of week the exercise may be conducted and other environment conditions may limit the viability of the exercise. For instance, on an overcast day finding the sun angle is difficult to measure. Similarly, access to the designated spaces for the field exercise may be limited to particular times and all of this impacts the possible results.

Case 2: Comparative understanding of historic buildings: Design dimensions

This fieldwork exercise was based on a tour of historic buildings along Collins St in Melbourne using either iPods or iPads on which students download a customised app from the AppStore for free. The intention was to communicate to students aspects of building elements within their historical context and to provide a firsthand experience for students to observe buildings within their street context. Looking at buildings and places *in situ* is a significant and established component of architectural history teaching. In designing this field activity, it was considered as being high for the design dimension of **content delivery**, given the focus on delivering historical information in the form of audio commentary and archival images. Since students were *directed to look* at specific features on buildings, a medium level for **directedness of learning** activity was attributed for that design dimension. That is, there was some degree of freedom for students to shape their own experience of the buildings, but some degree of direction. **Data capture** with the devices was low because apart from students taking the occasional photograph there was no explicit instruction in the field activity for students to record or gather data. The few students who made sketches with an iPad were not considered to be a central part of the main field activity. **Collaboration** is also ranked low because although students toured in groups, the intrinsic task of looking at the buildings was an individual one. A quiz accompanied the fieldwork and was used as a tool to direct student attention and to bring responses back to the classroom to facilitate further discussion and opportunities for learning. The quiz required students to listen to the audio, look at images and to then answer short questions, multiple choice questions, or provide drawn responses. This quiz is directly related to the fieldwork exercise and also provides insights to support the subject's teaching more generally, but forms a fairly minor component in the subject's overall assessment. As such **links to assessment** for this case study were considered as medium.

Challenges: In designing this field activity, it was found valuable to prime students in preceding lectures about the value of the tour and integrate this into the lecture content. A follow up tutorial was also conducted to discuss outcomes and debrief students. It was important that teaching staff, including tutors, were fully aware of the tour and able to communicate its relevance. For this, all teachers completed the tour themselves. From initial student feedback it was realised that audio commentaries should be an appropriate length of time, in most cases less than 2 minutes. Both content and style of delivery in the audio commentaries required careful design. Student preferences were for more building- and design-focus content, and for less general background history. Our response to this so far has been to design audio commentaries around ‘directed looking’ to pick out features of the environment, in the style of a traditional person-guided tour. Keeping the app simple and robust and making it publicly available on the Appstore worked well. However, at the same time the app needs to be tailor made for the particular subject so that, for example, it can include integrated digital assessment options, like a built-in quiz. It is important to use recognised techniques of teaching and learning appropriate and familiar to the subject if the tour is based mostly on the delivery of information. For example in learning about history, using images for context and international comparison, as they are used in lectures. Dealing with very large student numbers leads to constraints in terms of experimentation of design and delivery. The design and delivery motivations are overtly about content delivery; teaching, rather than overtly experimental or participatory in terms of content creation. This is because the app was designed to mimic and enhance an old established mode of fieldwork through a lecturer-led tour. This could have been conceived quite differently, but once embedded in the technological design, it was difficult to change direction.

Case 3: The interpretation of urban landscapes: Design dimensions

This fieldwork exercise was based on a tour of the Royal Botanic Gardens (Melbourne) and surrounding parkland with support through an iPad guide. The intention was to communicate to students aspects of physical change in the shapes and forms that constitute a historic landscape, and to achieve this via first-hand experience coupled with digital resources. The main objective of the use of iPads for this fieldwork exercise was to facilitate the delivery of more extensive visual and auditory materials, to promote new ways of learning while interacting within a site. It was expected that by providing access to images and audio explanations of features at the Royal Botanic Gardens students could better interpret the form and experience of designed landscapes, and the history of design and how this has changed over time. The customised iPad application provides access to standardised content and delivery to all students, thus allowing for a consistent mode of delivery.

A large array of historic images, maps, films and audio commentaries was provided to students in this field activity. Therefore it was considered high for the **content delivery** design dimension. An aim of using the iPads was to investigate the effectiveness of delivering mixed–media resources *in situ*. In particular focusing on photographs and participatory drawing and mapping by students to understand changes in landscapes over time. Given that students made brief records of their observations in the field by *using* the mobile device itself, **data capture** was rated as medium. As with Case 2, students had some freedom in how they observed the various stops in the park, but were nevertheless guided to look at specific features. The interaction of students with their environment was therefore considered as medium on the **directedness of learning**. The design dimension of **collaboration** was also medium given that apart from social interactions with members on their team there was no intrinsic need for collaboration amongst groups. The fieldwork tasks in this case study embedded in the customised app were directly **linked to assessment** exercises and so the field activity was rated as high for this dimension. Previously in this subject, students had often reported in evaluation questionnaires that they valued the presence of the lecturer in the traditional fieldwork excursion, and the dynamic experience this provided. In response, an important objective of this case study was to gauge the extent to which digital media for fieldwork could sustain a positive learning outcome despite the substitution of direct engagement of the teacher with one mediated by digital technology. The aim was to simulate the lecturer's presence while correspondingly advancing the quality and quantity of standardised information that could be provided by digital means that would otherwise not be possible.

Challenges: In our first design for the iPad guide, the lecturer's speaking style in the audio commentaries was found by students to be 'too formal' and out of character. In a second version, we set out to create more informal and even incidental content, as might be delivered by a teacher who is present in the field setting. These subsequent recordings were re-done at the field site, rather than the studio, and with the iPad's in-built recording capacity. This resulted in a less rigid and more personable recording. The lecturer chose a particular view for each stop and rested the iPad in position that captured that view, mimicking the way in which the lecturer would traditionally point out the most significant aspect at each stop. The lecturer then spoke directly into the iPad whilst remaining outside the view frame. This proved to be a success in terms of cost effectiveness (no studio needed), sound quality, and ease of importing the material directly into the iPad platform. The audio/film did not attempt to point at every element at each stop but rather to act as a hinge for incidental experience. This had implications for directed looking – the observation that in practice students spontaneously discovered the ability to align digital content with physical reality.

Further lessons learnt include the need to prime students in preceding lectures about the value of the tour by clearly integrating it into lecture content. Also clearly identified was the value of the full integration of the assignment and its assessment in the structure of the tour. Furthermore, there is the need to use established techniques of teaching and learning appropriate and consistent with methods of historic analysis introduced in the subject's lectures. One of the most critical issues was that of encouraging students to make use of the rich visual materials, within the various folders of historic reference material beyond the material directly related to each stop. In early testing it was noticed that most students did not take up the opportunity to explore the wealth of general learning content about the field site, but rather concentrated on the specific learning materials provided for each designated stop in the tour. This was addressed by re-writing the learning activities in such a way that they required the searching of images or plans in the general resources. This invited detour to find specific pieces of information led students to greater self-initiated exploration of these general learning resources as they carried out the field tasks of the tour.

Insights and reflections on design of mobile fieldwork

We have identified five key dimensions to be considered in the design of student fieldwork supported by mobile technology (see Table 1). The intention is not that all such fieldwork should be high on all five dimensions, but rather that the designers of field activities should be deliberative about where their activity falls on each dimension, rather than leaving it to accidental factors. Table 1 shows how our three cases studies of designing mobile-supported fieldwork can be described as low, medium and high on each dimension. For each of our three cases, for example, an active decision was made about the volume of content to be delivered. In case study 1, it was judged that the volume should be low, so that students might concentrate on carrying out field tasks. In contrast, for cases 2 and 3 it was a key intention that students should receive rich volumes of content *in situ*. Even in these latter cases, however, it was an important design intention not to flood students with rich multi-media, but rather to deliver a series of context relevant content. In case 3, students were also provided with a wealth of general learning content but students made relatively little use of them until 'reasons' to use them were introduced.

All of the case studies demonstrated that, despite the potential of mobile technologies to contain full instructions, there is a continuing need to make explicit to students before they go out to the field about why and how the mobile devices can support their learning experience. Even with this briefing, clear directions in mobile apps are needed by students to help them retain the purpose of the activity. For cases 2 and 3, the production of a mobile app as part of the teaching and learning 'toolset' required significant additional resources of both expertise and time. In case 3, clear guidelines for assessment deliverables, templates for submissions, example materials and carefully phased tasks were assembled for the fieldwork. Tutorial sessions also focused on providing feedback to students about the activities and expected submissions.

An issue encountered across the three studies was the need to carefully define the field areas within which students should work. This becomes important when students, armed with mobile apps, are free to conduct the exercise at any time. For example, accessibility to sites inside buildings raised issues for case study 1. Furthermore, the ability for students to engage with multiple sites through the use of apps, and for that to be undertaken within a reasonable time period, meant placing restrictions on the study areas. Similar issues were encountered for the access to equipment. While it cannot be assumed, it is increasingly true that students bring their own mobile devices. However, developing apps that run consistently across all, or even most, platforms is difficult and significantly increases the cost for educators. Providing basic mobile devices can still be a cheaper and more reliable and equitable option.

A significant issue across all three cases presented here related to the design dimension of collaboration. There was always the need to carefully consider the socialisation of learning, and the inherent pitfalls in isolating students from each other as they might focus on the devices rather than on insights with their peers or the fieldwork sites. While it is simpler to design a learning activity that can be carried out by an individual, there are potential benefits in designing a group task with designated roles. Collaboration amongst students can be further promoted by designing exercises that require students to share data and reflections they make on mobile devices whilst conducting fieldwork. These techniques embed social interaction and the opportunity for more socially-constructed learning in the tasks and mobile tools. As observed in case 1, however, a designed collaboration can sometimes lead to a mechanical division of labour between students and insufficient reflection on the structure of the larger field activity.

An important factor in student reception of mobile-supported fieldwork is the way the exercise and technology is framed in relation to the delivery of the subject as a whole. One danger is to frame the mobile device for students as something 'instead of' rather than 'in addition to' the involvement of the teacher; as observed in case study 3. A key lesson learned from all three cases was the need to prime students in preceding lectures about the value of the fieldwork exercise with the mobile devices and integrate this into the lecture content. It is desirable for content presented in a mobile app to be commensurate and continuous with material presented in class. There was also a need to allow sufficient time for students to complete activities both in and away from the field. All of these points were considered and addressed to an extent in the three case studies presented here while further improvements could be made. Nevertheless, despite all of these issues leading to less than perfect learning experiences, student reception and perceived value of our three mobile-supported exercises was generally positive. Observations of students confirmed that they carried out the tasks in the way intended, although the need for improvements and further more explicit directions or new forms of content was always apparent.

In addition to these points of learning design, there are a host of practical issues around mobile-supported fieldwork that should be mentioned. Significant problems can be screen glare in outside settings as well as audio levels and background noise. However, after some experimentation with recording levels, both the iPad and iPod Touch apps had ample volume to cope with most situations. As an overall practical note, it is important to not underestimate the time needed to create an app, and to consider developing and using the app over a number of semesters to get back value out of this development. Finally, safety concerns for fieldwork are also very real. Crossing a street, for example, whilst watching or listening to content on a mobile device brings the risk of harm. Prominent directions to safety should be built into apps and reinforced through student briefings.

In summary, mobile-supported fieldwork is a significant design and development challenge for teachers and institutions, but offers great potential. Mobile technology brings the versatility to instruct students, to provide rich and extensive content, and to provide various tools to record, measure and collaborate. Armed with mobile tools, students can be given greater freedom to explore and learn without the ongoing presence of a teacher. The three reported case studies have shown that it is possible but not straightforward to achieve this freedom and retain learning value. The five design dimensions presented here offer one view of the design decisions that underpin the achievement of these goals and the delivery of mobile-supported fieldwork.

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Author contact details: Dora Constantinidis. Email: dorac@unimelb.edu.au

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