Can the Incorporation of Quick Response Codes and Smartphones Improve Field-based Science Education?

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Abstract

Innovative approaches to field-based biology classes are needed to overcome logistic and financial constraints to running them. Quick Response (QR) technology, which links users to online content by scanning barcodes with their smartphones, provides an inexpensive, customisable way to support field-based learning. This paper reports on the trial of mobile learning, using hand-held devices and online material, in an undergraduate biology class. Students conducted a wildlife survey with reference to an online identification guide, accessed by scanning QR codes on site. Students expressed mixed opinions about the use of QR technology in field-based classes. Technical problems with scanning QR codes, weak wifi coverage and apprehension towards new technologies appeared to influence their attitudes towards mobile learning. However, they felt that they benefited from online resources and endorsed QR codes for learning. To improve student engagement with QR technology, staff should provide students with adequate training, test QR scanning software before use, and emphasise cellular coverage.

Introduction

The integration of field-based activities into teaching is considered a fundamental component of studies in biology (Burke da Silva, 2014). Field-based teaching promotes greater engagement with course material (Burke da Silva, 2014), and facilitates the development of skills and knowledge that students would otherwise be unable to gain through ordinary classroom experiences (Lonergan & Andresen, 1988; Eaton, 1998; Rickinson, 2001; Heffernan, Heywood, & Ritter, 2002; Dillon et al., 2006). It enables students to apply, reinforce and test the theoretical concepts learnt in lectures (Burke da Silva, 2014), and makes science relevant (Kent, Gilbertson, & Hunt, 1997) through real-world scientific exploration (Longergan & Andresen, 1988; Hefferan et al., 2002; Burke da Silva, 2014). This allows students to integrate the theory and practical components of a course (Lonergan & Andresen, 1988). Accordingly, academic staff (Smith, 2004; Scott, Fuller, & Gaskin, 2006; Burke da Silva, 2014) and students alike consider fieldwork to be an effective and engaging learning tool (Fuller, Gaskin, & Scott, 2003; Burke da Silva, 2014). Indeed, students frequently rate fieldwork as their favourite component of units that incorporate field-based activities, as well as of their experience of undergraduate studies (Burke da Silva, 2014). Courses that offer field-based activities may also have greater recruitment and retention rates (Smith, 2004).

Yet the incorporation of field-based practicals in undergraduate science courses is declining, both in Australia and elsewhere (Smith, 2004; Burke da Silva, 2014). Barriers to field-based classes are both university-driven, and driven by academic staff and students. University-driven factors include reductions in funding (Burke da Silva, 2014), compounded by the high cost of running field-based classes (Salter, 2001; Smith, 2004; Burke da Silva, 2014), increasing student enrolments and associated logistical and environmental concerns, greater regulatory requirements (e.g. animal ethics, research permits, and health and safety requirements) (Burke da Silva, 2014) and the provision of long-distance courses (Salter, 2001). A decreasing number of academic staff with the motivation and/or experience to run field trips, a fear of litigation in the event of things going wrong (Smith, 2004) and the pressure to increase research output rather than invest in teaching activities carrying a heavy time burden (Salter, 2001) present additional barriers to field-based activities. Students are also increasingly reluctant to attend extended field trips due to part-time employment and potentially, their inability to afford to participate (Smith, 2004; Burke da Silva, 2014). Furthermore, while modern teaching laboratories allow online resources to be integrated into practical classes, field-based classes, by their very nature, are held outside of these environments, resulting in a temporal disconnect between practical exercises and subsequent access to online resources. Unless these issues are addressed, further decreases in field-based activities are inevitable (Burke da Silva, 2014).

To circumvent these constraints, innovative approaches to field-based teaching are needed. These should aim to maximise learning outcomes and enhance the student experience without concomitant increases in cost or the logistical complications arising from large numbers of students in the field. Importantly, the value of field-based teaching must be emphasised to university administrators who are focused on the cost and logistics associated with fieldwork. This will require the development of 'outside of the box' ideas (Burke da Silva, 2014). Recent advances in technology present a potential avenue through which to develop cutting edge field-based teaching approaches.

Smartphones are now part of everyday life, providing an opportunity to integrate mobile learning– the use of devices that allow users to access information from any location at any time (Traxler, 2007) – into classes (Hwang, Po-Han, & Hui-Ru, 2011; Gikas & Grant 2013) without a large infrastructure commitment from universities. Indeed, the use of smartphones in schools and tertiary institutions is increasing (Herrington et al., 2009; Hwang et al., 2011; Williams & Pence, 2011). In particular, software that decodes 2-dimensional barcodes, termed Quick Response (QR) codes (Denso Wave Inc., 2003), can be readily installed on smartphones equipped with a camera. Such software is usually free (Lee, Lee, & Kwon, 2011), making it readily available and accessible to all students.

QR codes direct users to key online resources (Lee et al., 2011). They have the capacity to store far more information than standard barcodes; users can access a variety of online resources, including text, video, images, podcasts, websites and automatic text messages, simply by scanning the QR code with their smartphone or other mobile device (Law & So, 2010; So, 2011; Adkins, Wajciechowski, & Scantling, 2012; Rikala & Kankaanranta, 2012). QR codes are inexpensive and versatile, and can be incorporated into hard copy or electronic teaching materials (Law & So, 2010; So, 2011; Lee et al., 2011). Hence, they are increasingly being integrated into schools and tertiary institutions (e.g. Susono & Shimomura 2006; Lee et al., 2011; Rikala & Kankaanranta, 2012; Lai et al., 2013; Martin & Ertzberger, 2013). Of particular interest is the flexibility of QR codes to provide learning opportunities both within the classroom and outdoors (So, 2011). Such 'location independence' (Law & So, 2010) is relevant for field-based learning. Lee et al. (2011), for example, used QR codes for identifying intertidal species during field trips in South Korea. However, despite the increasingly ubiquitous nature of QR codes, published research into their efficacy in educational settings is limited, particularly within tertiary institutions.

The aims of the present study were two-fold. First, to trial the novel integration of hand-held device technology into undergraduate field-based practical teaching; and secondly, to assess the efficacy of using online resources, linked via QR codes, to enhance undergraduate student experiences during field-based teaching. To this end, a third year biology class at Monash University (Clayton campus, Australia) was used as a case study. As part of their practical classes, students conducted lizard surveys along transects in an on-campus bushland reserve, before submitting a written report on their findings. Each transect was marked with a QR code that linked students to online resources comprising details about lizards in the local area and general information about the reserve. To gauge the success of the practical, we surveyed students before and after the practicals via questionnaires.

Methods

Practical task

Participants in the study were third year students, generally in their final semester of their undergraduate degree, undertaking the 'Biology of Australian Vertebrates' (BIO3132) unit in 2013 and 2014. Students in the unit are generally ~20 years of age, with an even number of males and females. The practical task involved surveying lizards in the Jock Marshall Reserve (JMR), a bushland reserve, approximately 3 ha in area, comprising predominantly indigenous vegetation and a 1-ha lake. Students used three different sampling techniques to survey lizards: checking under artificial cover objects (ACOs), pitfall trapping and visual encounter surveys. Three transects were established in the JMR in 2010, with a total of 30 ACOs (10 per transect) and 15 pitfall traps (5 per transect) placed in suitable habitat along the three transects. ACOs provide a sheltering site for lizards and can be lifted during surveys to catch any lizards sheltering beneath them. For the purpose of this practical, terracotta roofing tiles were used. Pitfall traps comprised small (5 L) buckets dug into the ground with their tops flush with the soil surface. Small mesh drift fences were placed on the ground along either side of the buckets to direct any animals towards the buckets so that active lizards could be captured by falling into these. The visual encounter surveys involved searching for active or basking lizards, and checking under naturally-occurring objects (e.g. logs, rocks) for sheltering lizards for 30 minutes.

Students were divided into three groups of ~15-20 students, and each group was allocated a transect and demonstrator. As a group, they then checked each pitfall trap and ACO for lizards, and made note of any incidental captures of other taxa found using these methods. General information on habitat was also noted for each trap and ACO, as well as of the general area searched during visual encounter surveys. Lizards were identified with reference to an online field guide, linked via QR codes (Fig. 1). They were then measured (snout-vent length, tail length; in mm), weighed (in g) and checked for any signs of tail loss before being released at the site of capture.

After conducting the surveys, students completed a report from the perspective of an environmental consultant. This entailed a discussion of lizard diversity, a critical evaluation and comparison of survey techniques, and recommendations for future survey methods. Students had access to the survey data from the previous 4-5 years, as well as from the survey that they conducted.

Website development and content

The beginning of each transect was marked with a sign containing the transect number and QR code (Figure. 1, below), which directed students to our website (jockmarshallreserve.com.au), developed by bhive (http://bhivegroup.com.au/) for the purposes of the practical. This is a cross platform website that has been mobile optimised for use across all mobile device operating systems (i.e. accessible using Apple, android and web-based systems). It contains key information on local lizard species, including an identification guide (Figure. 2, below); links to the Atlas of Living Australia (http://www.ala.org.au/); a photo gallery; and a distribution map (Figures. 3. and 3b, below).

Figure 1: Marker post delineating the start of one of the lizard survey transects in the Jock Marshall Reserve.
(The metal post included a bronze sculpture of a blue tongue lizard and a QR code (see inset) that the students scanned with their smartphones at the start of the lizard survey.)

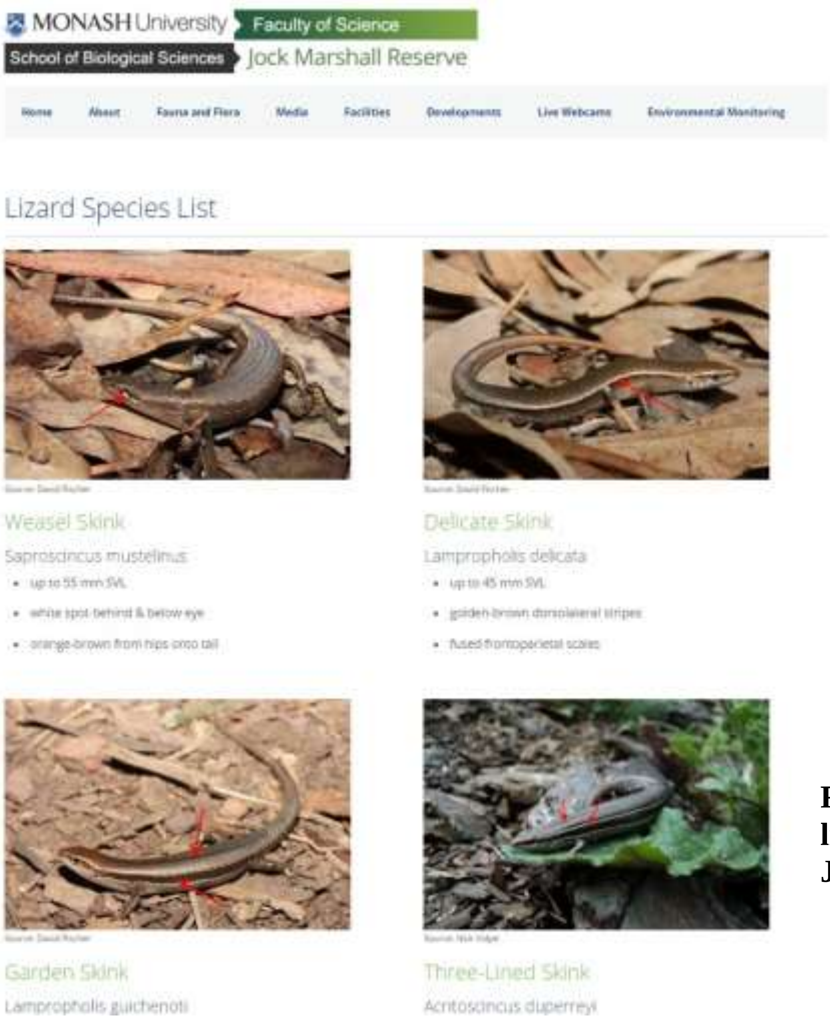

Figure 2: A sample of the online lizard identification guide on the Jock Marshall Reserve website.

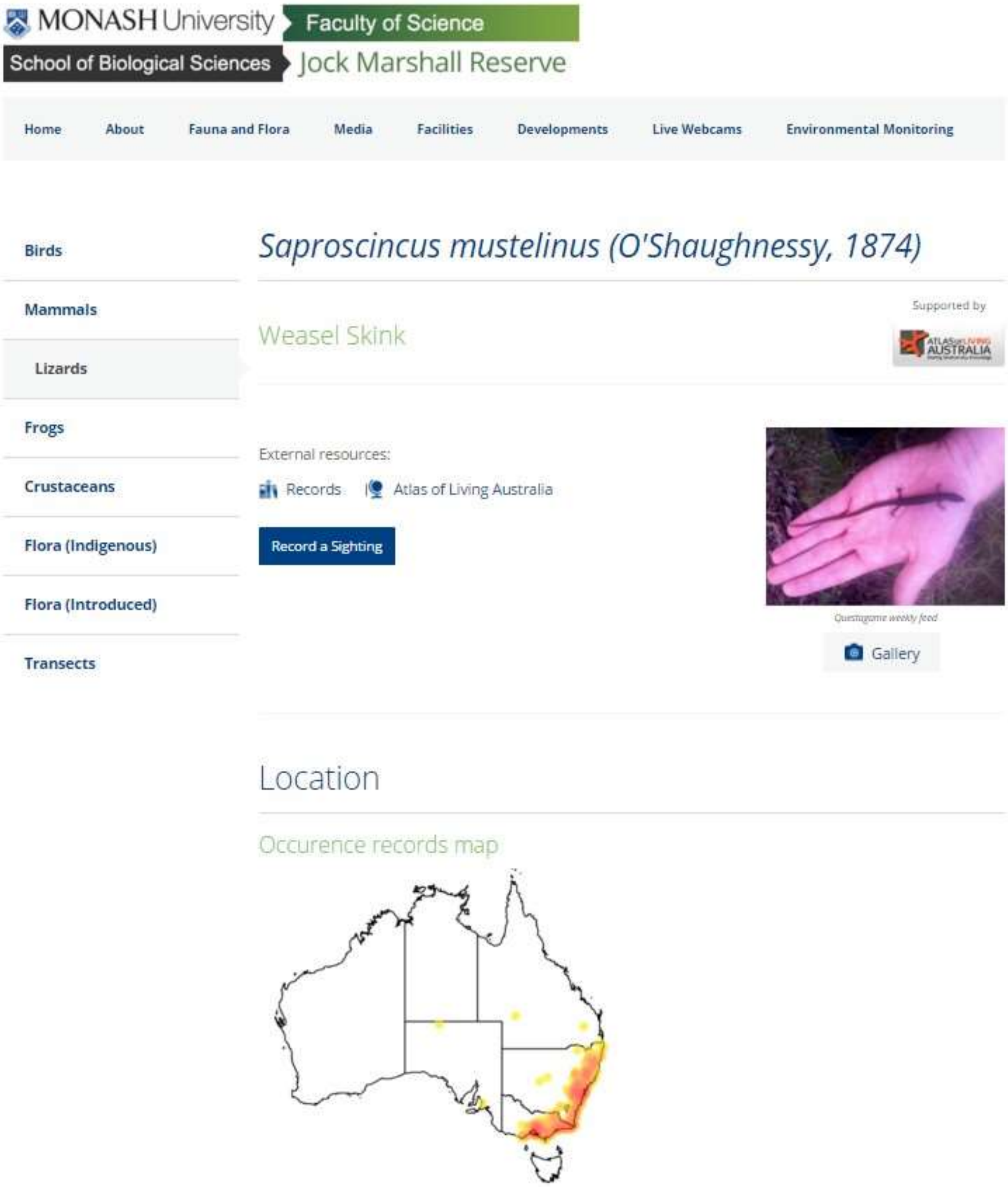

Figure 3a: An example of the information included in the online identification guide for a common lizard species found at the Jock Marshall Reserve.

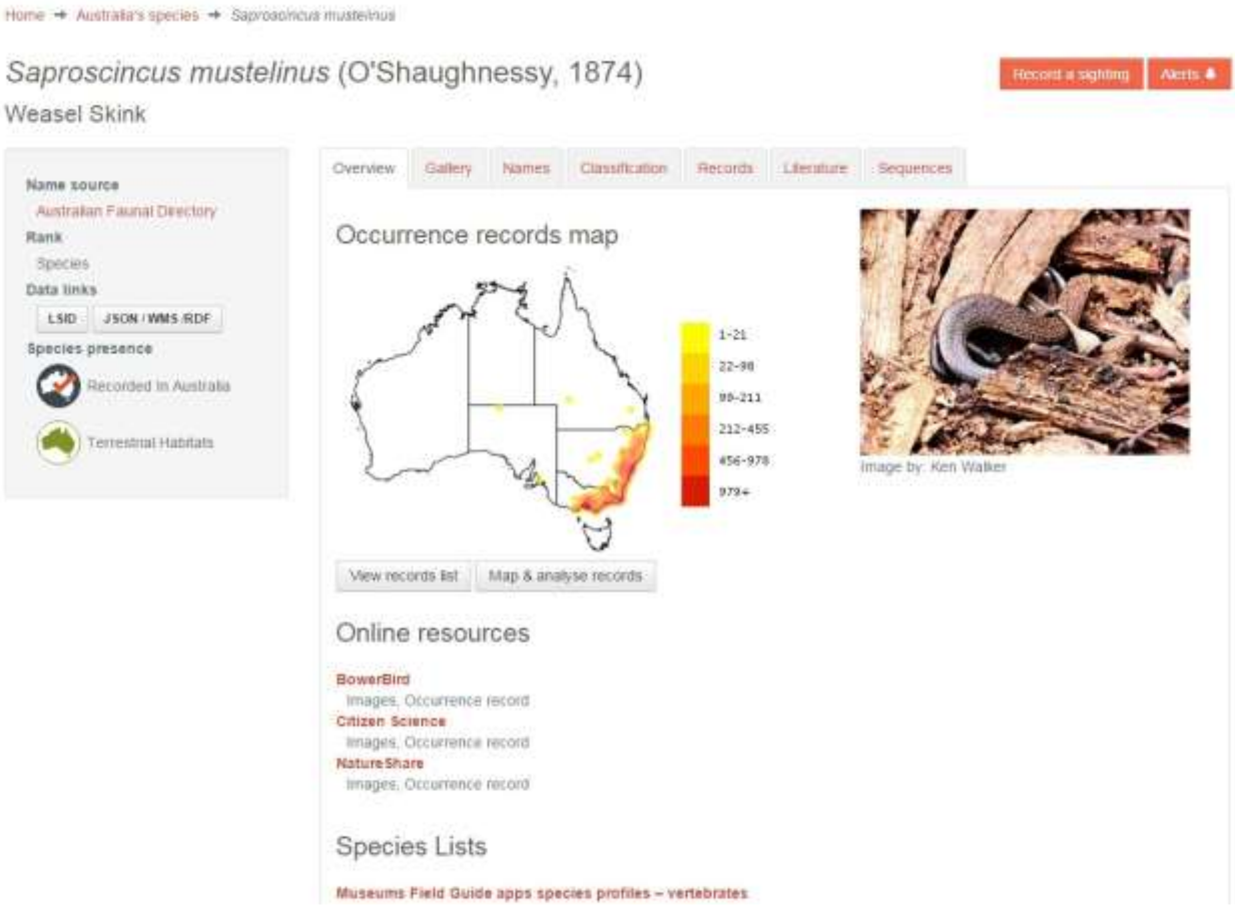

Figure 3b: An example of the information included in the online identification guide which is linked to the Atlas of Living Australia database.

Also available on the website are photographic descriptions of each trap; pictorial lists of the indigenous and introduced flora and fauna of the JMR (via the Atlas of Living Australia); general information about the JMR, including its geology, history, conservation significance, management and current uses; and a satellite image of the reserve. The wifi infrastructure within sections of the JMR was also upgraded to improve the capacity for students to access internet resources through their smartphones without having to rely solely on their data/cellular coverage from their phone provider.

Teaching staff were briefed on QR codes and how to use them prior to the practicals. Students scanned QR codes using either their personal device or one of three iPads supplied during the practical. Hence, all participants had equal access to the website during the practical. QR code applications were downloaded at the start of the class before conducting the lizard survey, with no recommendations provided on which application to download.

Student survey

Students were surveyed via questionnaires over two years (2013 and 2014) in order to assess their perceptions of the value of field-based learning, technology use in practicals, and the integration of technology into undergraduate field-based practicals (Table 1, Questionnaires 1 and 2, see Appendix, pp. 62-71). Participation was voluntary and anonymous. Before completing the questionnaires in both years, students were provided with a background to the study, how student surveys would be conducted and the reasons behind the study. In 2013, students were questioned on their attitudes prior to conducting the lizard survey only (as the QR code infrastructure and JMR website had not been developed at this stage). Students in 2014 were given two questionnaires; the first before participating in the lizard survey and the second a week after conducting the lizard surveys. A total of 94 students completed the questionnaire in 2013. In 2014, 99 (Monday: 55, Friday: 44) and 47 (Monday: 23, Friday: 24) students completed the pre-practical and post-practical questionnaires, respectively.

All three questionnaires contained questions about the enrolment details of BIO3132 students (Table 1, see Appendix). The students enrolled in BIO3132 were generally completing a Bachelor of Science degree, either as a stand-alone degree or as part of a double degree (Table 2, see Appendix). Almost all students were completing a major within Biological Sciences (2013: 94.7%, 2014: 94.9%), generally in Zoology (Table 2, see Appendix). The 2013 and 2014 pre-practical questionnaires were identical, and entailed questions about the amount of fieldwork respondents had participated in, their attitudes towards field-based classes, and their use of handheld technology and QR codes in their Monash studies (Table 1, see Appendix). The post-practical questionnaire in 2014 focused on student attitudes in response to their experience of the lizard surveys (Table 1, see Appendix). This included questions on the value of field-based learning, QR code technology and access to online resources. The questionnaires included multiple choice (yes/no/unsure, select from a series of options), short answer, Likert scale (Likert 1932) and open-ended questions. The latter allowed students to provide more specific details and to share any ideas about the role of technology in undergraduate classes. To view the questionnaires in their entirety, see Online Resources 1 and 2 in the supplementary material.

Statistical analyses

For each lizard survey in 2013 and 2014, we ran two classes (held on Monday and Friday). The data from the Monday and Friday classes were analysed separately to identify whether inter-class responses differed significantly. Where no significant differences were found, data were pooled for further analyses. Since the questionnaires were anonymous, we were unable to compare individual responses to the pre- and post-practical questionnaires in 2014. Descriptive statistics, generally percentages or means ± standard error [SE], were calculated for student responses (e.g. percentage of students that provided a specific response) and the Likert scale data (e.g. percentage of students that agreed or strongly agreed with a statement; mean Likert scale score). Likert scale data were analysed using two-tailed t-tests in Microsoft Excel 2013. The results for Likert scale responses are presented as mean values ± S.E. The student responses to the short-answer or open-ended questions were analysed qualitatively, with specific examples provided in the Discussion.

Results

Pre-practical student surveys

The questionnaire response rate was high in both 2013 (82%) and 2014 (90%). Although virtually all students had completed field-based practical classes during their degree (2013: 98.9%, 2014: 94.6%), the majority had not done a substantial amount of fieldwork outside of their degree (2013: 82.8%, 2014: 74.3%). However, the vast majority of students believed that field-based practical classes were an essential component of science education (agree/strongly agree; 2013: 92.5% [4.6 ± 0.07], 2014: 85.4% [4.3 ± 0.09]).

Almost all students owned at least one handheld device (2013: 95.7%, 2014: 96.9%). There was a relatively even split between students who owned iPhones and other smart phones, whilst relatively fewer students owned iPads or tablets (Table 3). Although many students (2013: 66.7%, 2014: 44.3%) had made use of their handheld devices during their degree, this was generally based on their own initiative, and involved internet searches, taking notes or photos, using a calculator or stopwatch, or accessing Moodle, the learning management system used by Monash University. In fact, only 11 students (8 in 2013, 3 in 2014) reported using their handheld device as a formal, integrated component of their practical class.

Few students had previously had online access during field-based practical classes (2013: 16.0%, 2014: 12.5%). Of these students, nearly all (2013: 100%, n = 15; 2014: 90.9%, n = 12) believed that this online access had improved their learning ability during field-based practical classes.

Prior knowledge of Quick Response codes was relatively low in 2013 (36.2%), but higher in 2014 (59.8%). However, no student had previously used QR codes in a field-based practical class prior to undertaking BIO3132.

Post-practical student surveys

The post-practical questionnaire response rate was 43%. In 2014, most students (94.7%) used smartphones during the practical class, with a smaller number of students also accessing the material using an iPad or tablet (18.4%). The vast majority of students (87.9%) found the screen size of their smartphone to be sufficient to access the online materials associated with the practical.

Student opinions about the value of fieldwork and technology use in undergraduate biology classes were remarkably similar between the Monday and Friday practical classes. Based on Likert scale responses, there were no significant differences between classes in student enjoyment of the lizard survey (Monday: 3.8 ± 0.17, Friday: 4.0 ± 0.17; t = -0.87, P = 0.39), or their perceptions of whether field-based practical classes form an essential component of science education (Monday: 4.7 ± 0.15, Friday: 4.7 ± 0.10; t = 0.17, P = 0.87) and if they should be used more widely (Monday: 55% Yes, Friday: 47.8% Yes). Likewise, student perceptions of the capacity for online access to improve engagement with practical material (Monday: 3.7 ± 0.22, Friday: 3.6 ± 0.24; t = 0.44, P = 0.66), comprehensiveness of the online resources (Monday: 3.8 ± 0.18, Friday: 3.7 ± 0.22; t = 0.52, P = 0.60), the ability of QR codes to improve learning (Monday: 3.1 ± 0.20, Friday: 3.3 ± 0.24; t = -0.63, P = 0.53), and whether technology should be used more in practical classes (Monday: 3.5 ± 0.14, Friday: 3.3 ± 0.21; t = 1.11, P = 0.27) did not differ significantly between practical class days. Therefore, the data were pooled for further analyses.

Most students (70.3%) agreed or strongly agreed that they enjoyed the practical class (3.9 ± 0.12). The main reasons provided were getting outdoors and completing a field-based practical (78.7%), learning lizard handling skills (76.6%), and gaining skills and experience in wildlife surveys (61.7%). There was also a significant increase, relative to the pre-survey questionnaire, in the number of students who believed that field-based practical classes are an essential component of science education (97.8% agreed/strongly agreed [4.7 ± 0.09] vs 85.4% [4.3 ± 0.09]; two-tailed t-test t = 1.98, P = 0.009).

Just over half (56.5%) of the students agreed or strongly agreed that having online access during the practical improved their engagement (3.7 ± 0.16). In total, 63% believed that the online resources provided all of the information required for the practical (3.7 ± 0.14). However, only 43.5% of students agreed or strongly agreed that QR codes improved their learning during the practical (3.2 ± 0.16), though 51.2% of students believed that QR codes should be used more widely in practical classes at Monash University. Students identified specimen identification in field-based units and links to online resources as the main potential uses for these. Only 37.8% of students believed (agreed, strongly agreed) that other aspects of modern technology should be used in practical classes.

Discussion

Although student engagement during the lizard survey was high, there were mixed responses as to the value of integrating mobile technology into field-based practical classes. The majority of students believed that they benefited from having access to online resources during the practical, but their resistance to the use of mobile learning appears to be due to technical issues with scanning the QR codes and trepidation associated with switching to new technologies. Below, the efficacy of using QR code technology and online resources to improve student engagement during field-based practical classes is discussed.

Students value field-based science education
Whilst few students had participated in a significant amount of fieldwork outside of their degree, most were positive about incorporating field-based practical classes into science education; an attitude that was enhanced after participating in the lizard survey. Indeed, numerous studies have shown that field-based education promotes learning and increases student engagement with course content (Kent et al., 1997; Eaton, 1998; Heffernan et al., 2002; Fuller et al., 2003; DeHaan, 2005; Dillon et al., 2006; Burke da Silva, 2014). The lizard survey and subsequent write-up provided an authentic science experience, allowing students to practice scientific inquiry in a relevant and collaborative environment (Heffernan et al., 2002; Lee & Bulter, 2003). This is particularly important as students gain most of their fieldwork experience during their degree, and thus universities have a core responsibility to adequately prepare students for a career in biology. Whilst this study was not able to examine whether enhanced student engagement was directly associated with the integration of technology into the practical, it does highlight the potential benefit of integrating technologies that overcome some of the impediments in running field-based practicals into undergraduate classes.

Integration of QR codes into field-based classes shows promise, but technical problems must be overcome
Although 56.5% of students felt that having online access during the lizard survey increased their engagement, fewer than half of the respondents believed that the use of QR code technology enhanced their learning during the lizard survey, with one student going so far as to ask "what is wrong with paper?" in the questionnaire. This may have been influenced by a lack of familiarity with QR codes. Kennedy, Judd, Churchward and Gray (2008) reported a strong association between how frequently undergraduate students used a particular technology and their desire to use it in the classroom, suggesting that students are more likely to report favourably on technology use if they are accustomed to using it. University students have diverse technological backgrounds, and familiarity with one form of technology does not necessarily translate to familiarity with another (Kirkwood & Price, 2005; Lorenzo, Oblinger, & Dziuban, 2006; Kennedy et al., 2008). Indeed, the assumption that people who own smartphones use QR codes does not always hold (Schulz, 2013), and in our study, <60% of students surveyed in 2014 were aware of QR codes. In fact, a comment by one student, who stated in the questionnaire that access to online resources "might have been more effective...if we had a brief introduction on how to use the application" implies that some students felt hampered by a lack of practical knowledge of QR codes.

Some of the resistance to QR code technology could have been due to technological problems encountered by students during the lizard survey. Several students commented that they were unable to scan the QR codes with their mobile devices due to general technical problems with their mobile devices, issues with their QR code scanner or, in one case, insufficient battery charge. The ability to scan QR codes can also be hindered by the ability of students to target QR codes correctly with their devices (Law & So, 2010), insufficient camera resolution (Lee et al., 2011), small screen sizes (Rikala & Kankannranta 2012; Gikas & Grant, 2013), technological problems with mobile devices, and difficulties scanning QR codes that are distorted by curved surfaces, suboptimal lighting, or the presence of reflections. Such problems may lead to frustration and negative experiences (Rikala & Kankaanranta, 2012). Nonetheless, QR codes are generally resilient to minor distortions, and can correct for errors due to the presence of up to 30% dirt or damage (Law & So, 2010; Denso Wave Inc., 2013), so it is unlikely that these were major sources of frustration for students. The more likely cause for most students was inadequate wifi coverage in the JMR; although the wifi infrastructure in the JMR was upgraded prior to the practical, wifi coverage during the lizard survey was weak, and students were forced to use their personal data or share with others, which caused some frustration. The need for students to use their own personal data allowance was not intended, but could have had a negative perception of cost-shifting from the university to the student, and raises potential issues in terms of student equity.

Students expressed reluctance towards modern technology in classes but endorsed QR code use in more university courses.

Only 37.8% of students endorsed the use of other aspects of modern technology in practical classes. Walker and Johnson (2006) noted that a sense of personal capacity or capability affected willingness to use technology-based services, while Meuter, Ostrom, Bitner and Roundtree (2003) found an inverse relationship between levels of consumer technology anxiety and technology usage. Student responses about the use of online resources in our study may thus have been affected by their attitudes towards technology generally; students who consider themselves ill-equipped to effectively use technology may be less likely to engage in classes using technological approaches to teaching. The perceived benefits and ease of use of new technologies may also exert an influence on attitudes, engagement and the likelihood of adopting them (Davis, 1993; Agarwal & Prasad, 1999; Walker & Johnson, 2006). Students may have felt that new or additional technologies would not advance, or could potentially impede, their academic progress. For example, one student commented in the questionnaire that they “like actually holding things (e.g. skulls/plants)…Just because it is new technology doesn’t mean that it is more useful or better”. Nonetheless, over half of the students felt that using online resources enhanced their engagement with the lizard survey, and endorsed the integration of QR codes into more courses at Monash University. This indicates that despite some resistance to technology use in practicals, most students believed that it aided learning in some way. In particular, the flexibility of QR codes to instantly connect students with a broad array of online tools and resources (Law & So, 2010; Adkins et al., 2012; Rikala & Kankaanranta, 2012) may cater, at least in part, for the diversity in technological abilities previously reported among students (Kirkwood & Price, 2005; Lorenzo et al., 2006; Kennedy et al., 2008).

Students identified several ways in which QR codes could enhance practical classes, providing additional evidence that they perceived value in the use of QR codes within a teaching context. For example, students suggested that QR codes could be used to assist in specimen identification and provide easy access to online resources. One respondent commented that students could be directed to online dichotomous keys to aid in species identification. Certainly using QR codes in this context negates the need to transport heavy field guides, which may be a consideration in whether or not a field trip proceeds (Lee et al., 2011). They could also direct students to web pages that provide interactive diagnostic information. Smartphone applications, for example, have incorporated recordings of bird calls into bird field guides as well as additional details that would be precluded from inclusion in the paper version by the sheer volume of information (e.g. Morcombe & Stewart, 2014). Thus, QR codes could be used to quickly and easily link students to targeted websites that contain information developed specifically for practical classes. The ability of QR codes to connect students (Lee et al., 2011) would also promote peer-assisted identification of unknown specimens. These are just a few examples of the numerous ways in which QR codes could be used to improve student learning and engagement.

Conclusion

Whilst it is difficult to disentangle the effects of technological problems during the practical from the perceived usefulness of QR codes, it is clear that QR technology holds much promise to improve field-based science education. Access to online resources, customised for field-based practical classes, via QR codes may enhance the field experience of undergraduate biology students. However, there are several key challenges that need to be addressed in order for QR technology to realise its full potential in science education settings:

1. Students are rarely in possession of all of the technological skills necessary to complete their studies when they first undertake their university degrees. Many of these skills have to be acquired during their secondary education and undergraduate studies (Caruso & Kvavik, 2005; Kvavik, 2005). A key element of integrating novel technologies into classes is therefore to provide adequate training prior to use to increase both student abilities, confidence and by extension, engagement. Teaching staff should explain to students in advance how online resources, accessed via QR codes, will be integrated into their classes, and provide a demonstration of how to use QR code scanning software. Ideally, students should be encouraged to download and practice using decoding software prior to the relevant practical classes. These steps will not only help mitigate any anxiety (Meuter et al., 2003) in students who are reluctant to use novel technology, but will reduce the likelihood of problems associated with using unfamiliar technology.

2. Some decoding software was unstable. To reduce problems associated with this, software should be trialled before use and students informed of the most appropriate software to install on their devices.

3. Students expressed frustration at the lack of wifi in many areas of the JMR. Given current wifi technology and the potential for field-based biology classes to be held in less populated areas, it is advisable to emphasise cellular, rather than wifi, coverage. This will mediate student expectations and allow them to focus on the task at hand rather than becoming frustrated by intermittent or no internet access. Students were advised to use their cellular data during the Friday practical class, after wifi issues were reported in the Monday class, and qualitatively, this acted to reduce the number of negative comments about the QR codes.

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Appendix

Table 1. Summary of questions included in the 2013 and 2014 pre-practical questionnaires, and in the 2014 post-practical questionnaire. (Exact wording of questions in the questionnaires has not been used (for the complete questionnaire, see Online Resource 1 and 2 in the supplementary material).

Topic	Question	Answer type
Pre-practical questions (2013 and 2014)		
Experience with field-based practical classes	Have you completed field-based practical classes during course?	Yes/no
	Amount of fieldwork completed outside of Monash degree?	Likert scale: 1 (none) – 5 (substantial amount)
	Do you believe that field-based practical classes are an essential component of science education?	Likert scale: 1 (strongly disagree) – 5 (strongly agree)
Use of technology in undergraduate practical-based teaching	Handheld devices owned?	Select option(s)
	Have any of these handheld devices been used in practical classes in your course? If so, how?	Yes/no, Short answer
	Have you been required to access online resources during field-based practical classes? If so, did this improve your ability to learn?	Yes/no
	Knowledge of QR codes?	Yes/no
	Previous use of QR codes in practical classes at Monash?	Yes/no/not sure
Post-practical questions (2014)		
Experience of the lizard survey in the Jock Marshall Reserve	Did the QR codes and online resources enhance your ability to learn?	Likert scale: 1 (strongly disagree) – 5 (strongly agree)

	Did access to online resource improve engagement with practical material?	Likert scale: 1 (strongly disagree) – 5 (strongly agree)
	Did the online resources contain all relevant information for the practical?	Likert scale: 1 (strongly disagree) – 5 (strongly agree)
	Type of handheld device used to scan QR codes during the practical?	Select option,
	If using a phone, was the screen large enough?	Yes/no
	Your enjoyment of practical?	Likert scale: 1 (strongly disagree) – 5 (strongly agree),
	Factors contributing to your enjoyment?	Select option(s)
Use of QR codes in practical teaching	Should QR codes be used more widely in practical classes?	Yes/no, select options
	How should they be used?	Short answer
	Should other aspects of modern technology be incorporated into practical classes?	Likert scale: 1 (strongly disagree) – 5 (strongly agree)

QR codes refers to Quick Response codes.

Table 2. Summary of the degrees and majors of the students involved in the study in 2013 (n = 94) and 2014 (n = 99). (Note that several students had two majors in their degree.)

	2013	**2014**
Degree		
Bachelor of Science (BSc)	64.9%	74.5%
Bachelor of Science Advanced (BScAdv)	5.3%	3.1%
Bachelor of Science (BSc)- as part of a double degree	25.5%	17.3%
Bachelor of Environmental Science (BEnvSci)	4.3%	4.1%
Bachelor of Biomedical Science Advanced (BBioMedSciAdv)	—	1.0%
Majors		
Ecology and Conservation Biology	17.2%	22.5%
Genetics	7.5%	2.2%
Marine and Freshwater Biology	6.5%	7.9%
Plant Science	5.4%	—
Zoology	84.9%	87.6%

Table 3. Ownership of handheld devices amongst the students involved in the study (2013: n = 94, 2014: n = 99). (Note that some students owned more than once type of device**.)**

Handheld device	2013	2014
iPhone	46.8%	51.5%
Other smartphone	47.8%	43.3%
iPad	19.2%	28.9%
Other tablet	12.8%	13.3%

QUESTIONNAIRE 1

BIO3132 PRE-PRACTICAL QUESTIONNAIRE

2014

BACKGROUND INFORMATION

[NOTE: These questions will provide us with the necessary context to interpret your responses. You will remain anonymous and this information is not for the purpose of trying to identify individual students].

1. What course are you enrolled in?

Bachelor of Science

- ☐ Bachelor of Science (BSc)
- ☐ Bachelor of Science: Advanced with Honours or Science Scholar Program
- ☐ Bachelor of Science (as part of a double degree)

Bachelor of Environmental Science

- ☐ Bachelor of Environmental Science
- ☐ Bachelor of Environmental Science (as part of a double degree)

Other

- ☐ Please indicate what course: ____

2. Are you completing a major within Biological Sciences?

- ☐ Yes
- ☐ No

If YES, please indicate which major (tick all that apply)

- ☐ Ecology and Conservation Biology
- ☐ Genetics
- ☐ Marine and Freshwater Biology
- ☐ Plant Sciences
- ☐ Zoology

If NO, please indicate what major(s) outside of Biology you are completing: ___________________________

YOUR EXPERIENCE WITH FIELD-BASED WORK

3. Have you completed field-based practical classes (including fieldtrips) during your course?

- ☐ Yes
- ☐ No

If YES, please list the units that this involved (see attached list of BIO/GEN units):

____

4. How much fieldwork have you completed outside of your Monash degree? (Circle One)

[As a guide, 'Some' would involve 1-2 fieldtrips, with 3+ being a 'Substantial Amount']

None		*Some*		*Substantial Amount*
1	2	3	4	5

5. Please indicate your opinion with respect to the following question.

I believe that field-based practical classes are an essential component of science education? (Circle One)

Strongly Disagree		*Neutral*		*Strongly Agree*
1	2	3	4	5

<u>THE USE OF TECHNOLOGY IN UNDERGRADUATE PRACTICAL-BASED TEACHING</u>

6. Please indicate which of the following handheld devices you own? (tick all that apply)

- ☐ iPhone
- ☐ Other Smartphone
- ☐ iPad
- ☐ Other Tablet device

7. Have any of these handheld devices been used in practical classes in your course at Monash?

- ☐ Yes
- ☐ No

If YES, briefly outline how and the unit(s) involved:

____

____

____

8. Have you been required to access online resources <u>during</u> field-based practical classes (including fieldtrips)?

- ☐ Yes
- ☐ No

If YES: a) briefly describe how:

____

____

____

b) did access to the online resources improve your ability to learn during the practical class?

- ☐ Yes
- ☐ No

If YES, briefly describe how this improved your learning:

____

____

9. Do you know what a Quick Response (QR) barcode is?

- ☐ Yes
- ☐ No

If YES, provide a brief description of a QR barcode:

____

10. Have QR barcodes been used in any of your practical classes at Monash?

- ☐ Yes
- ☐ No
- ☐ Not Sure

If YES: a) briefly outline how and the unit(s) involved:

____

____

____

b) How useful did you find the QR codes during the practical class? (Circle One)

Completely Useless		*Neutral*		*Extremely Useful*
1	2	3	4	5

QUESTIONNAIRE 2

BIO3132 POST-PRACTICAL QUESTIONNAIRE

2014

<u>BACKGROUND INFORMATION</u>

[NOTE: These questions will provide us with the necessary context to interpret your responses. You will remain anonymous and this information is not for the purpose of trying to identify individual students].

1. What course are you enrolled in?

Bachelor of Science

- ☐ Bachelor of Science (BSc)
- ☐ Bachelor of Science: Advanced with Honours or Science Scholar Program
- ☐ Bachelor of Science (as part of a double degree)

Bachelor of Environmental Science

- ☐ Bachelor of Environmental Science
- ☐ Bachelor of Environmental Science (as part of a double degree)

Other

- ☐ Please indicate what course: ____

2. Are you completing a major within Biological Sciences?

- ☐ Yes
- ☐ No

If YES, please indicate which major (tick all that apply)

- ☐ Ecology and Conservation Biology
- ☐ Genetics
- ☐ Marine and Freshwater Biology
- ☐ Plant Sciences
- ☐ Zoology

If NO, please indicate what major(s) outside of Biology you are completing:

____

YOUR EXPERIENCE OF THE LIZARD SURVEY IN THE JOCK MARSHALL RESERVE

3. The use of Quick Response (QR) barcodes, and the online resources they linked to, enhanced my ability to learn during the practical. (Circle One)

Strongly Disagree		*Neutral*		*Strongly Agree*
1	2	3	4	5

4. Having access to the online resources during the practical improved my engagement with practical material. (Circle One)

Strongly Disagree		*Neutral*		*Strongly Agree*
1	2	3	4	5

5. The online resources contained all of the information that I required during the practical. (Circle One)

Strongly Disagree		*Neutral*		*Strongly Agree*
1	2	3	4	5

Please list any additional information or online resources you would have found useful:

____

____

____

6. What handheld device did you use to scan the QR barcodes during the practical? (Tick all that apply)

- ☐ iPhone/Smartphone
- ☐ iPad/Tablet

If you used an iPhone/Smartphone, was the screen large enough for you to access the information you required?

- ☐ Yes
- ☐ No

If you used an iPad/Tablet, was it too large to carry around during the practical?

- ☐ Yes
- ☐ No

Please provide any additional comments on these issues.____

____

7. I enjoyed the lizard survey practical. (Circle One)

Strongly Disagree		*Neutral*		*Strongly Agree*
1	2	3	4	5

What were the biggest factor(s) contributing to your enjoyment of the practical? (Tick all that apply)

- ☐ Handling lizards (& other small vertebrates)
- ☐ Getting outdoors and doing a field-based practical class
- ☐ Obtaining skills and experience in wildlife surveys
- ☐ Other:

____

8. Please indicate your opinion with respect to the following question.

I believe that field-based practical classes are an essential component of science education? (Circle One)

Strongly Disagree		*Neutral*		*Strongly Agree*
1	2	3	4	5

<u>THE USE OF QR BARCODES IN PRACTICAL TEACHING</u>

9. Should QR barcodes be used more widely in practical classes at Monash?

- ☐ Yes
- ☐ No

If YES, please list how and what units might benefit from their incorporation:

____

____

____

10. Other aspects of modern technology could be incorporated into practical classes at Monash?

Strongly Disagree		*Neutral*		*Strongly Agree*
1	2	3	4	5

Please outline what else could be used in practical classes:

____

____

____