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Exploring science pedagogy on the web 2.0/mobile border: Teachers' views of a mobile wiki-based inquiry approach

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Abstract

This paper reports on teachers' experiences of a 10-week, wiki-based, predominantly mobile science education intervention for secondary school students. It was designed to shift traditional pedagogical approaches towards more inquiry-based approaches by combining the strengths of wikis and mobile smart devices. The four participating Macau science teachers, with shared responsibility for 250 students, noted greater student engagement and reported some shifts towards more constructivist pedagogy and more active student learning. Evidence emerged of the value of personalization, collaboration, online feedback, and authentic learning, but the lack of mobile optimization of the wiki platform negatively impacted the degree of personalization, collaboration and authenticity. Lessons were learned about the need for educational technology interventions to carefully consider the intersection between software and hardware; the reasons for the recent decline of wikis as educational tools; and the ongoing educational value of web 2.0-style collaboration in our increasingly mobile era.

Keywords: mobile learning, wikis, science education, inquiry approaches, qualitative research

INTRODUCTION

Contemporary digital and especially mobile technologies, which support personalization, collaboration and authenticity in interactions and learning, hold the potential to expedite a shift away from traditional pedagogical approaches in science education and other subjects and towards social constructivist approaches where active learning is promoted. However, such a shift depends on teachers' views of the technologies and their affordances and limitations.

This paper reports on the views of four secondary science teachers in four separate Macau schools, with a shared responsibility for 250 students, regarding a 10-week wiki-based, predominantly mobile science intervention. This intervention sought to exploit the strengths of wikis, which can facilitate collaborative learning, and to combine these with the strengths of mobile smart devices, which can facilitate authentic, networked learning in everyday settings. The central focus was initially very much on the collaborative use of wikis, for which mobile devices were primarily viewed as a vehicle which was convenient (due to widespread student ownership), flexible (due to anytime, anywhere access), and potentially enriching (due to the increased levels of personalization, networking and authenticity possible with mobile devices). However, the fit between wikis and mobiles proved to be problematic.

In light of numerous calls in the educational technology literature to avoid the exclusive reporting of positive results (Burston, 2016; Crompton & Burke, 2018; Persson & Nouri, 2018) and to publish negative results from which much can be learned (Crompton et al., 2017; Pegrum, 2019), the current paper recounts both the successes and failures of this intervention, detailing their interconnectedness. In evaluating the intervention, it was found that teachers' reports of greater student engagement in some cases, along with some shifts towards more social constructivist pedagogy on the part of teachers and more active learning on the part of students, were offset by the limitations identified,

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Contribution to the literature

- Well-designed educational technology interventions can provide scope for active, student-centered, inquiry-based pedagogies in science education, with mobile devices providing scope for personalization, collaboration and authenticity in learning.
- Educational technology interventions must carefully consider the intersection between software and hardware, especially on mobile devices.
- Established web 2.0 platforms such as wikis need to be optimized for mobile usage in order to remain relevant in an increasingly mobile era.

notably in the lack of mobile optimization of the selected wiki platform, Wikispaces. Important lessons were learned. Methodologically, in such interventions, there is a need to carefully consider not only the software (in this case, Wikispaces) and the hardware (predominantly mobile phones) but the fit between them. Educationally, some reasons became apparent for the recent decline of wikis as learning tools—including the demise of Wikispaces, which occurred not long after the end of the intervention—as well as about what web 2.0-style collaboration through other platforms may still have to contribute to education in our increasingly mobile era.

LITERATURE REVIEW

Given the tension between the use of wikis and the use of mobile devices that surfaced in this study, the literature review below covers the principles underpinning the broad transition from a web 2.0 to a mobile era; common pedagogical frameworks for considering digital learning and mobile learning in particular; and studies of learning outside the classroom via mobile devices. The last of these areas helps to highlight the potential and the limitations of the intervention described in this paper and supports the development of insights to inform future research.

Transitioning from a Web 2.0 Era to a Mobile Era

With its "architecture of participation" (O'Reilly, 2005, p. 3) that arguably represents Tim Berners-Lee's original vision of a read-write web (Gillmor, 2006; West & West, 2009), web 2.0 is all about collaboration enabled by lowering technological barriers to authorship and publishing (Pegrum, 2009). Over time, web 2.0 has also become about personalization, notably via tailored search and social media newsfeeds (Dudeney et al., 2013; Pegrum, 2009), or, more precisely, it has become about collaboration from personal hubs. Concomitantly, it allows for elements of authenticity through individualized self-presentation and membership in networks.

In the first decade of the 2000s, there was considerable fanfare about the democratic potential of a number of web 2.0 tools, central among them wikis, with their emphasis on widespread participation and the crystallization of collective intelligence (Mader, 2008; Pegrum, 2009; West & West, 2009), as exemplified in Wikipedia (Lih, 2009; O'Sullivan, 2009; Reagle, 2010). Educationally, wikis were widely viewed as valuable in supporting student collaboration, generally in tandem with an explicitly or implicitly social constructivist pedagogical approach (ELI, 2005; Mitchell, 2006; Ruth & Houghton, 2009), and sometimes alongside other tools with a similar philosophical grounding such as blogs and podcasts (Green et al., 2008; Richardson, 2010). More recent studies have continued to find educational value in wikis while simultaneously identifying research gaps and design challenges (Abdekhodaee et al., 2017; Deng, 2018).

A shift towards the use of mobile devices to access the web began in the very heyday of web 2.0, with many key services and tools eventually released in app format (Pegrum, 2014). Educationally, it has gradually become apparent that the newer mobile learning paradigm allows for an increased degree of personalization through individualized hardware and software choices, personal assistants, and adaptive learning apps, as well as an increased degree of collaboration through anytime, anywhere sharing (Burden & Kearney, 2017; Pegrum, 2014, 2019) involving networked individuals (Castells, 2013; Rainie & Wellman, 2012) who straddle an analogue, local space of places and a digital, global space of flows (Castells, 2010). But above all, the mobile learning paradigm allows for an increased degree of authenticity as learning takes place in—and is immediately shared from—the real-world contexts where it applies. Such authentic learning enables teachers and students to take advantage of user-generated content (UGC) stemming from user-generated contexts (UGCX) (Aguayo et al., 2017; Cook, 2010; Cook & Santos, 2016). Contextual mobile learning, indeed, has been viewed as a new generation of digital learning (Kinshuk, 2015; Sharples, 2016; Traxler & Kukulska-Hulme, 2016).

Some web 2.0 tools, like blogs, have adapted well to the mobile paradigm; others, like social networking and social sharing platforms, have positively thrived as apps; and many new networking apps are continuing to appear. But some existing tools have been less successful in making the transition, with their older desktop-oriented formats seeming unwieldy on mobile devices and hampering the instantaneous networking typical of

the mobile era, and they have ultimately failed to compete with mobile-first collaborative platforms. As became increasingly evident in the course of the current research, it may well be that wikis—with the exception of the largely consumption-oriented Wikipedia (where 1% of editors contribute more than three-quarters of the content; Matei & Britt, 2017)—are turning into a casualty of the mobile era, which has seen the demise of once-popular services such as Wetpaint and, more recently, Wikispaces. The reasons for this decline are further elucidated in our investigation below.

Framing Digital and Mobile Learning

There is a consensus in the research that digital and mobile technologies are highly engaging for students, at least initially (Pegrum, 2019). There is also a consensus that although they can support any pedagogical approach from the traditional to the progressive (Bower, 2017; Hockly, 2016), they lend themselves particularly well to supporting progressive approaches such as social constructivism and its various incarnations like task-based or problem-based learning (Cochrane & Narayan, 2017; Tai, 2012). Often, however, this potential is not realized (Crompton et al., 2017; Davidson, 2017; Stevenson & Hedberg, 2017).

General digital learning frameworks are often applied retrospectively to mobile pedagogy. TPACK (Angeli et al., 2016; Mishra & Koehler, 2006) emphasizes the need for teachers to design learning at the point of intersection of their content, pedagogical and technological knowledge. SAMR (Cochrane et al., 2016; Dudeney et al., 2013) encourages teachers to progress from using technologies to merely enhance learning tasks to using them to transform learning, generally pushing education in a social constructivist direction and towards the higher levels of the Revised Bloom's Taxonomy; notwithstanding a number of critiques of SAMR, its broad thrust has resonated with many teachers (Pegrum, 2019). The newer T3 (Magana, 2017, 2019) focuses more explicitly on students' roles in varied task types, and advocates building towards technology-supported activities based on inquiry design and social entrepreneurship.

Specific mobile learning frameworks reveal the particular contributions that mobile (as distinct from general digital) technologies can make to teaching and learning. The iPAC framework (Burden & Kearney, 2018; Kearney et al., 2012) highlights the three constructs of personalization, collaboration and authenticity, which can be foregrounded in well-designed mobile learning tasks. The 3 Mobilities framework (Pegrum, 2014, 2019) suggests that tasks incorporating all three levels of mobility—of the devices, the learners and the learning experiences—are likely to produce the richest pedagogical outcomes, with tasks at the first level mainly involving personalization, at the second level personalization and collaboration, and at the third level personalization, collaboration and authenticity.

Much of the literature on mobile learning echoes the key points of emphasis in these frameworks, linked to the fundamental insight that, as noted earlier, digital and mobile technologies facilitate a shift from transmission to constructivist pedagogies. Researchers recognize the considerable scope in mobile learning for personalization (Bower, 2017; Cochrane & Narayan, 2017; Kukulska-Hulme, 2016); for collaboration, sometimes linked to teacher-student partnerships and improved feedback (Cochrane et al., 2016; Kukulska-Hulme & Viberg, 2018; Pegrum, 2009); and for authenticity and contextualization (Bachmair & Pachler, 2015; Sharples, 2016; Traxler & Kukulska-Hulme, 2016). The last of these areas, typically linked to tasks at the third level of the 3 Mobilities framework, is where mobile learning most clearly surpasses the limitations of web 2.0 accessed on fixed hardware; contextual mobile learning comes into its own as students personally create and share UGC using the recording and networking capabilities of their mobile devices within their real-world settings (Aguayo et al., 2017; Cook & Santos, 2016).

Of course, for the full pedagogical potential to be realized, the technological tools must be adequate to the learning tasks. In terms of general digital frameworks, appropriately designed wiki tasks may be at the transformation levels of SAMR, and at least at the transformational, or T2, levels of T3. In terms of mobile learning frameworks, wikis can support collaboration and personalization, but the difficulty of using them on mobile devices means that they may do so less efficiently or effectively than newer tools; and their limited mobile-friendliness certainly constrains their role in supporting authentic, real-world learning. This raises the question: what is the place of web 2.0-style collaboration—and the web 2.0 mainstay, wikis—in an era of mobile technologies and pedagogies?

Connecting Classrooms with the Real World Through Mobile Learning

A number of studies, many focusing on STEM component subjects and in particular mathematics, have investigated the value of mobile devices for connecting in-class learning with authentic, contextualized, out-of-class learning (e.g., Alioon & Delialioglu, 2019; Sawaya & Putnam, 2015). The aim is typically to help students build bridges between academic learning and its real-world applications as seen in community "funds of knowledge" (e.g., Jay & Xolocotzin, 2015; Kalir, 2016). This process often lends itself to the integration of both personal and collaborative elements:

> Content captured on one mobile device can sync with or be instantly uploaded to the cloud and accessed from another mobile device or desktop.

> This connectivity also supports collaboration by learners working together on common documents or projects. There are many collaborative productivity applications (e.g., Google Drive) that support such interactions (Sawaya & Putnam, 2015, p. 11).

Authenticity also frequently comes to the fore, as in a study of primary school geometry classes in the USA, where students searched for and photographed angles in the school playground and marked them using dynamic protractor software, in the process consolidating and extending their understanding as they learned to avoid common misconceptions (Crompton, 2015). This led to recommendations for task designs which "[c]onnect geometry to real-world occurrences or real-world authentic applications" and "[c]onnect the contextualized concepts with decontextualized versions in the classroom" (Crompton, 2016, p. 311). In a study of primary school mathematics classes in England, a mobile learning approach aimed "to help children 'find the math' in their out-of-school lives and to make connections between this and the mathematics that they engage with in the classroom" (Jay & Xolocotzin, 2015, p. 87). Students documented their out-of-class economic activity with the help of digital cameras and written notes, with these artefacts being used to stimulate in-class discussion. Ultimately, a number of students came to "see some of their [everyday] activities in mathematical ways" (p. 94).

Both authenticity and collaboration were foregrounded in a study of two primary mathematics classes in Finland, where students in the experimental class worked in groups on a mobile intervention that supported them in collaboratively noticing, digitally recording, and describing quantitative relations in their everyday settings (McMullen et al., 2019). Students were found to moderately increase their capacity for spontaneously focusing on quantitative relations in daily surroundings. Meanwhile, in a project conceived with the intention "to empower [participants] through choice, control and collaboration", middle school students in Israel used mobile phones to "undertak[e] out-of-class activities that involved exploring the mathematics of real life phenomena" (Daher, 2017, p. 14). To begin with, students carried out suggested tasks in which they collected data about real-world phenomena and attempted to come up with mathematical models for these, before going on to create their own authentic tasks. Students were found to develop autonomy and voice, engage in collaboration, and take more responsibility for their learning.

Similar research has been conducted in higher education. In a study of a university computer networking course in Turkey, groups of students were tasked with finding and photographing or videoing "real-world analogical or real examples of the abstract networking concepts in their daily life" (Alioon & Delialioglu, 2019, p. 657), before agreeing on one final document to submit as a group and then receiving instructor feedback. Students reported greater collaboration with peers and the instructor and indicated that finding authentic examples improved their understanding and retention of course content. In a study of a university mathematics methodology course, pre-service teachers connected school maths and everyday maths by carrying out mobile, real-world investigations into key disciplinary concepts and practices, collecting digital recordings and notes, and producing mobile media interpretations; it was found that teachers were able to make some disciplinary connections with everyday commercial and civic activities, effectively bridging curriculum and community (Kalir, 2016). Interestingly, a wiki was used both for the preliminary discussions of everyday maths and for sharing teachers' mobile media interpretations, though these activities did not particularly involve mobile communication.

The above studies made use of mobile devices to connect more theoretical in-class learning with more authentic, contextualized out-of-class learning, mostly with a focus on mathematics, and with a variety of software and practices employed to support personalization as well as collaboration and sharing of learning. Overall, these projects demonstrated some success in facilitating a shift towards more social constructivist, active learning designs.

METHODOLOGY

The current intervention focused on the advantages and limitations of combining wiki software with mobile hardware. The primary focus was on promoting shared learning via Wikispaces, selected because it was one of the most widely used wiki services at all levels of education, with wikis in general viewed as a key collaborative educational tool of the web 2.0 era (e.g., Deng, 2018; Mitchell, 2006; Richardson, 2010). A secondary focus was on accessing this tool via mobile devices, which was anticipated to increase the potential for personalization, collaboration, and especially authenticity of learning in everyday settings, concomitant with building bridges between in-class and out-of-class learning; this was enabled by students' widespread personal device ownership.

Participants

Four science teachers, three male and one female, aged 30 to 40, from four different secondary schools in Macau, participated. The study took place from October to December 2017. The teachers were responsible for a total of 250 Secondary-Two science students (57% female and 43% male). All of the teachers and 98% of the students owned mobile digital devices, e.g., tablets

Table 1. Inductive coding structure employed in QSR NVivo (version 11)

First- and second-order themes	Number of coding references	Number of words coded	Number of teachers
Learner engagement	41	1,421	4
Behavioral engagement	16	498	4
Cognitive engagement	14	474	4
Emotional engagement	11	449	4
Pedagogy	39	1,110	4
Pedagogical approaches	18	497	4
Feedback	12	373	3
Changing pedagogies	9	240	4
Technology	42	1,425	4
Challenges and limitations	32	901	4
Affordances	5	292	3
Improvements	5	232	2

and/or smartphones. Prior to the study, all four teachers made use of a learning management system (LMS), allowed technology integration in class, and had taught with mobile devices. However, only one operated a BYOD (bring your own device) policy where students could make use of their personal devices in class, and none had taught with a wiki before.

Research Contexts

In each of the participating schools, two science classes taught by the same teacher were randomly assigned as an experimental group (EG) and a control group (CG). Instructional methods for the CG remained unchanged throughout the study, generally adhering to a conventional presentation-practice-production (PPP) pedagogical model whereby teachers give a presentation, often in PowerPoint; students then practice questions similar to test items, with answers provided at the end; and finally, students are expected to produce accurate answers in homework tasks, which are subsequently graded by teachers.

EG students were randomly assigned into groups of five for the 10-week intervention, during which they were encouraged to use their personal mobile devices (complemented as they wished by non-mobile computers) to access their class Wikispaces area as a collaborative learning space. Over the 10 weeks, teachers posted five sets of written formative questions of real-world relevance in Wikispaces, following this model:

(a) Test the pH level of rain this week by using the pH paper given to you. Take a photo of the result and post it on your personal wiki page.

(b) Why is rain naturally acidic? What causes the acid rain?

(c) What's the main source of acid rain in Macau?

These questions were aligned with the instructional units' intended learning outcomes. Each student was required to submit his or her answers by the end of the day on which the questions were set, ideally posting accompanying photos or videos (typically recorded on a mobile phone) and writing at least 50 words per question, as well as reporting the information sources consulted. Students were asked to comment on their group members' answers, and teachers were to respond with detailed written evaluations of students' learning and address any misconceptions which came to light. The next day in class, teachers would choose several examples, with answers ranging from the most to the least accurate, for face-to-face discussion.

The current study reports exclusively on results pertaining to teachers' views of the use of Wikispaces over 10 weeks, with students' data intended to form the focus of a separate study.

Data Collection

Semi-structured interviews were conducted with the four participating teachers by the first author, focusing on questions about the role of Wikispaces in supporting students' learning, with extensive discussions arising in each interview regarding the interplay between wikis and mobile devices. All questions were asked and answered in the teachers' native language, Cantonese, with the translations reported here being the work of the first author.

Data Analysis

The data were explored inductively, through segmenting, coding and the development of category systems in NVivo, version 11. Broad first-order codes were identified based on the most prominent themes and were then further analyzed to identify second-order themes. **Table 1** shows the coding structure and hierarchy that emerged.

FINDINGS

Theme 1: Teachers' Views on Learner Engagement

The teachers mentioned three main forms of learner engagement (Fredricks et al., 2004) (41 references, **Table 1**) in relation to students undertaking Wikispaces tasks on their mobile devices. These were: behavioral engagement, the extent to which students willingly

engaged in tasks (referenced 16 times); emotional engagement, the extent to which students liked and cared about tasks and learning (11 times); and cognitive engagement, the extent to which students invested themselves in learning content, potentially developing critical and creative skills in the process (14 times).

Teachers' views of students' behavioral engagement, perhaps the most easily observed form of engagement, were mixed. Ms. Kelly saw behavioral engagement as important, noting however that although students were capable of finding information by themselves, they were "quite lazy" and preferred to wait for her to supply the information. Mr. Stanley felt behavioral engagement on Wikispaces was challenging because his students had "got used to paperwork" and he believed finding information online was too time-consuming compared to finding it in print media. Mr. Collie, while acknowledging the educational value of online interaction, suggested that encouraging students to interact online out of school required a cultural change which was difficult to achieve, given that "students are reluctant to do [online] assignments after school … and even forget to do them". In contrast, Mr. Kevin drew an interesting distinction between the use of textbook questions and the posing of questions online, observing that "usually students will not open the book again at home unless the unit is going to end or a test is coming", whereas the use of independent activities and follow-up questioning in Wikispaces resulted in students being "more active than before".

The degree of emotional engagement by students sheds some light on their behavioral engagement. Again, there was a range of views. Mr. Collie noted that there was no app for using Wikispaces and stated: "students do not like using it because it's not direct enough", referring to the lack of mobile convenience. Ms. Kelly suggested that games are emotionally engaging for students but in the case of Wikispaces, "it would be difficult for the platform to combine learning with games well". She also observed that emotional engagement hinges on how tasks are defined, remarking that "when you label a task as an assignment in Wikispaces, students think of it as usual homework and are reluctant to finish it". To address this, she believed that her use of Wikispaces could be improved through the incorporation of more "hands-on activities" and "video clips". Mr. Stanley agreed that videos are engaging for students. However, neither teacher appears to have explored the capability of Wikispaces to display embedded videos and associated activities. Mr. Kevin, by contrast, felt his students appreciated the chance to seek information online instead of in a textbook. He found that class discussions were richer, and he could "praise students for doing a good job" and concluded that: "at least some students who were not interested in science learning before are kind of different now; they converted their attitude from indifferent into interested".

Regarding cognitive engagement, which is of prime importance, teachers again presented mixed views. Mr. Collie saw cognitive engagement as his students' "personal problem", that is, their responsibility, and he believed that Wikispaces did not significantly motivate them to engage with the science content. Mr. Stanley dismissed the tool as an enabler of cognitive engagement: while stating that "using computers is always a part of my teaching", he expressed a preference for communicating "face-to-face… not through the machine". Although he conceded that online interactions can be beneficial for providing written feedback, he noted that this did not require the Wikispaces interface per se. Ms. Kelly, on the other hand, despite her students' aforementioned preference for teacher-supplied information, believed that appropriately designed tasks encouraged learners to engage with online content, promoting lateral thinking where they were more likely to question information, explore tangential topics and ultimately, in her words, come to "know more". She found that when using Wikispaces, her students asked more questions in class and could better "explain information that they had found themselves". Similarly, Mr. Kevin observed that some learners would "try to digest [new] knowledge and select useful information related to the teaching goals".

In short, both Ms. Kelly and Mr. Kevin drew attention to improved content knowledge resulting from their students' use of Wikispaces. For both of them, the intervention prompted more real-world understandings of scientific topics. Ms. Kelly explained that, for example, students "need to understand the nature of nitrogen, and then get to know why it can be used as preservatives and refrigerants", and she noted that usually "only a few of the students can do this". Dismissing rote learning as "useless", she indicated that the intervention fostered her students' ability to locate the correct information and to "relate knowledge" to more authentic contexts. Mr. Kevin enjoyed asking students to find information online instead of using textbooks, and believed this saved valuable class time that could now be spent on discussions where students linked in-class learning to what they had found online regarding real-world applications of the content.

Theme 2: Teachers' Views on Pedagogy

Teachers commented quite extensively on the pedagogical aspects of their use of Wikispaces (39 references, **Table 1**). Several subthemes emerged, regarding teachers' pedagogical approaches (18 references); their changes in pedagogy, coded as a separate, related category (nine references); and their use of feedback (12 references).

In the interviews, teachers generally endorsed progressive pedagogical approaches, stressing the need for hands-on learning, critical thinking, learner engagement, and a balance between face-to-face and online instruction. They broadly indicated disdain for an overreliance on textbooks, rote learning, excessive homework, and passive reception of subject content. However, this translated in varied ways into their usage of Wikispaces.

Mr. Stanley, as noted earlier, felt that his students were used to paperwork, and considered that teaching them to critically assess the mass of online information was too time-consuming. Mr. Collie was more neutral about Wikispaces, placing emphasis on the desirability of students being willing to ask good questions in the context of an efficient classroom with technology on hand to be used as appropriate, but without the need for extensive administrative time. Ms. Kelly was more positive about Wikispaces supporting her preferred pedagogy, which emphasized "hands-on activities rather than paperwork" (but, as stated earlier, she felt there was a need to further develop this aspect of her use of Wikispaces). Mr. Kevin saw considerable advantages in using Wikispaces to increase students' time-on-task through homework activities, which motivated them to connect classroom content with their everyday out-of-school lives:

> The learning time in school is very limited, so how can students make use of time better after school? Our teachers try to make homework interesting enough so as to arouse their interest to do it. For this approach, I'm not sure if other subjects are feasible but it seems suitable for the science class, because science is related to their life. For me, I think it's effective to continue using this approach.

He also stressed the advantages of students finding information in individual ways, making judgements about it, and arriving at their own opinions.

Of particular interest were comments regarding actual and potential pedagogical changes resulting from the use of Wikispaces. Despite his conservative position of endorsing students' continued usage of paper-based resources, and declining to teach them critical literacy skills for assessing online material, Mr. Stanley acknowledged possible advantages if digital technologies were easier to use:

> I prefer digital teaching, which is convenient enough and would not be as rigid as books, which can also make my teaching more flexible. However, one problem here is that the hardware devices are not convenient enough and I need to finish many steps to impart knowledge to students.

Mr. Collie acknowledged that the Wikispaces project had prompted a pedagogical change whereby he began encouraging students to engage in more independent critical thinking:

> I rarely taught students in this way before—I used to give them answers directly and tell them what is right or wrong rather than asking them to think about it themselves … I tried [the Wikispaces approach] and the result was better than what I expected.

Ms. Kelly referred to the emergence of new teacher-learner partnerships in which her students "would give feedback in class when we were reviewing the homework together". Among the teachers, Mr. Kevin commenced the project from the most progressive pedagogical position, which appears to have been reinforced rather than changed by his participation.

Despite a general preference for face-to-face learning, three of the four teachers recognized that face-to-face feedback could be complemented by online feedback. Mr. Stanley indicated that having students' answers to problems recorded in an online space provided opportunities for him to "make clear some mistakes that my students made or tell them how to correct mistakes in brief words". Ms. Kelly found that Wikispaces enabled her to offer a greater amount of feedback, although due to technological difficulties this was unidirectional; she explained that "it [was] impossible for students to give me feedback because of the imperfect operation [of the tool]", so she invited them to give her their feedback in class. Mr. Kevin, while acknowledging that responding to students online can be time-consuming, saw value in offering some online feedback, and particularly appreciated the chance this gave him to "select some students based on their online answers to decide which ones should share their answers" in class.

Theme 3: Teachers' Views on Technology

While teachers mentioned some affordances of Wikispaces for learning (five references, **Table 1**), these comments were considerably outweighed by comments about its limitations and challenges (32 references), particularly with respect to mobile devices. This led to some suggestions for improvement (five references).

Teachers articulated a number of affordances of online spaces for augmenting face-to-face learning spaces. Notwithstanding his reticence to use Wikispaces for technical reasons, Mr. Stanley appreciated the value of an online space where content can be dynamically updated by the teacher and students. When digital tools are well-designed, he suggested, writing and feedback processes can be streamlined in a way far superior to "learning with books". Ms. Kelly realized that not all her students could receive feedback in a face-to-face setting and found the online space useful for reaching more

reticent students. Mr. Kevin noted the advantages of students becoming actively involved in curating and sharing content: "students would find some video clips themselves and put them on the [Wikispaces] page after they had actually watched them".

All of the teachers made extensive comments on the inherent limitations of Wikispaces. Mr. Stanley discovered that he had to spend a lot of time supporting students technically since Wikispaces did not work smoothly on all hardware. This was echoed by Mr. Collie, who lamented the lack of a mobile app version of Wikispaces, and Mr. Kevin, who stated that Wikispaces' lack of optimization for mobile devices made it difficult for students to add and modify content in real time from their real-world settings: "for example, they wished to upload pictures as soon as they found something useful in the street rather than go back home to use a computer".

Once teachers and students had accessed Wikispaces, they encountered problems with the interface. Mr. Stanley found that it was difficult for him to post and grade questions on Wikispaces, while his students struggled with a convoluted interface where they "needed to press lots of buttons to hand in homework or reply to me". Ms. Kelly observed that only her top students could navigate the interface with relative ease and that, as mentioned earlier, the tool's "imperfect operation" restricted the potential for multidirectional feedback. Mr. Kevin spoke of his own frustrations in learning how to upload media through trial and error in the Wikispaces interface. Other complaints comparing Wikispaces unfavorably with newer tools focused on the time it needed "to update gradually" (Mr. Stanley) and the lack of immediate notifications when students posted work (Mr. Collie). While some of these issues could have been ameliorated through more training or greater experience with Wikispaces, the fact remains that, for teachers and students alike, Wikispaces lacked the smooth functionality they had come to expect in a mobile era: an intuitive interface, instant updating, and automatic notifications of new content.

The teachers' recommendations for improvements referenced such limitations. Mr. Stanley suggested that the interface "should be simplified and made easier for my students to use"; although he recognized that this was partly due to students' language levels—"they are junior secondary students, and their native language is Chinese"—it is worth bearing in mind that multilingual interfaces are another common feature of today's mobile apps. Mr. Stanley also recommended that Wikispaces should make it easier for students to "upload pictures, videos or their drawings to finish homework instead of words only". Mr. Collie desired better quiz functionality, alongside more functionality typical of mobile apps:

> I hope that students can log in without going through the webpage first and that messages will be sent automatically and continually to my phone once I log in—just as other apps do. If students have some feedback for me, I could be informed directly.

DISCUSSION

This study investigated how mobile-enabled teaching with wikis could support a shift towards more active, student-centered, inquiry-based pedagogies in the context of secondary science education in Macau. At least two important, and somewhat unanticipated, developments occurred. The first was the discovery that the use of certain older, well-established web 2.0 software such as wikis may prove surprisingly problematic on newer, now-dominant mobile hardware. The second, perhaps not unconnected with the first, was the closure of the wiki of choice, Wikispaces. The findings of this study therefore shed light on both the longstanding success and ultimate demise of wikis as educational tools, especially when viewed alongside the expanding presence and affordances of mobile devices for learning. In this climate, it is perhaps unsurprising that the teachers presented a rather mixed assessment of Wikispaces' capacity for improving students' engagement and learning.

It is revealing to consider the successes and challenges of the project in relation to the constructs of personalization, collaboration and authenticity which are associated with mobile devices in models such as the iPAC and 3 Mobilities frameworks, as discussed earlier. Collaboration has traditionally been viewed as the key educational affordance of wikis, and as noted earlier, has been foregrounded in past studies (e.g., Daher, 2017; McMullen et al., 2019), while the related concept of networked learning is seen as a key affordance of mobile devices. In this project, students worked individually to collect information and artefacts, but they shared these with peers on Wikispaces and learned through each other's examples and teacher feedback on their collective efforts; Mr. Kevin's class appears to have been most responsive in this regard. Feedback was an important consideration for the teachers, with some seeing potential for more democratized approaches supported by Wikispaces, though it was felt that technical issues, including an awkward interface and a lack of instant notifications, limited this potential.

Personalization is associated with the individualized hubs of web 2.0, but even more so with individually chosen and configured mobile devices. In this project, students were able to exercise agency in the use of their own personal devices, their choices of personally relevant examples when completing tasks, and their explorations of online information of personal interest. Ms. Kelly and Mr. Kevin both emphasized the value of the content, including UGC, shared by students and discussed in class feedback sessions. Feedback through

an online platform may not only be greater in quantity than face-to-face feedback, of course, but may be more targeted and individualized, a point touched on by teachers, though this was again seen as being circumscribed by the technical aspects of Wikispaces.

In the research literature, authenticity has also been foregrounded (e.g., Crompton, 2015, 2016) and is strongly associated with the most pedagogically sophisticated mobile learning tasks (e.g., Daher, 2017; Jay & Xolocotzin, 2015; Kalir, 2016). Significantly, both Ms. Kelly and Mr. Kevin reported that, through a combination of carrying out the Wikispaces tasks, sharing their recorded content, and exploring online information, students were able to build connections between in-class and out-of-class learning, effectively finding the science in their everyday lives (cf. Jay & Xolocotzin, 2015, p. 87, on finding the maths in everyday life) and discussing their findings with classmates. It is interesting to note the possibility of emergent teacher-student learning partnerships to which such an approach can give rise, as mentioned by Ms. Kelly. Once again, however, the limitations of Wikispaces became apparent. Even Mr. Kevin lamented its lack of mobile-friendliness, which created a barrier to students sharing learning directly and immediately from the real-world settings where they were making their science connections. In other words, the authenticity that is perhaps the greatest potential advantage of mobile learning was at least partially undermined by the older Wikispaces format.

Clearly, the platform—in the form of Wikispaces accessed primarily on students' mobile devices—presented technological limitations, which translated into pedagogical limitations. It proved difficult to use for immediate uploading, sharing, and commenting from the real-world locations in which students were observing and recording everyday instances of scientific phenomena, a problem compounded by the less-than-intuitive, more desktop-oriented interface, the slow speed of updating, and the lack of automated notifications. While its underpinning collaboration-oriented philosophy remained highly relevant, its technological awkwardness on mobile devices meant that Wikispaces proved less than fit for the contemporary mobile era. In this case, two options suggest themselves. Either wiki platforms need to move in the direction of Wikipedia, whose user-friendly (and multilingual) interface has normalized the use of mobile devices for editing articles, uploading materials, contributing to discussions, and receiving notifications; or alternatively teachers and researchers need to explore the use of mobile-first platforms, or apps, which offer similar collaborative functionality to wikis in addition to full mobile integration.

Despite the aforementioned problems, it is notable that some teachers—especially Mr. Kevin and Ms. Kelly—did manage to exploit the potential benefits of Wikispaces to some degree, and their students did engage cognitively (as well as behaviorally and emotionally) to some extent, raising the question of why such varying experiences emerged in the same project. In fact, the differences between the more and less successful uses of Wikispaces, notwithstanding its inherent limitations, appear to have stemmed in large part from an interplay of teachers' technological and pedagogical attitudes. Significantly, in the present study, these attitudes seemed to be loosely connected; in other words, a willingness to embrace new technologies was correlated with a willingness to embrace progressive pedagogies.

For example, on the technological side, Mr. Stanley was generally rather negative about Wikispaces—partly, though not only, because of its mobile-unfriendliness—and preferred to let students continue working with the paper resources they were used to; on the pedagogical side, he preferred direct instruction, and indicated that he found it too time-consuming to teach the critical literacy skills necessary to underpin his students' autonomous information searching. At the other end of the continuum, on the technological side, Mr. Kevin supported BYOD technology integration in class; and pedagogically, he found ways to use Wikispaces to support students' independent inquiries, to increase the range of feedback, to build connections between the classroom and the outside world, and to collect user-generated or user-curated content as a basis for classroom teaching. While a detailed analysis of the links between teachers' technological and pedagogical attitudes is beyond the scope of this article, an investigation of these issues would provide fertile ground for future studies.

CONCLUSION

It is apparent that digital technologies offer ways of extending the times and spaces of traditional education. With appropriate tools linked to appropriate designs implemented by teachers who are open to exploring new ways of teaching and learning, there is scope for promoting inquiry-based, active pedagogical approaches; for increasing the elements of personalization, collaboration and authenticity in learning; for democratizing and enriching feedback; and for building student engagement and agency.

However, it is crucial that tools are fit for their pedagogical purposes. This is a key lesson for educators and researchers who are developing educational technology interventions; and it is simultaneously a key lesson for educators who are attempting to work with well-established web 2.0 tools in what is now a predominantly mobile era. Wikispaces, used on mobile devices, facilitated some pedagogical shifts, but was too inherently limited in a mobile age where more can be achieved pedagogically through situated,

contextualized learning supported by immediate, in-situ networking. In other words, web 2.0 platforms like wikis need to evolve, or they will continue to be replaced by platforms that share much of their collaborative functionality but are optimized for the current era.

This study was limited in a number of ways, given that it focused on only four science teachers in the setting of a single territory who participated in an intervention of 10 weeks. Further research which includes appropriate pre- and post-intervention questions could investigate in more depth the relationship between teachers' existing and evolving technological and pedagogical attitudes. It would also be appropriate to study the attitudes of science teachers in a range of other settings and over longer periods of time. Finally, there are important questions to be asked about which web 2.0 tools remain fit for the current mobile era, and which need updating or replacement.

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