An exploration of inquiry-based authentic learning enabled by mobile technology for primary science

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Abstract: The rapid development of mobile technologies has been shown to assist in science learning, but more research is needed on the pedagogical integration of such technologies into authentic learning in a formal science curriculum. Thus, we conducted a study on exploring the impact of a learning platform nQuire-it together with its scientific mobile sensors in an authentic and inquiry-based learning environment on students’ science learning. To examine the effectiveness of this learning platform and its mobile sensors, a mixed methods study was conducted for analysing students’ performance in science inquiry, conceptual understanding and ability to connect content knowledge with daily life experiences. The results suggested that the learning platform together with scientific mobile sensors supported students’ authentic science learning in following dimensions: academic performance, learning motivation, interest in learning and ability to link knowledge gained in and outside the classroom.

Keywords: nQuire-it; science inquiry; authentic learning; mobile learning.


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This paper is a revised and expanded version of a paper entitled ‘nQuire-it: Engaging Students in Authentic Inquiry Learning’ presented at the ‘22nd Global Chinese Conference on Computers in Education (GCCCE 2018)’, Guangzhou, China, 25–29 May 2018.
1 Introduction

Information and Communications Technologies (ICTs) have commonly been merged with science teaching and learning in the collection of scientific data, lectures, virtual experiments, assessment and monitoring (Mills et al., 2019; De Jong, 2006; Fallon, 2019; Weng et al., 2018). Together with a well-designed pedagogy (i.e., inquiry-based learning, flipped classroom, seamless learning or mobile learning), ICT-supported learning enhances scientific knowledge and cultivates learning skills (Hong et al., 2019; Lai et al., 2007; Raes et al., 2013; Sun, et al., 2016).

Among different types of ICT tools, mobile technology has witnessed intensive development and is increasingly implemented in learning both in and out of classrooms (Alioon and Delialioğlu, 2017; Sharples et al., 2014; Wong et al, 2016). The advantages of mobile technology are particularly visible in an authentic learning context. Students can record information and interact with their peers more conveniently and effectively than via traditional pencil-and-paper methods. Research attention has increasingly been paid to how mobile technology can generate learning artefacts, strengthen motivation and enhance cognitive skills (Burden and Maher, 2014; Huang and Chiu, 2015; Wong and Looi, 2011).

Research has highlighted the potential of mobile sensors, which combine mobile and sensor devices in a way that promotes student motivation, engagement, autonomy and self-directed learning (González et al., 2014; Hwang and Tsai, 2011; Yun et al., 2017). This technology has also been shown to enhance students’ knowledge, cooperation skills and positive attitudes towards science (Aristeidou et al., 2015; Charitonos et al., 2016; Okada et al., 2015). Its effectiveness in facilitating active learning has also been demonstrated, specifically by asking users to collect first-hand data and input various inquiries (Kerawalla et al., 2011). However, studies have concluded that a successful mobile learning activity requires not only hardware and software, human resources (i.e., teacher education) and parental support, but also planning, pedagogical design and additional strategies, none of which have been fully addressed in the research field (Bano et al., 2018; Krajcik and Delen, 2016; Fu and Hwang, 2018). A review of the literature suggests that more work is needed on the pedagogical implementation of mobile technologies in different settings (Bamberger and Tal, 2008; Liu et al., 2016; Waight and Abd-El-Khalick, 2011). Meanwhile, to develop new theories of mobile learning, studies must continue to examine the new functions and applications associated with a ubiquitous learning environment (Huang et al., 2011).

To address the problems described above, we assess the effectiveness of a newly developed mobile learning platform, nQuire-it (n.d.), and its accompanying mobile sensors, in inquiry-based authentic learning in a formal science curriculum. We thereby aim to gain insight into students’ conceptual understanding and attitudes towards science learning. The research findings are discussed with a focus on promoting mobile learning and a mobile technology supported curriculum.

2 Literature review

2.1 Authentic learning in science education

The idea of authentic learning was introduced in the early 1990s (Deboer, 1991). It was defined as an approach providing real-world and problem-based activities that can
enhance knowledge and skills (Herrington and Oliver, 2007; Gometz-Puente et al., 2013). In the field of educational technology, authentic learning is learning that is seamlessly integrated or implanted into meaningful, real-life situations (Wong and Looi, 2018). In informal learning contexts, activities based on real-life experiences have long been considered as effective in linking life knowledge with knowledge learned in class (Achiam et al., 2016; Anderson et al., 2003). Studies have emphasised the importance of this practice-based approach in helping students to gain a deeper understanding of the relationship between claims and evidence in constructing scientific arguments (O’Neill and Polman, 2004) and to improve students’ attitude and motivation (Bamberger and Tal, 2008).

Research has found that authentic activities promote scientific inquiry because they provide natural problem-solving contexts with high degrees of complexity (Abrahams and Reiss, 2012; Lee and Butler, 2003). Authentic learning has been found to strengthen the process of conceptualisation, which in turn helps students to personalise their learning experiences and deepen their scientific understanding (Achiam et al., 2016; Giamellaro, 2014; Prins et al., 2018).

2.2 Inquiry-based authentic learning

Inquiry has always been an essential part of science education. As noted in the National Science Education Standards (NRC, 1996), a crucial strategy in teaching science is the integration of inquiry with authentic content (Chinn and Malhotra, 2002; Edelson, 1998; Matuk et al., 2019). Crawford (2014) defined inquiry as the process of motivating students to use their critical thinking skills, and this includes asking questions, designing and carrying out investigations, interpreting data as evidence, creating arguments, building models and communicating findings, all in the pursuit of deepening their understanding of the natural world by using logic and evidence. He emphasised the application of science inquiry in authentic learning contexts (Crawford, 2007).

Inquiry-based learning empowers students to question, plan, investigate and draw conclusions, and the inclusion of authentic learning allows students to experience the process of working as a scientist. Research has demonstrated that such activities improve students’ thinking skills, scientific investigation abilities and collaborative learning (Anderson, 2002; Aydeniz et al., 2011; Feldman and Pirog, 2011). Hume and Coll (2010) proposed a specific definition of “authentic scientific inquiry” in which “students have ownership over and commitment to open-ended problem-solving opportunities in a variety of contexts where they have to: draw on their existing science ideas to analyse the problem; plan a course of action; carry out the plan to obtain information that they can analyse; interpret analysed information to reach a conclusion and evaluate; and finally communicate their findings in some form”. This definition provides a framework for integrating inquiry-based learning in authentic learning contexts.

2.3 Mobile technology supported authentic learning

Technology has been applied to authentic teaching and learning to promote students’ effective learning (Bozalek et al., 2013). Different technological tools, each with their own merits, can serve as a platform for accessing multimedia, collecting and analysing real-time data and sharing ideas (Herrington et al., 2009; Ucar and Trundle, 2011). Research has generally confirmed the potential of integrating mobile technologies into authentic science learning activities and overcoming certain difficulties found in science
classes (Wong and Looi, 2018). Hung et al. (2012) declared that with the help of mobile devices, inquiry-based learning activity can effectively improve students’ in-field investigation performance.

Numerous studies have shown that integrating mobile technologies with authentic learning is an efficient way to increase student knowledge and performance (Ward et al., 2015). In particular, mobile technologies improve the mobility and convenience of educational activities (Pu et al., 2016), and they further allow students to collect evidence to be used in decision making (Lai and Hwang, 2015). Some experiments and field trips are unfeasible, but mobile technology allows for their inclusion in informal learning contexts (Gunter and Reeves, 2016; Herrington et al., 2009).

However, the outcomes of these activities, including enhanced student performance, social interaction and personal motivation, vary considerably depending on the quality of technologies or tools, lesson plans and learning materials (Bamberger and Tal, 2008). Studies have cautioned that students cannot receive good returns on investment in authentic learning activities if the use of technology is not well planned (Wilde et al., 2012). Researchers have also observed that authentic resources may be used passively when activity guidance is not clear enough or not closely bound to the content (Bostock, 2002; Lee and Songer, 2003). Misconceptions may arise and frustration may occur when feedback on students’ knowledge is insufficient (Rosenbaum et al., 2006). Furthermore, research has shown that students’ greatest difficulties in learning in different settings arise from the change in the teacher’s role and unclear learning objectives in student-centred classrooms (Nicaise et al., 2000).

To address the above problems in the context of science learning, we used a web-based learning platform – nQuire-it and its accompanying mobile sensors in Hong Kong primary schools. This trial was conducted to assess science instruction supported by mobile technologies in an authentic inquiry-based learning context. Our goals were to demonstrate the effect of well-designed mobile learning activities on students’ science learning, and to gain insights into integrating a new mobile technology into an authentic learning context.

3 Purposes and research questions

This study was conducted to explore the effectiveness of using a mobile learning platform together with its mobile sensors in improving students’ knowledge of and attitudes toward the subject and authentic learning.

The following questions guided the research.

- How can we integrate nQuire-it and mobile sensors into authentic inquiry-based learning in regular science classes?
- To what extent does the authentic inquiry-based learning supported by nQuire-it enhance students’ conceptual understanding of science?
- To what extent does the authentic inquiry-based authentic science learning supported by nQuire-it improve students’ attitudes toward science learning?
4 Methodology

4.1 Participants

As this was the first study of the nQuire-it platform in Hong Kong primary schools, we carried out the research in two stages to better implement the nQuire-it learning activities in schools. In the first stage, prior to fully implementing the nQuire-it learning activities, we conducted a pilot study by randomly selecting 14 Primary 4 students (aged 10–11) from one primary school to test the feasibility of nQuire-it and its learning activities. Personal tablets were commonly used at the pilot school. In the second stage, the experimental study was conducted with 27 Primary 4 students. They were chosen from another local primary school at which e-learning was widely used. Among 27 students, 14 students were assigned to the experimental group and the remaining 13 to the control group after obtaining their consent.

4.2 Context, topics and procedures

NQuire-it is a free online learning platform developed by The Open University, UK (http://www.nquire-it.org/#/home, see Figure 1). Three types of task are included in the platform: Sense-it, which requires students to download the mobile sensor apps for measuring data. It is suitable for conducting authentic mobile learning because it can be used to record different scientific data (i.e., accelerometer, magnetic field, light and sound) (see Figure 3). Spot-it, which requires students to take photos of their observations in daily life; and Win-it, which requires students to accept challenges and compete with others. The data collected can be shared and discussed in nQuire-it (see Figure 2).

Figure 1 nQuire-it learning platform
The pilot study, which brought the students into initial contact with nQuire-it and its learning activities, was to ensure the students had sufficient knowledge of and positive attitudes toward the topic. After experiencing nQuire-it and its learning activities in their
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normal General Studies class, the students did a post survey on the attitudes towards the nQuire-it learning activities. The survey recorded their initial responses to the nQuire-it and its learning activities.

In the experimental study, the topic of noise pollution was selected and designed to fit the features of nQuire-it and the learning objectives of topic three of the General Studies course, Science and Technology in Everyday Life (Hong Kong Education Bureau, 2017). The lessons were also designed to fit the five criteria for authentic learning: high-order thinking, knowledge depth, connectedness to the world beyond the classroom, substantive conversation and social support for student achievement (Newmann and Wehlage, 1993). Likewise, nQuire-it was used as a platform to encourage students to generate ideas or record their own observations and experiences. To minimise errors resulting from students’ unfamiliarity with the platform, a trial activity was conducted before the real one. Sample guiding questions and comments were also provided.

In the pedagogical design of the learning activities, the students went through a process of inquiry learning, which involved questioning, investigating, sharing and commenting, discussing and reflecting. The lesson design is briefly presented in the appendix 1 (three lessons). In these specific lessons, the students were required to collect data, take photographs in their daily lives and answer related questions to associate their knowledge and real-life experiences. To encourage cooperation and communication, they were divided into groups (Ooi et al., 2018). Three activities on the nQuire-it platform were created: “Measuring Sound Intensity at Home,” “Looking for Noise Pollution Sources” and “Looking for Noise Pollution Reduction Infrastructure.” To record their changes in knowledge, attitude, skills and sensitivity to the surrounding environment, a pre-test and post-test were administered before and after the intervention, respectively. Last, the semi-structured interviews were conducted with four participants from the experimental group (S1–S4) and the control group (S5–S8), respectively.

Similarly, in terms of the design of learning activities in the control class, apart from using the teaching resources of a traditional classroom, such as PowerPoint, textbooks and worksheets, the students watched educational television programmes and engaged in group discussion.

4.3 Data sources and analysis

The data in this project were investigated through both quantitative and qualitative analysis. The post survey in the pilot study was built on Miedihensky and Tal’s (2008) research and focused on three items: 1) pre-knowledge of mobile sensors, 2) general views on nQuire-it and 3) attitudes towards authentic learning supported by nQuire-it. For Section 1, three “yes” or “no” questions related to the participants’ pre-knowledge of mobile sensors were asked. For Section 2, there were five five-point Likert-scale questions on the students’ attitudes towards Sense-it and nQuire-it. For Section 3, there were six five-point questions regarding the students’ views on authentic learning. Frequency analysis was conducted and the average mark for each question was calculated.

In the experimental study, the students’ performance and attitudes were examined in a post-test. Interviews, feedback and interactions were conducted to gain insight into their overall performance. The pre-test and post-test each had three and four parts respectively. In both pre and post-tests, Part 1 was related to students’ attitudes towards learning and their ability to link their knowledge to an authentic learning context, Part 2
to their attitudes towards General Studies, Part 3 to their conceptual understanding. Additionally, Part 4 was designed for asking their views on nQuire-it supported learning. For the items of part 1, 2 and 4, they were revised from relevant studies conducted by Schumm and Bogner (2016), Velayutham et al. (2011) and Tuan et al. (2005). The seven questions for Part 3 were modified from the sample lesson content and reflective questions related to noise pollution from the Education Bureau’s curriculum materials (Hong Kong Education Bureau, 2016), with 20 as a perfect score. Please refer to the Appendix 2 for further information on the test and marking scheme.

Levene’s test was used to identify the equality of variances for a variable calculated for more than two groups in the database (Levene, 1960), given the small research sample used. The test of normality and a histogram created by the Statistical Package for the Social Sciences (SPSS) were used to check the test’s validity, whether student performance was close to the normal distribution, and whether the test was too hard or easy. To test the magnitude of the effect of the lessons on the student performance, effect size was calculated by estimating Cohen’s d in a t-test, using the formula $d = \frac{2f}{\eta^2} \frac{1}{1 - \frac{\eta^2}{1}}$ (Cohen, 1988). It was suggested that $d = 0.2$ represents a ‘small’ effect size, $d = 0.5$ represents a ‘medium’ effect size, and $d = 0.8$ represents a ‘large’ effect size. Afterwards, frequency, average scores, percentage change between the pre-test and post-test and the divergence between groups were calculated. Paired samples t-tests were performed to identify differences and their significance between the experimental and control group in the pre-test and post-test. Four questions were asked during interview, and each interview took around 15 minutes. The questions mainly focused on the students’ motivation, how they benefited from the learning activities and their aspirations for using mobile learning technologies in the future (see Appendix 2).

5 Results and discussions

5.1 Initial results from pilot study

In Part 1 of the post survey, 70% of the participants knew that sensors existed in mobile devices. However, only 30% of them reported using Sense-it functions in scientific activities, and none of them used the mobile sensors for learning activities. This showed that although the students were aware of the mobile sensors, a large proportion of them had a shallow understanding on how mobile sensors could be used in science.

In Part 2, related to the students’ views on Sense-it, 94% of the participants strongly agreed or agreed that Sense-it was interesting and useful. More than 88% considered it to be well designed and easy to operate, and more than 82% believed that it was suitable for teaching topics in General Studies. All of the students agreed that they would be willing to introduce Sense-it to their friends. This implied that the students generally developed positive views of the platform and mobile sensors, and recognised their potential in terms of obtaining and sharing information.

Regarding Part 3, which was about students’ perspectives on using nQuire-it for authentic learning, over 94% of the students strongly agreed or agreed that the platform could increase their interest in General Studies, knowledge of the things around them, ability to link knowledge learnt in classroom with real-life knowledge and engagement in scientific inquiry. Half of the students strongly agreed and 37.5% agreed that they would continue to use nQuire-it after class. All of the students mentioned that they were willing
to share recorded data with their classmates. This showed that nQuire-it has the potential to improve students’ motivation for self-directed learning. Its positive influence on students’ motivation was demonstrated in the later experimental study.

5.2 Findings of experimental study

5.2.1 Quality of tests

Using an independent-samples t-test of the differences between the pre-test and post-test for both groups of students, Levene’s test, the significance value was found to be 0.233, which is greater than 0.05, suggesting that the variability in the two conditions was not significantly different. This underlined the equality of the variances in scores. For the performance of students in the pre-test and post-test, the test of normality gave a value significantly lower than 0.05, indicating that the data showed no difference from a normal distribution graph. In the histogram, the data was also found to be close to the normal distribution curve (Figures 4 and 5). This suggests that the difficulty of the questions was suitable for testing the students’ performance.

The descriptive statistics test showed that the experimental and control groups both gave positive feedback on how interesting the lesson was with M Experimental group = 3.31; M Control group = 3.27 and its design with M Experimental group = 3.64; M Control group = 3.27. In their interviews, students S1 and S4 from the experimental group reported that they had obtained daily life knowledge through the activity, and student S2 explained that she had been motivated by the use of the tool. Similarly, students S6 and S8 in the control group found that the activities were more interesting than those in normal lessons. Given the preceding data, the high quality of both classes was indicated.

Figure 4 Histogram on pre-test score
5.2.2 Students performance in tests and interviews

Changes in the students’ conceptual understanding were observed during and after the lessons. The results of both groups in the performance test showed an improvement compared with the pre-test and post-test, but the experimental group showed a more obvious enhancement, with a 39.9% increase for the experimental group compared with 22.5% for the control group (see Figure 6). Analysing the paired samples correlations, the pre-test scores of the experimental group and control group were, respectively, non-significantly moderately correlated ($r = 0.530, p = 0.051$) and slightly significantly correlated ($r = 0.734, p = 0.004$) with their post-test scores.

Figure 5   Histogram on post-test score

Figure 6   Plotted graph on estimated marginal means
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Table 1 shows the results of the paired samples t-test, that a significant difference was found between the pre-test and post-test scores of the two groups, with $t$ (13) = 5.04, $p = .000$ for experimental group and $t$ (12) = 3.58, $p = .004$ for the control group, while the mean score of the experimental group in the post-test ($M = 12.39$) was 3.53 higher than those in the pre-test ($M = 8.86$), and the mean score of the control group in the post-test ($M = 11.12$) was 2.03 higher than that in the pre-test ($M = 9.08$).

Table 1  

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental group</td>
<td>14</td>
<td>8.86</td>
<td>2.74</td>
<td>12.39</td>
<td>2.68</td>
<td>5.04***</td>
</tr>
<tr>
<td>Control group</td>
<td>13</td>
<td>9.08</td>
<td>2.67</td>
<td>11.12</td>
<td>2.93</td>
<td>3.58**</td>
</tr>
</tbody>
</table>

Note: ***$p < .001$; **$p < .01$

Furthermore, the calculation of effect size from the paired samples test, Cohen’s $d = 0.5$ was found to be the medium between the two groups compared with the post-test, which suggested that around 66–69% of the students in the control group scored lower than the students in the experimental group in the post-test. An effect size (0.6) of medium to strong was also found between the differences in the pre-test and post-test scores of the two groups, showing that around 73–76% of the control group students showed less improvement than the experimental group students.

The differences among the student responses can be seen in responses to question 7 (see Figure 7), which required the students to describe methods of protecting themselves against noise pollution. Although neither group had been exposed to any related issues, as seen in Figure 7, the marks of the experimental group increased (+112.28%), whereas those of the control group fell (–8.00%). This proved that after completing lessons with nQuire-it, the students had an increased awareness of their surroundings and better critical thinking skills.

Figure 7  

![Average total mark in question 7](image)

In the open-ended questions 1, 6 and 7, which required students to give examples of their answers, the experimental group showed a 29.97% increase in the number of examples given, whereas the control group only showed a 6.65% increase (see Figure 8). The improved motivation to link learned knowledge with daily life experience was more visible in the experimental group than in the control group.
Additionally, in the interview section, students S1 and S4, respectively expressed that the lesson had helped them to understand topics in the immediate environment, and that their new knowledge had made them more effective in learning secondary school or higher level science. In brief, it was found that nQuire-it improved not only the students’ knowledge of and attitudes towards the topic, but also their motivation, ability to link knowledge with their daily life experience and their performance in critical thinking. As for questions relating to the students’ views of the lesson, the experimental group showed greater agreement with the statement that the lesson was interesting (M_{experimental} = 3.31; M_{control} = 3.27) and “Applicable to life” (M_{experimental} = 3.46; M_{control} = 3.36) (see Figure 9).

Apart from the results of the questionnaire, the interviews revealed the students’ interest in the learning activities. Students S1 and S2 in the experimental group mentioned that mobile measuring tools and iPads increased their interest and improved their learning. After listening to our description of the lesson, students S5, S6, S7 and S8 wanted to try learning with mobile tools. This suggested that using mobile tools in authentic learning helps to enhance students’ attitudes toward learning. After learning about noise pollution,
the experimental group showed few differences between the pre-test and post-test (4%; 0%), specifically for questions related to ‘motivation to apply General Studies knowledge in daily life’ in 2.4 and ‘enjoyment of lesson activities in school’ in 2.5 (see Figure 10). However, as seen in the same graph, the control group showed a negative percentage change between the pre-test and post-test (−10.39%; −6%).

Figure 10 Responses to questions 2.4 and 2.5

In the interviews, student S1 in the experimental group mentioned that learning this subject was more interesting and informative with this tool. In the experimental group, student S2 stated that she had been encouraged to learn more actively with nQuire-it due to her increased interest in the surrounding environment. Student S4 mentioned that he became more aware of relevant knowledge and information in the environment around him, such as the sound of the television. This indicated that the students became intrinsically motivated to learn about daily life knowledge in science.

However, in the control group, student S6 said that the lesson activities (watching videos and group discussions) could not be implemented in regular lessons due to a lack of time. From the results of the questionnaire and interview, it can be assumed that the students in the control group placed little faith in the method suggested by the Education Bureau due to time limits, whilst the students in the experimental group discovered the possibilities of a new learning way that involved mobile tools, which could save more class time.

5.2.3 Students interests in daily life knowledge

In Part 1 of the questionnaire, regarding interest in General Studies and knowledge about the world around them, the students showed a change after the lesson, as indicated in Figure 11. In response to statement 1.1, regarding their willingness to learn actively outside the classroom, the experimental group and control group showed a +8.00% and −2.04% change, respectively. In response to 1.2, regarding their willingness to share learning outcomes, the experimental group and the control group showed a +15.03% and −3.40% change, respectively. This suggested that the students’ interest in active learning was greatly enhanced by nQuire-it and its learning activities. Regarding knowledge of the
world around them in 1.3, and the motivation to think about the relationship between their surrounding environment and science in 1.4, the participants in the experimental group showed a –1.96 % and –7.69 % change, respectively, and those in the control group showed a –2.04 % and –5.49 % change, respectively. This suggested that there was no significant difference between the two groups of students in terms of the change in their level of interest in authentic knowledge.

Figure 11 Responses to questionnaires item 1.1 to 1.4

In addition, in the experimental group, 59 items of sound data were collected by Sense-it (see Figure 12), which means that on average, more than 4 pieces of sound data were generated by each student. Besides, 65 “Likes” or “Dislikes” were found in the comments or other data, with an average of 4.64 per student. This showed that the students in the experimental class were moderately motivated to collect data and interact with others via online activities.

Figure 12 Example of data graph recorded by students
Of all of the students who recorded data using Sense-it, 50.6% also posted comments in nQuire-it learning platform. For example, when listening to a series of sounds, the student commented not only on the recording’s time and location, but also on the possible reason (i.e., construction site) for the noise level.

7 Conclusions and implications

To conclude, this paper suggests that authentic inquiry-based learning in science supported by a newly developed technology, nQuire-it, enhances students’ conceptual understanding, inquiry-related skills (including observing and merging knowledge with their own experiences) and attitudes (including their motivation to study the subject). Specifically, the nQuire-it platform and Sense-it mobile tools can be well integrated into authentic inquiry-based learning by improving students’ performance and attitudes towards a formal curriculum, as supported by research on mobile learning (Chung et al., 2018; Firsova et al., 2014). A series of tests showed that compared with those in a control group, students in an experimental group held more positive attitudes towards nQuire-it, science topics and General Studies, and showed a stronger motivation to link learned knowledge with daily life experience. These findings were consistent with those of Katrin et al. (2018) and Kantar and Dogan (2015), who found that an authentic context can lead to increased motivation and interest. Moreover, besides improvement in academic performance, students greatly increased their awareness of surrounding knowledge after experiencing nQuire-it learning activities, echoing the findings reported in Sung et al. (2016) reviewed study that learning with mobile technology is significantly more effective than traditional teaching methods that only use pencil and paper or desktop computers. Meanwhile, other studies have established the effectiveness of using mobile technology to support authentic inquiry-based learning (Looi et al., 2011; Naismith et al., 2004; Sharples et al., 2014).

Although the small size of a sample may affect the quality of the research, this study suggests that there is initial value in using mobile technology to support authentic science learning, with the combination of a learning management platform and mobile sensors. The implications of these findings are as follows. First, technology is being rapidly developed, and as educators and teachers, we need to consider how to integrate new technology with pedagogy (i.e., inquiry-based learning, seamless learning, and flipped classroom). Such an effort could highlight the merits of the new technology and facilitate teaching (Hwang et al., 2015). Therefore, more lesson plans should be developed and tested. Second, more data should be collected during student activities in an authentic learning context. These research findings can provide evidence for using mobile technology to link knowledge obtained in and outside the classroom (Lan and Huang, 2012; Wong et al., 2015).

In conclusion, when integrating nQuire-it or other mobile technology tools into science learning activities, it is important to have well-designed teaching plans along with an effective method of increasing student motivation and engagement (Song and Wen, 2018). Various other conditions, such as time, facilities, technical support, qualified manpower and a positive atmosphere, are also necessary to support this kind of learning environment. To merge this learning approach with a formal curriculum, government and schools should each seek to foster an open learning environment complete with sufficient resources and training.
Acknowledgement

We would like to thank Professor Mike Sharples from Educational Technology in the Institute of Educational Technology at The Open University, UK, who is leading nQuire-it team for kindly supporting the nQuire-it implementation and research in Hong Kong.

References


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### Appendix 1

#### Teaching flow – experimental class (1st Lesson)

<table>
<thead>
<tr>
<th>Teaching procedures (Time)</th>
<th>Learning focus</th>
<th>Materials</th>
<th>Pedagogical method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity 1: Filling in Pre-Test Questionnaire (10 min)</strong></td>
<td>By filling in the Pre-Test, student’s learning interest, understanding towards sound and noise, and its applications in daily life, will be tested.</td>
<td>Pre-Test Questionnaire</td>
<td><strong>Inquiry-based Learning:</strong> Questioning&lt;br&gt;- Raising questions on whether facilities built by government is effective in protecting students from noise <strong>Authentic Learning:</strong> High-Order Thinking&lt;br&gt;- Required students to reflect and criticise facilities built by government <strong>Connectedness to World beyond Classroom</strong>&lt;br&gt;- Investigating topics relate closely to students’ normal life</td>
</tr>
<tr>
<td><strong>Activity 2: Basic Teaching (5 min)</strong>&lt;br&gt;Briefly teaching basic knowledge related to sound and noise.</td>
<td>By using hand-outs and PowerPoint, teach knowledge related to sound and noise.</td>
<td>Noise pollution&lt;br&gt;PowerPoint&lt;br&gt;Noise pollution&lt;br&gt;Handouts</td>
<td></td>
</tr>
<tr>
<td><strong>Activity 3: Briefly Explaining How to Use the Online Platform (15 min)</strong></td>
<td>Briefly explain the method of using online platform, allows students to have activities after classes on the built platform, in order to understand science in daily life, and going through discussion, so as to stimulate their learning interest, thinking, communication and cooperation abilities.</td>
<td>Online Platform&lt;br&gt;nQuire-it&lt;br&gt;Mobile Platform&lt;br&gt;Sense-it</td>
<td><strong>Inquiry-based Learning:</strong> Planning&lt;br&gt;- Allowing students to plan their data collecting work on where and when should the data be collected <strong>Authentic Learning</strong>&lt;br&gt;Connectedness to World beyond Classroom&lt;br&gt;- Investigating topics relate closely to students’ normal life by asking them to collect data and collecting pictures</td>
</tr>
</tbody>
</table>
### Teaching flow – experimental class (1st Lesson) (continued)

<table>
<thead>
<tr>
<th>Teaching procedures (Time)</th>
<th>Learning focus</th>
<th>Materials</th>
<th>Pedagogical method</th>
</tr>
</thead>
<tbody>
<tr>
<td>After class activities:</td>
<td></td>
<td></td>
<td>Knowledge Depth</td>
</tr>
</tbody>
</table>
| Students were required to try working on tasks at home with their own devices on nQuire-it and Sense-it platform: | Allowing students to have trial on usage of the online platform, and return to the teacher in the next lesson. | Online Platform nQuire-it Mobile Platform Sense-it | - Not only to ask students in learning basic knowledge related to noise, but also exploring knowledge closely related to them in the activities out of class  
Social Support for Students Achievement  
- Grouping students in different groups  
- Provide online commenting function and direct Google drive connecting to teachers to provide peer and teacher support to the students  
Flipped Classroom  
- Students were required to finish online activities and comment to each other at home |

Activity (1): Measuring Sound Intensity at Home  
Activity (2): Look for Noise Pollution Sources  
Activity (3): Look for Noise Pollution Reduction Devices

---

### Teaching flow – experimental class (2nd Lesson)

<table>
<thead>
<tr>
<th>Teaching procedures (Time)</th>
<th>Learning focus</th>
<th>Materials</th>
<th>Pedagogical method</th>
</tr>
</thead>
</table>
| Activity 1: Allow students to share and discuss the difficulties of using the platform (10 min) | By answering students’ questions and explaining more kinds of resolving methods, increase students’ motivation in using the platform. | Online Platform nQuire-it Mobile Platform Sense-it | **Authentic Learning:**  
Substantive Conversation  
- Allowing students to talk to teacher on their difficulties to make sure they are working on the activities effectively |

Activity 2: Detail introduce the method of finishing tasks in nQuire-it (20 min)  
By explaining the instructions detail on the three kinds of activities, and providing students with more examples on using the platform, raise students’ interest towards the lesson topic and encourage them to finish the activities.  
Online Platform nQuire-it Mobile Platform Sense-it

Inquiry-based Learning:  
- Allowing students to investigate the answers on the topic with the use of nQuire-it and Sense-it tools in groups  
Authentic Learning  
Connectedness to World beyond Classroom  
- Investigating topics relate closely to students’ normal life by asking them to collect data and collecting pictures
An exploration of inquiry-based authentic learning enabled

Teaching flow – experimental class (2ng Lesson) (continued)

<table>
<thead>
<tr>
<th>Teaching procedures (Time)</th>
<th>Learning focus</th>
<th>Materials</th>
<th>Pedagogical method</th>
</tr>
</thead>
<tbody>
<tr>
<td>After class activities:</td>
<td>Allow students to make record and finish tasks on the platform at home and exchange their ideas on the platform.</td>
<td>Online Platform nQuire-it Mobile Platform Sense-it</td>
<td>Knowledge Depth</td>
</tr>
<tr>
<td>Students were required to finish three tasks at home with their own devices on nQuire-it and Sense-it platform</td>
<td></td>
<td></td>
<td>- Not only to ask students in learning basic knowledge related to noise, but also exploring knowledge closely related to them in the activities out of class</td>
</tr>
<tr>
<td>Activity (1): Measuring</td>
<td></td>
<td></td>
<td>Social Support for Students Achievement</td>
</tr>
<tr>
<td>Sound Intensity of Home</td>
<td></td>
<td></td>
<td>- Grouping students in different groups</td>
</tr>
<tr>
<td>Activity (2): Look for Noise Pollution Sources</td>
<td></td>
<td></td>
<td>- Provide online commenting function and direct Google drive connecting to teacher to provide peer and teacher support to the students</td>
</tr>
<tr>
<td>Activity (3): Look for Noise Pollution Reduction Devices</td>
<td></td>
<td></td>
<td>Flipped Classroom</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Students were required to finish online activities and comment to each other at home</td>
</tr>
</tbody>
</table>

Teaching flow – experimental class (3rd Lesson)

<table>
<thead>
<tr>
<th>Teaching procedures (Time)</th>
<th>Learning focus</th>
<th>Materials</th>
<th>Pedagogical method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 1: To share students’ result on the platform in the class (15 min)</td>
<td>Share students’ recorded data and finished tasks on the online platform, concluding their observation and further explain the knowledge and understanding about sound, noise and government pollution.</td>
<td>Online Platform nQuire-it Mobile Platform Sense-it</td>
<td>Inquiry-based learning: Making conclusion</td>
</tr>
<tr>
<td><em>Activity 2: Conclude Lesson (2 min)</em> To revise lesson content by reading “small conclusion” in the handouts.</td>
<td>By the use of hand-outs and PowerPoint, and revising answers of fill in the banks in “conclusion” part, make a conclusion towards what new knowledge students have learn.</td>
<td>Noise pollution PowerPoint</td>
<td>- Students making conclusion after collecting data, commenting others’ data and sharing their own data</td>
</tr>
<tr>
<td>Activity 3: Filling in post-test Questionnaire (10 min)</td>
<td>By filling in the questionnaires, student’s learning interest, understanding towards sound and noise, and its applications in daily life, will be tested.</td>
<td>Post-test Questionnaire</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 2

I. Questionnaire in Pilot Study

Questionnaire towards usage of application nQuire-it in science investigation

Part 1: Pre-knowledge of mobile sensors

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1) Before this lesson, you know that there are various sensors within smartphones.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2) Before this lesson, you have tried to use function of mobile sensors for scientific inquiry activities.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3) Before this lesson, you have tried to use Sense-it for scientific inquiry activities.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Part 2: Views towards sense-it

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>No opinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1) Sense-it is an interesting software.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2) Sense-it is a useful software.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3) Sense-it was well designed and easy to control.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4) Sense-it is suitable in the learning topic in Primary General Studies.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5) I would recommend Sense-it to my friends to use.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Part 3: Views towards authentic learning

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>No opinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1) nQuire-it can make me more interested in studying General Studies.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2) nQuire-it can make me more interested in knowledge things around me.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.3) nQuire-it can make me more interested in think about relationship between things around me and scientific principles.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.4) I would continuous to use nQuire-it after the lesson.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5) nQuire-it makes me more interested in having scientific inquiry activities.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.6) I am willing to share data I have got in share function of nQuire-it with my fellow classmates.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
II. Pre-test questionnaire for experimental study

Part 1: Personal

<table>
<thead>
<tr>
<th>Question</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>No opinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1) I am interested in learning daily life knowledge related to General Studies.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>1.2) I like to share my study with my classmate.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>1.3) I am interested in learning about things around.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>1.4) I will think about the relationship between things around and General Studies.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Part 2: View towards general studies

<table>
<thead>
<tr>
<th>Question</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>No opinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1) I am interested in learning science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>2.2) I like the subject, General Studies.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>2.3) Learning about knowledge of General Studies is difficult for me.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>2.4) I think I am apply what I have learnt in having General Studies classes in school, in my daily life.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>2.5) I enjoy the activities in General Studies classes in school.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Part 3: Understand towards Noise pollution

1. Give examples of objects which produce sound around you.
2. How does sound spread?
   When air particles _____________, _____________ was produced in air.
   When the _____________ of people around feel the sound wave, they can hear the produced sound.
3. What is the unit of sound? (Circle the answer)
   A) Lumen  B) Decibel  C) Quintal  D) Var  E) Setsuna
4. Where do Hong Kong’s noise pollution come from? (Circle the answers; You may choose more than one answer)
   A) Transport  B) Buildings  C) Residents  D) Construction site  E) Products
5. What impacts can noise pollution bring to us? (Circle the answers; You may choose more than one answer)
   A) Deaf  B) Irritable  C) Dropped Blood Pressure  
   D) Gastric ulcer  E) Positive psychological impacts

6. What do you think the government can do to improve the pollution problems?

7. What can we do to protect ourselves from the environment of noise pollution?

8. III. Post-test questionnaire for experimental study

Questionnaire towards usage of application nQuire-it in science investigation

Part 1: Personal

<table>
<thead>
<tr>
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<td>○</td>
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<td>○</td>
</tr>
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Part 2: View towards general studies

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<td>○</td>
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<tr>
<td>2.5) I enjoy the activities in General Studies classes in school.</td>
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<td>○</td>
<td>○</td>
<td>○</td>
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Part 3: Understand towards Noise pollution

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2. How does sound spread?
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An exploration of inquiry-based authentic learning enabled

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8. What do you think the government can do to improve the pollution problems?

9. What can we do to protect ourselves from the environment of noise pollution?

Part 4: View towards the inquiry-based lesson

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>No opinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1) I think that the process of learning about noise pollution was interesting.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.2) I think that the course was well designed.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.3) I can apply what I have learnt in the lesson to my daily life.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.4) I have learnt knowledge related to noise pollution before having this learning activity.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5) I am interested in learning about knowledge of noise pollution.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

V. Test paper marking scheme for experimental study

Marking Scheme

1. Give examples of objects which produce sound around you. (Total: 3)
   Any, each examples + 1;

2. How does sound spread? (Total: 6)
   a) 振動 (Vibration) + 2; 振動 (Vibration, but wrong word) + 1.5; Max: 2
   b) 聲波 (Sound Wave) + 2; 聲音 (Sound) + 1; Max: 2
   c) 耳膜 (Eardrum) + 2; 耳朵 (Ears) + 2; Max: 2

3. What is the unit of sound? (Circle the answer) (Total: 1) [B] + 1;
4 Where do Hong Kong’s noise pollution come from? (Total: 2.5)
   [A] + 0.5; [B] + 0.5; [C] + 0.5; [D] + 0.5; [E] + 0.5;

5 What impacts can noise pollution bring to us? (Circle the answers; You may choose more than one answer) (Total: 2.5)
   [A] + 0.5; [B] + 0.5; [not fill in C] + 0.5; [D] + 0.5; [not fill in E] + 0.5;

6 What do you think the government can do to improve the pollution problems? (Total: 3)
   Each reasonable answers + 1;
   Answers found in environmental protection department’s information +2 (Acoustic panels, green buildings, laws, urban planning, special materials for roads, restrictions of pollution production, prevention walls…);

7 What can we do to protect ourselves from the environment of noise pollution? (Total: 2)
   Each reasonable answers + 1;

VI. Interview Questions for Experimental Study

1 Do you think that this kind lessoning method help you in understanding different scientific topics?

2 Do you like this kind of lessoning method?

3 Have you ever tried to learn knowledge related to this topic by yourself after classes and out of classroom?

   Are you excited in using mobile technologies to learn in the future?