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Integrating mobile phones into teaching and learning: A case study of teacher training through professional development workshops

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Abstract
This paper presents the development and implementation of a professional development workshop series on integrating mobile phones into science teaching for a group of teachers in Sri Lanka. The series comprised a 3-day Planning Workshop followed by implementation of the planned lessons in real classrooms and a subsequent 1-day Reviewing Workshop. During the Planning Workshop, teachers were provided with a hands-on-session on the use of mobile phones in science teaching followed by collaborative lesson planning activities. The methodological approach taken to evaluating the initiative was qualitative, and data were collected using observations and fieldnotes. The data were analysed using thematic analysis techniques with the support of NVivo8 (QSR International Pty Ltd., Victoria, Australia) qualitative data analysis software. It was found that as professional development for teachers was provided separately as Planning and Reviewing Workshops, these workshops supported the teachers in recognising the educational potential of mobile phones, in learning how to use them in science teaching and learning, in changing their attitudes towards the use of mobile phones in teaching and in sharing knowledge and skills relating to mobile phone applications in science teaching and learning.

Introducing the research

Integration of new technologies into science teaching and learning demands the development of teachers' content knowledge, practices and attitudes. Before discussing these pedagogical requirements, it is important to understand the specific features of science teaching and learning and the underlying didactics required for science education. Osborne and Hennessy (2003) state that there are two interrelated components of science teaching, namely: science explanations and ideas about how science works. The didactics of science teaching should cater to both these areas developing science content knowledge alongside understanding of the processes of science (Wellington & Ireson, 2008). Elaborating these two components further, Wellington (2004) states that the content of science includes facts, laws and theories, and the processes of science consist of observing, measuring, recording, processing data, hypothesising, trying things out, investigating, handling things, watching and monitoring, and communicating and discussion. In order to be able to develop these two components during a science lesson, the teacher should have an extensive knowledge base and should use a variety of different resources. Indeed, Kress, Jewitt,

Practitioner Notes

What is already known about this topic

- Mobile phones provide new opportunities for science teaching.
- Providing professional development, including hands-on experience, is important in introducing new technologies to teachers.

What this paper adds

- The training, provided separately as Planning and Reviewing workshops around an opportunity to implement lessons in real classroom settings, is effective.
- Providing a hands-on-session and relevant activities during the Planning Workshop allowed teachers to explore the educational potential of mobile phones while developing their skills to use them in science teaching.
- The sequence of Planning Workshop, lesson implementation, followed by the Review Workshop, provided opportunities to change participants' attitudes on the use of mobile phones in science lessons.

Implications for practice and/or policy

- Provide teachers with relevant experience, knowledge and skills to use mobile phones in their science teaching.
- Provide a detailed procedure on how to conduct a professional development workshop on the use of mobile phones for teaching.
- Review existing practices and provide training on the ways of integrating mobile phones with existing teaching and learning practices.

Ogborn, and Tsatsarelis (2001) highlighted the multiple ways in which science teachers commonly present information to their students such as photo and video evidence, statistics, diagrams, tables, graphs, demonstrations, models, materials and chemicals, scientific equipment and everyday entities.

Today, the potential of new technology to support teachers in developing both these two components of science education through a range of software and hardware tools, and thus bring different approaches for teaching and learning into schools, is well recognised. From an extensive literature survey of the new digital tools then available, Osborne and Hennessy (2003) identify different groups of tools such as data capture, processing and interpretation tools, graphing tools, modelling environments, simulation tools, publishing and presentation tools, all relevant to science teaching. As discussed in their report, they consider that these tools support both teaching and learning through expediting and enhancing certain manual processes (and thus providing more time for thinking, discussion and interpretation); through linking school science to contemporary science; through providing immediate visual feedback; through fostering self-regulated and collaborative learning; and also through improving motivation and engagement. A later study by Hennessy *et al* (2007) highlights the value of simulation tools used in hands-on mode, which were seen to provide challenge, motivation and engagement for a wide range of student groups. However, it is necessary that, in order to harness these aforementioned potentials of information and communication technology (ICT), the teachers need first to be professionally developed through provision of opportunities to enhance their ICT-related knowledge and practice.

Moreover, adding value to the potential of ICT, recent research findings on the use of mobile phones and personal digital assistants (PDAs) in education show that they can provide new

opportunities for science teaching and learning. For example, Chen, Kao, Yu and Sheu (2004) report a study on using PDAs for natural science learning where Taiwanese primary school students learned to identify different kinds of butterflies. The PDAs were connected to a database of different butterfly species for content-based image retrieval and also included an online nature journal for recording observations. A more recent study in the UK by Hartnell-Young and Heym (2008) reports the value of using the mobile phone camera to ensure the validity of data collection during secondary school science experiments. According to their report, images that were taken during the experiments helped the pupils to accurately record physical observations which enabled them afterwards to validate the results of their experiment. Kukulska-Hulme and Traxler (2005) suggest that this potential of mobile phones to support learning is both due to their range of functions such as Short Messaging Service (SMS), Multimedia Messaging Service (MMS), video, camera, the Internet, voice recording and Bluetooth, and their attributes which include being personal, informal, contextual, portable and ubiquitous.

Even though the potential of ICT and mobile phones are now recognised, one barrier to them being exploited in teaching and learning is the lack of teachers' confidence in the use of technology (Scrimshaw, 2004). This is by no means limited to the situation in England, Balanskat, Blamire and Kefala (2006) reviewed studies carried out relating to the impact of ICT in education in schools across Europe and concluded that "limitations in teachers' ICT knowledge make them feel anxious about using ICT in the classroom and thus not confident to use it in their teaching" (p. 50). On the other hand, teachers who have confidence in using ICT in their classroom can identify the potential of ICT (Cox, Preston & Cox, 1999). Therefore, boosting teachers' confidence in their pedagogical knowledge and actions in using ICT and mobile phones in the classroom is important if we are to realise the potential alluded to above.

In addition, the important role of the teacher's pedagogical knowledge and actions in using technology in a lesson in achieving the desired outcomes is highlighted by Cox *et al* (2004). They describe an example where a teacher reports that creating a presentation of a biology experiment using ICT encouraged students to provide better scientific explanations of the dynamic processes than when they had previously written up experiments by hand. Rogers and Finlayson (2004) discuss the different pedagogical actions required for the implementation, integration and effect of using ICT in subject teaching in their study of the outcomes of a national professional development initiative in teaching with ICT. The pedagogical actions identified from science teachers' evaluations of the programme that was carried out over 1100 secondary schools are: careful preparation by teachers for lessons with ICT, setting up clear teaching objectives, taking decisions about lesson formats and classroom arrangements, and learning to accommodate their teaching styles to make the best use of the facilities available. Moreover, selecting the appropriate ICT resources for the right teaching and learning objective (Wellington, 2000), sequencing and structuring of learning activities, and adapting them to the particular needs of the learner (Hennessy *et al*, 2007) are also identified as further key aspects when using ICT in a science lesson. Thus, it is clear that the enhancement of the effectiveness of science teaching and learning through integrating new technology depends on the teacher's pedagogical decisions and actions. In order to develop teachers' pedagogy effectively, professional development initiatives should include opportunities to improve: their understanding of the potential of different technologies for supporting learning and of the most appropriate pedagogical uses of technology; their confidence with the technology and their competence in using it in science teaching and learning.

Fishmana, Marxa, Besta and Tal (2003) note that professional development, ie, teacher learning includes changes in the knowledge, beliefs and attitudes of teachers that lead to the acquisition of new skills, new concepts and new processes relating to the work of teaching. Particularly, changes in attitude, values and beliefs develop the confidence of teachers for ongoing learning

(Phelps & Graham, 2004). Therefore, when providing professional development, shifting teachers' beliefs, values and attitudes must be one of the focal objectives. Moreover, when designing the activities of a professional development intervention, consideration of the individual teacher's needs, concerns and interests, along with those of his or her school, and providing engaging learning activities that are supportive, instructionally focused and collaborative, are important (Hunzicker, 2011).

Studies relating to the teachers professional development on the use of ICT, including mobile devices in teaching and learning, are rare. McFarlane, Roche and Triggs (2007) report a project in which one of the objectives was to investigate the implications of mobile technologies for practitioners, particularly in terms of continuing professional development. Three primary and two secondary level schools in the UK participated in this project. Prior to introducing mobile devices to the pupils, the primary and secondary school teachers were provided with professional development in different ways. The primary teachers were released from school to attend professional development activities before starting the project. They were also provided with one-to-one hands-on training by a teacher who visited the school. In these training sessions, the teachers had flexibility to attend a whole day or half a day sessions. However, for the secondary schools, a single teacher training event of 6 hours was provided, and the staff received their mobile devices at that time. In addition to this, the secondary teachers who taught science received extra twilight sessions of training where they got together as a group for discussion and development of teaching materials. At post-project interviews after first year of the project, it was found that a majority of the secondary teachers were not happy about the professional development they received. One of the issues (out of three) that were identified as key contributors to problems encountered and a less positive take-up of the project in secondary schools was "rushed initial training for teachers." Some thought they needed more basic training on how to use the devices, and more hands-on experience in smaller groups.

Another study reported by Sutherland, Robertson and John (2009), which focused on a more successful integration of a range of ICT tools with teaching, highlighted that, when providing professional development to teachers and, particularly when the focus is on new technologies, consideration of participants' inexperience or immaturity with the new technology is important. In this study, teachers, teacher educators and researchers worked together to create a professional learning community known as a subject design team (SDT). The focus of the community was to develop and disseminate emerging professional knowledge relating to teaching and learning with ICT. There were three levels of activity. At the meso level, the focus was to create SDTs in which subject teachers, teacher educators, researchers and research students worked together to develop learning initiatives. These were sequences of work and research involving the use of ICT in English language, history, geography, modern foreign language, science, music and mathematics lessons which were designed, implemented and researched in individual teacher's classes. At the micro level, the teacher and a researcher worked together intensively on the design, realisation and evaluation of these subject design initiatives. At the macro level, the core team of university researchers, teacher educators and research students worked together to develop the theoretical and methodological coherence of the project.

Lastly, from Australia, Herrington, Manteiz, Herrington, Olney and Ferry (2008) report another professional development project that involved a large team. This initiative aimed to investigate the potential uses of the smartphone and iPod by university teachers' innovative pedagogies using mobile technologies, to enhance teaching and learning in higher education. Professional development for the teachers was provided through participation in the design and implementation of an action-learning framework (an educational process whereby the participants study their own actions and experiences in order to improve their performance). This project consisted

of four phases. In the introductory phase, teachers carried out a comprehensive review of literature and familiarised themselves with the given iPod or Smartphone. A second phase followed where each teacher used one or more mobile devices to explore their use, and worked within the workshop environment to plan authentic exercises where mobile devices could be used as cognitive tools. In the third phase, the planned learning tasks were implemented, each following a different pedagogical strategy with a different teacher or discipline area. These implementations were evaluated to investigate the nature and effects of the pedagogical strategies they had implemented. In the final phase, knowledge about technology-based pedagogy that had been learned during the first three phases were explored and reflected on.

Aims of this study

Therefore, this study aims to investigate whether a group of teachers can be professionally trained to effectively integrate mobile phones into secondary level science teaching and learning. The particular research question to be addressed is how can teachers be supported in recognising the educational potential of mobile phones in science teaching and in successfully implementing their use in lessons.

In order to provide the rich details needed to document and describe the different stages of the professional development initiative to answer the above question, a case study approach was adopted. As Merriam (1998) describes, case studies are particularly useful for studying a process in an in-depth, holistic way that allows for deep understanding. This study took place in Sri Lanka.

The Sri Lankan context

Since 1994 in Sri Lanka, the Ministry of Education has implemented a number of initiatives to integrate ICT into teaching and learning. Even so, the computer to student ratio is 1:130 (Gunadasa, 2007) and, at present, the available ICT resources in most of the schools are inadequate (Ekanayake and Wishart, 2011a,b). However, the penetration level of mobile phones in Sri Lanka is high and reached 70% by late 2010 (Evans, 2011). Furthermore, mobile phones are cheaper than computers and most students know how to use them. Therefore, it appeared worthwhile to introduce the mobile phone as a teaching and learning tool to the Sri Lankan school system. However, it is important to note that the teachers in Sri Lanka are not generally acquainted with the educational potential of mobile phones, and teachers' personal use of ICT is also limited.

The continual professional development workshops

The findings of this study are based on a continuous professional development workshop series carried out in Sri Lanka. The sample used for these workshops was a group of 18 secondary science teachers comprising 5 male and 13 female teachers. They were selected purposively based on their reported competence in using mobile phone functions and their positive attitude towards the use of mobile phones as shown in their responses to an earlier questionnaire survey (Ekanayake and Wishart, 2011b). This survey on teachers' use of and attitudes towards ICT, including mobile devices, was administered to 200 teachers selected to represent all the different types of schools in one of the provinces in Sri Lanka. Moreover, when selecting the sample, the teachers' availability and travel difficulties to attend the workshops were also taken into consideration.

The knowledge of educational potential of mobile phones and the skills of using them varied from one workshop participant to another. This was evident from their responses to the survey questions, which were aimed to assess their competence in using mobile phone functions.

The professional development workshop included a 3-day Planning Workshop prior to introducing mobile phones into teaching, and a subsequent 1-day Reviewing Workshop as described below.

Planning Workshop

Day 1

Initially, there was a brainstorming session in order to gather participants' existing views on the use of mobile phones in teaching and learning. Then, there was a whole group discussion stimulated by a PowerPoint presentation on "mobile phones for school teaching and learning." During that, the researcher introduced the attributes and functions of mobile phones and ways of using them in teaching and learning while referring to some of the recent findings in research literature. Next, was the hands-on session, which provided practical experience for the participants on how to use mobile phones in science teaching and learning (Figure 1).

Then the main activities of the workshop were started, with participants working in four groups. Each group chose a lesson from the grades 6–11 national science curriculum into which mobile phones could be integrated and made initial plans as to how this might take place. The objectives of the selected lessons and the teachers' rationales for selecting them are given in Table 1 below.

Day 2

First, there was a whole group discussion following a PowerPoint presentation on Shulman's pedagogical actions and reasoning model (Shulman, 1987), which describes the activities that the teacher engages in when creating instructions for teaching and learning. During this, the aspects that needed to be considered when designing science lessons while integrating mobile phones were emphasised. This included considering students' knowledge and skills about mobile phone use, teachers' competence in using them and selecting the technology appropriately for the relevant activities. Then each group drafted their lesson plan (Figure 2) while referring to the stages of Shulman's model. During this, the participants considered further how they could integrate a range of mobile phone functions into their lesson. Finally, the tentatively designed lesson plans were presented to other groups by one of the group members. The feedback from peers was used to refine the lesson plans.

Between Day 2 and Day 3

Each group developed a concrete set of instructions that they used in their lesson implementation.

Figure 1: Hands-on-session

Table 1: Lessons selected for integrating mobile phones

	Objective	*How it is usually taught*	*Reason for using mobile phones*
Household chemicals	Identifying the chemicals that students used in their home.	A whole class brainstorming session	Connecting students' prior knowledge to the classroom with the help of photographs could enhance the effectiveness of this lesson.
The simple voltaic cell	Learning about the chemical reactions associated with a simple voltaic cell	A lab session with the class working in small groups	To record the deflection of the galvanometer as it is a transient event which is easily missed by some students in the group
Mutual relationships between organisms and the environment	To understand the mutual relationships between the organisms and the environment	Class explored the school garden recording findings with notes on paper	To bring images from the garden to classroom to help situate students' learning
The diversity of leaves	To understand the diversity of leaves in terms of their colours and shapes	By students picking leaves from the school garden, occasionally they would damage plants.	Bringing photos will create better attitudes among students towards the environment

Figure 2: As groups teachers designed their lessons

Day 3

One week after Day 2, the designed lessons were role-played by a member of a group while the others acted as students (Figure 3). There was a whole group discussion at the end of the role-play of each lesson where the pedagogical practices and the ways of using technologies to support

Figure 3: Role playing a lesson

these practices were critically evaluated. The lesson plans were fine-tuned upon the feedback received for each lesson.

Lesson implementation

One member of each of the four groups implemented their developed lesson in their schools as discussed below. The number of lessons was restricted due to the limited availability of the mobile phones which were loaned for a period of 1 month from one of the mobile phone operators in Sri Lanka.

Lesson 1: Household chemicals

This was a lesson of 80 minutes duration for grade 11 students. The lesson consisted of two components: a mobile phone-based activity and a group activity.

In the mobile phone-based activity, the images of household chemicals were captured by students from home using their mobile phones, brought them to the classroom and shared them via Bluetooth to the teacher's computer. Then the teacher embedded them in a Photostory, and a whole class discussion ensued where the teacher called on students to classify the chemicals as detergent, food additives, cosmetics and medicines. Then teacher sent the created Photostory to students' mobile phones. Finally, teacher set four questions, which were "name three food additives used at home," "name three cosmetics," "name three medicines found in home" and "name three detergents" as a homework.

In the group activity, students created a poster showing the different groups of household chemicals by taking pictures from newspaper advertisements and other magazines.

Lesson 2: Functions and reactions of the simple voltaic cell

This lesson was 80 minutes for grade 10 students. During the lesson, the teacher divided the students into five groups, each provided with two mobile phones, a natural fruit, connecting wires, a galvanometer and small metal plates. Then the teacher sent a video clip (visual instructions) to the students' mobile phones, asking them to follow these to construct and record the output of a simple voltaic cell. Next, students developed simple voltaic cells, with each group

using different metals and chemicals and videotaped their observations, sharing them with other groups via Bluetooth. Then in their groups, students presented their observations with the support of a poster as instructed by the teacher. After that, the teacher asked students about their observations and used their answers to develop their understanding of the science behind the observations. Finally, to assess the students' learning, the teacher sent four multiple choice questions to the students' mobile phones as SMS. During the planning stage of this lesson, teachers discussed alternative ways of delivering questions and decided to use SMS. Their argument for using SMS was that as it is novel, students will take more interest when attempting these questions. Upon receiving the students' answers, she sent feedback to each group again via SMS.

Lesson 3: Investigating the mutual relationships between organisms and the environment
This is for a lesson of 80 minutes duration for grade 11 students. The teacher introduced the levels of organisation in the ecosystem using a Photostory which contained images familiar to students from the school garden captured earlier using the teacher's mobile phone. Then the students in groups examined four locations in the school garden and completed a worksheet on the levels of organisation in the ecosystems in the assigned location. They were also asked to identify the relationships among the living and non-living entities within these ecosystems and to capture images that supported their findings. On returning to the classroom, each group sent their images to the teacher's computer via Bluetooth, presented their findings based on the worksheet and their images that were displayed to the class on the data projector. The teacher assessed the students as a group based on their completed worksheets, captured images and presentations.

Lesson 4: The diversity of leaves
This lesson was conducted for Grade 6 students and the duration of the lesson was 80 minutes. During the lesson, the teacher first introduced the concept of diversity using a PowerPoint presentation that contained images captured from the school garden using her mobile phone. Then the students in groups went to the school garden and collected the images of the leaves (different leaf colours, shapes, edges, and pinnate or non-pinnate) using mobile phones. On returning to the classroom, based on the images they had in their mobile phones, each group constructed a dichotomous key to leaf identification and presented it to the class. After each presentation, the teacher pointed out the important facts to note.

Reviewing Workshop
During the Review Workshop, the teachers presented their experiences, reflections and thoughts about the use of mobile phones in science teaching and learning. In order to stimulate discussion, two different sets of questions were provided by dividing the participants into two groups. The groups were:

1. the four teachers who conducted the lessons, and
2. other teachers involved in lesson planning activities.

The following questions were given to the former group and they were asked to present their views.

1. How did you use the mobile phone in the following processes: (a) planning, (b) implementation, (c) evaluation and reflection?
2. How did students use the mobile phones during lesson implementation?
3. What are the problems that you came across during the lesson implementation?

While they were preparing their reflections for presentation, the latter group was given the following question and asked to write their views individually.

In general, what do you think about the use of mobile phones in the process of teaching science?

All the teachers were asked to write their views. Then each individual lesson conductor presented his or her reflections on the lesson in detail. After each presentation, a whole group discussion was

conducted, providing opportunities for all participants to discuss their reflections and thoughts on the use of mobile phones in science teaching and learning.

Method

The methodological approach of this study was qualitative. The main vehicle used for data collection was the professional development workshop series described in the previous section. During the planning and reviewing workshops and lesson implementations, data were collected using observation via video, audio recording and fieldnotes. Then data were analysed using thematic analysis with the support of NVivo8 (QSR International Pty Ltd., Victoria, Australia) qualitative data analysis software.

First, all the paper-based materials were translated computerised and uploaded into the NVivo8 software. After that, all the video and audio files were also uploaded to NVivo8 software without transcribing or translating them as the NVivo8 provides new level of flexibility to transcribe audio and video data while playing them. As the first step of thematic network analysis, an initial set of coding that is related to the aims of this study was derived. This follows Miles and Huberman (1994)'s point, stating that by creating a prelist the analyst is able to tie research questions directly to the data. Then the initial list of codes was refined by adding more new codes that emerged from the data, modifying some initial codes and removing other redundant initial codes. Afterwards, the following materials were dissected into meaningful segments and assigned to the relevant code (node in NVivo8):

- uploaded paper-based data materials
- transcribed and translated audio and video data (of all episodes that were relevant to any of the selected codes)

After coding, all the dissected segments were organised into different basic nodes. Then the basic nodes were reviewed and they could be represented as three global themes (Themes 1, 2 and 3). There were 367 data segments (from teacher comments and relevant fieldnotes) in total in the data obtained during all three workshops and subsequent lesson implementations. Of these comments, 186 pertained to Theme 1 "workshops enabled teachers to recognise the potential of mobile phones for science teaching and learning," 57 pertained to Theme 2 "workshops helped teachers to share knowledge and skills relating to mobile phones for science teaching and learning" and 124 pertained to Theme 3 "workshop created an attitudinal change in participating teachers toward using mobile phones for science teaching and learning." Within each of these global themes, sub-themes could be identified and are described in the next sections.

As the approach of this study is qualitative, the trustworthiness of the research was of concern throughout the study. For example, while coding the data by asking another colleague researcher to code a sample of data using the same coding framework and match it with the original coding framework and also check the representation of the data segments within some nodes, the researchers achieved credibility. By triangulating audio and video data with the fieldnotes, reliability of data interpretation was achieved. Furthermore, by providing a detailed explanation of the processes of data collection throughout the workshops and analysis, confirmability is assured.

Findings and discussion

Tables 2, 3 and 4 show the results of the qualitative analysis of themes within the data organised by the three global themes.

Theme 1: Professional development workshops enabled teachers to recognise the potential of mobile phones for science teaching and learning

As shown in Table 2, the data from the professional development workshops revealed that teachers reported that the workshops had supported them in recognising the potential of mobile

Table 2: The frequency of coded segments that supported Theme 1

Individual theme 1 (node)	*Frequency 186*	*Percentage 50.68*
Experience gained in the hands-on session helped them to understand the potential of integrating mobile phones in lesson planning and implementation	64	17.44
Whole group discussions and PowerPoint presentations helped them to understand the potential	27	7.36
Receiving feedback/suggestions from other groups	18	4.90
Students' attention towards the lesson and engaging them actively in learning	15	4.09
Preparation for the skills required to use mobile phones	12	3.27
Engaging in the set tasks collaboratively and actively	11	3.00
Discussing the potential of mobile phones for science teaching during the Review Workshop	11	3.00
The mobile phones enable to learn science as a collaborative learning activity	10	2.72
Develop the students' observation skills	8	2.18
Video function for assessing both students' learning and behaviour	7	1.91
SMS and image capture for assessing student learning	3	0.82

Table 3: The frequency of coded segments that supported Theme 2

Individual theme 2 (node)	*Frequency 57*	*Percentage 15.53*
Sharing supported developing skills	19	5.18
Share the problems that they had come across	19	5.18
Review Workshop allowed participants to share their experience	8	2.18
Collaboration created an environment for teachers to share knowledge, skills and attitudes	4	1.09
Invented pedagogies were shared with other teachers	4	1.09
Teachers' active engagement in discussions, presentations, role playing, providing feedback, and developing teaching and learning aids	3	0.82

Table 4: The frequency of coded segments that supported Theme 3

Individual theme 3 (node)	*Frequency 124*	*Percentage 33.78*
Teachers' positive attitudes regarding the students' use of the mobile phones	39	10.63
Implemented lessons successfully using small group approach inside the classroom and/or outside the classroom	24	6.54
Exploratory activities that the participants engaged in during the hands-on and lesson planning sessions	17	4.63
Possible use of mobile phone as a teaching and learning tool	15	4.09
Mobile phones supported engaging students in learning	10	2.72
Data from the brainstorming session show teachers' attitudes	7	1.91
Review Workshop showed a clear change in the teachers' understanding of the educational potential of mobile phones	4	1.09
Hesitation to give mobile phones to students' hands during the learning activities	3	0.82
Workshop opens a space to clarify the doubts on the use of mobile phones	3	0.82
Image, video and sound recording in the creation of teaching and learning aids	2	0.54

phones in a variety of ways. The most frequently observed finding was that engaging in hands-on activities trialling a range of different functions with potential use in lesson planning and implementation helped teachers to recognise the mobile phones' potential (17% of comments). This was not unexpected, McFarlane *et al.*'s (2007) study had shown that a lack of basic hands-on

training on how to use mobile devices in teaching and learning led teachers to report dissatisfaction with the professional development they were provided. Moreover, they went on to show a lack of participation in using mobile devices in lessons.

In addition, it was noticed that the activities of the hands-on session aimed at the teachers who had never used mobile phone in teaching and learning, in line with the professional development provided in Sutherland *et al* (2009), were particularly useful. The hands-on session provided opportunities for participants to identify the educational potential of mobile phones and also to develop the skills of using them in science lessons.

The data given in Table 2 also show that providing opportunities for participants to be involved with whole group discussions accompanied by PowerPoint presentations, which included the findings of international research on the use of mobile phones in teaching and learning, supported teachers in recognising the potential of mobile phones in teaching (7% of data segments). As does actively engaging in the collaborative development of lesson plans through both presentation and role play during which they received feedback/suggestions from other groups on their understanding of the potential use of mobile phone functions in their lessons (supported by 5% of comments). Such collaboration is listed as one of the characteristics in Hunzicker's (2011) checklist for effective professional development of school leaders.

Discussing the potential of mobile phones for science teaching during the Review Workshop following the lesson implementation when the four teachers who conducted the lessons in real classroom settings presented their experiences enables teachers to recognise the potential of mobile phones. This was supported by 3% of the data segments (from teacher comments and relevant fieldnotes). The potential teachers described include: bridging classroom learning with the home environment and the outside world, providing instructions through step-by-step video, and evaluating student learning in novel ways.

Data also revealed that asking further questions on lesson conductors' experiences, their students' learning benefits from using mobile phones and problems they encountered enhanced teachers' further understanding of the potential of the mobile phones in science teaching and learning.

In addition to providing opportunities to develop participants' knowledge on the potential of mobile phones, the professional development workshops supported them in determining a range of pedagogical actions, such as:

1. Preparation for the skills required to use mobile phones in science lessons (supported by 3% of data segments). Providing evidence at the Review Workshop, a participant reported that:

   "As a consequence of our understanding during the hands-on-session, on how to use and where to use mobile phones, we could design and implement our lessons while integrating mobile phones and achieve the expected outcomes." (Reviewing Workshop\Teacher 2)

2. Matching the phone function to the appropriate pedagogical actions (Wellington, 2000) required when including mobile phone-based lesson. For instance, during the planning stage of the lesson on "the simple voltaic cell," group members argued about whether to select video camera facility or the image capture facility for the student activity, comparing and contrasting the advantages and disadvantages of each approach.
3. Recognising the potential of SMS and image capture for assessing student learning and video function for assessing both students' learning and behavior (supported by about 2% and 1% teacher comments and relevant fieldnotes respectively). One of the teacher's comments below provides evidence for this.

   "While the students were engaged in the scientific experiment, I could assess students by viewing their video recorded observations and facilitate them accordingly." (Reviewing Workshop/Teacher 6)

4. Obtaining students' attention towards the lesson and engaging them actively in learning (supported by 4% of data segments). One teacher expressed his views as follows:

> "I have been teaching this lesson for last five years. I have used the overhead projector and the data projector to show photographs captured (or downloaded) from different locations based on my points of view. Sometimes these images were not familiar to the students and therefore they were not fully engaged in the lesson. However, in this lesson students brought the images of mutual relationships that they had observed, understood and experienced in the school environment as saved images in their mobile phones. Therefore it was easy to construct the lesson inside the classroom with active student participation." (Reviewing Workshop\Teacher 13)

The teacher who conducted the lesson on the "voltaic cell" said:

"Throughout the lesson, interactions among the students were high because they had collaboratively constructed the simple voltaic cells twice; I mean constructed a cell using fruits and then using laboratory equipment. During this time, they shared their skills and knowledge. Further, I observed that they had plenty of discussions about the best way of presenting their findings when they were creating their posters. They argued, discussed, and sometimes replayed their video clip according to one member's suggestion and came to an agreement." (Day 4-Reviewing Workshop/Video\Day 4)

Furthermore, the opportunities provided by the mobile phones to learn science as a collaborative learning activity was also evidenced from the findings. For instance, the teacher who conducted the lesson on "environmental relationships" explained how students collaboratively engaged in the activity:

"While I was observing the lesson, I saw how students were engaged in the activity collaboratively; how they supported each others' tasks while doing their own role; how they completed their worksheet by integrating each other's ideas; and how creatively they presented a quality summary of their findings. This was amazing. I found that we could achieve the expected goals better than expected [smiling]." (Reviewing Workshop\Video\Day 4\ Teacher 14)

Thus, from the above findings it is clear that having both the Planning Workshop and the Review Workshop following lesson implementation provided opportunities to develop teachers' understanding of the potential of mobile phones in science teaching and learning in addition to providing opportunities for them to identify their pedagogical needs when integrating this technology.

Theme 2: The professional development workshops helped teachers to share knowledge and skills relating to mobile phones for science teaching and learning

The data from the brainstorming session at the beginning of the professional development workshops revealed that only three participants had used image or video to capture relevant objects in their day-to-day lives to show them to the students during the lessons. The rest of the participants had used mobile phones only for communication and playing games. Thus, as the group had teachers with diverse experience, the professional development workshops were a favourable environment for the participants to share knowledge and skills among each other and with the researcher (as shown in Table 3, about 5% of comments). One of the participants described how sharing supported her in developing skills:

"During the hands-on-session while doing the activities, my colleague helped me to develop my skills on uploading images from mobile phones to computers and using them in Photostories and moviemaker, which I have never used in my life." (Reviewing Workshop/Teacher 8)

Furthermore, as the lesson planning activities were carried out collaboratively in four groups, it created an environment for teachers to share knowledge, skills and attitudes (1% of comments). Sharing was observed through the teachers' active engagement in discussions, presentations, role playing, providing feedback, and developing teaching and learning aids. Moreover, during the lesson planning activities, participants' own mobile phone use enhanced opportunities to share knowledge and skills among themselves. For example, about 5% of the comments from the

participants reported that by using both SMS and voice calls they solved problems that they came across while developing teaching aids during the period of the Planning Workshop between days 2 and 3. In contrast, in the other workshops on the use of mobile devices for teaching found in the literature (Herrington, Herrington, Manteiz, Olney & Ferry, 2009; McFarlane *et al*, 2007) there was no evidence reported of participants using the mobile devices for sharing the information.

The Review Workshop also allowed participants to share their experience on how the mobile phone supported teaching and learning of their planned science lessons by providing opportunities to present the lesson conductors' real classroom experiences. About 2% of the data segments supported this. A similar finding has been reported in Herrington *et al.*'s (2009) study. However, in that study, teachers explored pedagogies on appropriate use of a mobile device for different target groups individually. Then the invented pedagogies were shared with other teachers.

The series of workshops not only provided opportunities to share knowledge among participants but also with the teaching community by publishing the lessons, outcomes and recommendations on the Sri Lankan "schoolnet" website (http://www.schoolnet.lk/index.php?lang=en&for=default&page_id=40), which is widely accessed by teachers and students countrywide.

In addition to sharing the potential of mobile phones, the professional development workshops provided a good opportunity for teachers to share the problems that they had come across during the planning and lesson implementation stages. For example, inadequate memory was found to be an issue during the lesson on the "simple voltaic cell." The teacher had to delete some video clips that were not relevant to the lesson. During the Review Workshop, the teacher who conducted the lesson on the "simple voltaic cell" stated that this problem arose due to her inexperience and she said that the availability of memory should have been checked before the lesson or even before giving mobile phones to the students. Other issues such as loss of charge were quickly dealt with by replacing batteries. As the battery ran out during the lesson on the "simple voltaic cell" and that on "environmental relationships," it affected the continuity of students' engagement, as in each case one group had to go to the teacher and wait until the teacher changed the battery.

Theme 3: The professional development workshop created an attitudinal change in participating teachers towards using mobile phones for science teaching and learning

The data from the brainstorming session of the Planning Workshop included two main views that participants had related to the use of mobile phones in teaching and learning. One is that they had not used mobile phones in teaching and they speculated on the educational potential of mobile phones. For instance, one participant said:

"I think the mobile phone will support in providing fascinating learning opportunities for the students as it has a still camera, video camera and the internet. Further as this is a novel experience it may be easy to get the students' attention." (Planning Workshop\Teacher 3)

The other one is their hesitation to put mobile phones into students' hands during the learning activities, as they were having doubts about the student's possible misuse of mobile phones. One of the participant's views provides evidence for this.

"I think mobile phone is a good teaching tool. Mm . . . but I do not think it is a learning tool because it may cause disciplinary problems in schools." (Planning Workshop/Teacher 5)

However, the findings from the Review Workshop showed a clear change in the teachers' understanding of the educational potential of mobile phones for science teaching and also their positive attitudes regarding the students' use of the mobile phones (as shown in Table 4 and 10.6% of data segments supported this). They particularly noted the support of mobile Internet to find information, of voice call, SMS and MMS to share materials and facilitate discussions when planning and of image, video and sound recording in the creation of teaching and learning aids. One of the teachers described how mobile phones supported their group in preparing a teaching aid as follows:

"None of our group members or our schools has a digital camera. But three of us have mobile phones with the video function. Therefore, we decided to create the video clip in my house. Only two members could come and two could not make it due to unavoidable reasons. We carried out the experiment with a number of fruits and video recorded the observations. Then we selected the best video clip that was rich enough to provide instructions. After that, we MMS it to other members of our group and received their feedback. During the lesson implementation we understood that how effective this was." (Reviewing Workshop\Teacher 13)

Furthermore, 4.6% data segments (from teacher comments and relevant fieldnotes) showed how the exploratory activities that the participants engaged in during the hands-on and lesson planning sessions followed by opportunities to critically evaluate their appropriate use through discussion created a favourable environment for attitude change. Importantly, the Review Workshop data provided evidence of the teachers' positive attitudes regarding the students' use of the mobile phones in learning activities.

"While I was observing the lesson, I saw how students were engaged in the activity collaboratively; how they supported each others' tasks while doing their own role; how they completed their worksheet by integrating each others ideas while reviewing what they captured from the school garden and saved in the mobile phone; and how they shared their findings via Bluetooth with others while presenting a summary of their findings. This was amazing." (Reviewing Workshop\Teacher 14)

As supported by about 6.5% data segments, the teachers reported that they implemented four lessons successfully using small group approach inside the classroom and/or outside the classroom due to the appropriate integration of mobile phones. The following view provides evidence for this.

"The use of mobile phones enhanced this leaning activity by providing the opportunities such as capturing relevant videos, sharing it with other groups, constructing the poster by viewing video clips, and also solving technical issues before going to the teacher." (Reviewing Workshop\Teacher 6)

Besides, teachers appreciated (supported by 4% of the data segments) the possible use of mobile phone as a teaching and learning tool as it can be easily integrated with the other ICT hardware/software available in schools. They made particular use of Bluetooth to share images and files. The teachers also highlighted the potential use of mobile phones to assess students' learning and behaviour during and after the lesson, which Fishmana *et al* (2003) noted as an important input for professional development. The possibility of sending questions to students and receiving their responses via SMS; revisiting students' saved images and videos and providing feedback; and recording students' engagement during experiments were all highlighted. The teachers particularly appreciated the flexibility of assessing students' work irrespective of time and location using the information saved in their mobile phones.

Moreover, it was noted that the Review Workshop opened a space to clarify some teachers' doubts about the use of mobile phones in science teaching and learning through asking further questions based on the lesson conductors' experience. This was reflected from one student's views as follow:

"Today our science lesson was different. We used the mobile phone camera to capture images of the mutual relationships between organisms and the environment, and brought the images from the school garden into the classroom. This was a different experience. We could see the relationships in the real world. We studied them; we discussed them and captured the relevant images. After that we completed the worksheet and discussed and shared our ideas while referring to the pictures. Finally we presented our findings for the other groups." (Implementing Lesson\Lesson 3/ Student View/Audio Files)

In summary, it was clear that the sequence of Planning Workshop, lesson implementation followed by the Review Workshop provided opportunities to change participants' attitudes on the use of mobile phones in science lessons. One of the participants' views during the Review Workshop provided evidence for this change.

"Before attending the workshops, I had a suspicious feeling about the use of the mobile phone in science teaching and learning. However, when we were planning our lessons, implementing the lessons and discussing each others experience, I realised that the mobile phone is a useful tool which has much potential and can make the teaching process successful and interesting" (Reviewing Workshop/Teacher 4)

Thus, as Fishmana *et al* (2003) recognised, this change of teachers' attitude may lead to the acquisition of knowledge, new skills and new processes related to the integration of mobile phones in science teaching and learning.

Obviously there are concerns about the sustainability of such a heavily supported initiative. A short follow-up study was conducted 11 months after the evaluation workshop by contacting the participants to investigate how they have been integrating mobile phones into their usual science teaching and learning activities. Out of 18 participants, 16 responded. According to them, they had continued to integrate voice call, SMS, MMS, the Internet, image capture, and video functions into their science teaching and learning activities. Image capture was most popular, with half using it for their teaching activities. A threefold increase in mobile phone use from the beginning of the professional development workshops to teaching activities after the workshops clearly showed that there is a change of teachers' attitudes towards the use of mobile phones in science teaching and learning.

Conclusion

This case study has shown how structuring professional development workshops separately as a Planning Workshop and a Reviewing Workshop around an opportunity to implement lessons in real classroom settings provided many opportunities to develop teachers' knowledge, skills and attitudes towards the use of mobile phones in science teaching and learning. These opportunities included both developing their students' understanding of the concepts of science and their engagement with science processes and skills such as observation and recording.

Providing a hands-on-session at the beginning of the Planning Workshop allowed teachers to explore the potential of mobile phones for science teaching. Moreover, including activities that lead to whole group discussions and allowing teachers to engage in activities in small groups both in Planning and Reviewing workshops enhanced the teachers' professional development opportunities. These created a favourable environment in which to share knowledge and skills with each other as well as with the researcher.

However, while these workshops provided a successful one-off training initiative that supported the teachers to integrate mobile phones into their lessons, further studies should be carried out to investigate the sustainability of this type of professional development in Sri Lankan schools.

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