Exploring the Internet of "Educational Things"(IoET) in rural underprivileged areas

Putjorn Pruet
School of Engineering and Digital Arts
University of Kent
Canterbury, United Kingdom
pp303@kent.ac.uk

Deravi Farzin
School of Engineering and Digital Arts
University of Kent
Canterbury, United Kingdom
F.Deravi@kent.ac.uk

Chee Siang Ang
School of Engineering and Digital Arts
University of Kent
Canterbury, United Kingdom
C.S.Ang@kent.ac.uk

Narong Chaiwut
School of Information Technology
Mae Fah Luang University
Chiang Rai, Thailand
narong.cha@mfu.ac.th

***Abstract*—In this paper, the design and development of an Internet of Things (IoT) educational mobile learning tool for primary school students in rural underprivileged areas of northern Thailand will be presented. This is aimed at providing effective learning activities and utilising the large number of under-used tablet computers which are still available in schools from the government's discontinued ''One Tablet PC per Child'' (OTPC) policy. During previous studies, we found tablet computers had the potential to enhance students' engagement and learning performance. However, most rural schools were lacking internet connectivity. Our aim is to design and develop an effective solution for students in rural underprivileged areas of Northern Thailand which will provide them with a mobile learning platform and an application which works with the existing schools' tablet computers. In this paper, we will outline the literature review in the area of mobile learning and Internet of Things (IoT) technology in education, discuss our preliminary study of the use of tablet computers by primary students in under developed areas and demonstrate the design and development of a mobile learning platform which addresses the provision of a reliable, low-cost, sensing WiFi device and child-friendly mobile application.**

Keywords— ICT4D, Internet of Things, ubiquitous computing, mobile learning, tablet computer, local wireless networks, computer education

I. INTRODUCTION

Thailand is a developing country which has been facing the need to improve its quality of educational provision following a lack of funding for schools, insufficient teaching resources and under-staffing across the country [1, 2]. According to the Programme for International Student Assessment (PISA) which ranked the education of 65 countries, Thailand was ranked below average; 48th in reading and science and 50th in mathematics [3]. With the aim to bridge the gap of the digital divide and addressing the uneven standards of education quality, the ministry of education provided tablet computers with installed learning contents to first grade primary students nationwide in 2012. The government-supported pilot study reported improvement of students in the areas of listening, speaking and reading [3]. On the other hand, the research study of [4] showed that students were passively learning using the tablet computer by reading, listening or watching learning contents from applications or websites. Particularly, students in rural schools struggled to access learning contents over the internet because schools' infrastructures were outdated and had unreliable internet connection. Recently, the OTPC project was ended in order to help to secure the national budget. Therefore, it is foreseeable that a large number of tablets will be discarded in school cabinets and not used by teachers or students. Taking account of the current situation, this work explores the design and development of a new educational resource based on the idea of the Internet of "education of things" (IoET) to make use of the schools' existing tablet computers. The aims of the study are:

- Understanding the current learning styles, attitudes of students and classroom interaction when using tablet computers in underdeveloped areas in Thailand.
- Designing and developing a mobile learning platform with the extension of the Internet of Things (IoT) for primary school students in rural, underprivileged areas.

II. RELATED WORKS

A. Mobile learning in underdeveloped areas

In 2014 mobile broadband subscriptions grew rapidly, almost five times faster than six years earlier (estimated to reach 2.3 billion worldwide) and the growth rates of developing countries are projected to be twice as high as in developed countries [5]. Rural areas of the developing world have increasing opportunities to use mobile devices and technologies. There are several reasons that a mobile device can empower the communication and interaction between teachers and learners in underdeveloped areas; for example, high rates of penetration, ownership, portability and information deliverability [6]. Several researchers have

978-1-4799-7961-5/15/$31.00 ©2015 IEEE

explored the effectiveness of mobile devices as development tools to promote quality and equality of education in underdeveloped regions. Reference [7] stated that low-cost, mobile learning technology has the potential to facilitate personalised and exploratory learning through a child-centred model in an underdevelopment context. Consequently, researchers identified the successful use of mobile devices to improve educational outcomes in five developing countries in Asia including the Philippines, Mongolia, Thailand, India and Bangladesh. In particular, they found that mobile devices highly supported and increased accessibility, flexibility and that they reduced barriers to learning [6].

B. Tablet computer use in educational settings

As a result of the strong growth of the tablet computer, the global, smart-connected, device market is driven rapidly by the core competence of mobility. According to IDC research, tablet computers dominate the desktop PC market with 180.9 million shipments compared to 134.4 million shipments of desktop PCs [8]. Gartner also predicted that in 2015 tablet computers will have 349.1 million units of worldwide sales rather than 263 million units of desktop computers [9]. This trend persuades educators, researchers and policy makers around the world to adopt tablet computers into their areas of interest. Notably, the use of tablet computers in education is significantly rising in many countries around the world by endorsing the huge investment to improve the use of educational technology in schools. For example, more than 3,300 schools across America were provided with tablet computers for conducting teaching and learning activity in the classroom in 2012 [10]. Eight counties in Europe including Estonia, France, Germany, Italy, Portugal, Spain, Turkey and the United Kingdom joined the study on the use of tablet computers to enhance teaching and learning practices [11]. The Ministry of Education in Turkey distributed 8,500 tablet computers to all K-12 schools across the country in 2011 [12]. In Asia, Singapore responded in 2013 to the expansion of the use of tablet computers in education by providing a tablet computer to every child in schools across the country [13]. Following this trend, the Ministry of Education in Thailand distributed 800,000 tablet computers to grade one students nationwide [14]. Several research studies confirmed that tablet computers play an important role in education and found various benefits accrued from the use of tablet computers in educational settings including (a) portability: more convenient to use in the classroom, (b) lower cost compared to a desktop computer, (c) advancement of touch screen interaction, (d) children in preschool are able to learn to use the device quickly, independently and confidently, showing freedom of exploration, (e) offering more user-friendly, easy to access and integrated learning than desktop computers [4, 13].

C. The Internet of Things technology (IoT) in education

Internet of Things has been identified as an emerging technology and will play an important role in many areas such as business, healthcare, transportation and education [15]. An internet connectivity is growing very fast and is commonly used in our daily lives; nowadays 5 billion "smart" connected objects are deployed and this will expand to 50 billion connected devices by 2020 [16]. The paradigm of IoT can be described as "many of the objects that surround us will be on the network in one form or another" [15]. In other words, objects (things) in the environment such as televisions, lamps, cars, mobile phones or even plants are connected by smart sensors, communicating and interacting through wireless networks or the internet anywhere, anytime. The integration of mobile devices and sensors in smart objects brings the concept of an Internet of Things which will also provide a new era in educational settings. The prediction of reference [17] revealed that smart objects will be used in higher education by 2017 and soon become widely used in K-12. IoT will place big challenges for educators and technology developers of the future to find new ways to make sure that the new learning strategies based on their use are appropriate for students in the 21st century.

D. IoT and tablet computer use in science education

Scientific literacy helps people to have more understanding about scientific and technology issues and provides the essential knowledge, skills and attitudes for future careers [18]. In order to prepare children for the key elements of a 21st century science curriculum, scientific literacy in education needs to be emphasised. As mobile learning emerges, various studies have developed mobile learning environments and activities that relate to science subjects: for example, a recent research in the UK [19] defined how the Internet of Things can enhance learning in science and other subjects such as technology and geography. The project required students and teachers to measure, share data and gain more understanding about their environment in an enjoyable way but also related directly to the curriculum with the ultimate goal to design the next generation of schools. Following deployment the project was found to provide "a new learning experience, which allows students and teachers to dive directly into the data being generated, stimulates open discussion and discovery and shifts time away from setup to higher-level learning activities in the classroom." However, researchers found students have less engagement and motivation when they are collecting data from fixed position weather sensors [19]. Reference [20] carried out research which created a mobile science inquiry system with primary school students in Hong Kong. Researchers confirmed that mobile technologies highly support students' science exploration and develop students' critical thinking skills. In the study, students are allowed to use a tablet computer and commercial science inquiry applications on the shelf. Results of the study showed the success of integrating the mobile learning and inquiry-based learning environment. However, it might be impossible to use commercial and complex applications especially with young students in underdeveloped areas/ countries due to the need for low cost technologies and ease of use software that meet the local context, which is crucial.

III. METHODOLOGY

We aim to explore how an innovative tablet learning platform can be designed to enhance the learning of primary school students in rural communities. Our research methods are divided in three parts including a) conducting a preliminary research study in order to understand students' learning styles and attitude towards tablet computer use, b) designing the mobile learning platform using the results of the preliminary research study, c) developing a prototype of the educational learning device

A. Preliminary study

In order to enable us to identify how a tablet-based learning system can be best designed to support learning, we carried out a preliminary research study in 2014. The study examined the use of tablet computers in four Thai schools, involving 213 students and 8 teachers in urban and rural schools in northern Thailand. Observation, questionnaire and interview methodology were conducted in order to understand students' learning styles and attitudes towards tablet computer use. We found that visual learning style (learn best by seeing through picture or video) was the most preferred learning style. Our result also showed that students had positive attitudes towards tablet computer use demonstrating enjoyment and productivity and they had high scores on acceptance of tablet computers. It was highlighted that students in rural schools had difficulty acquiring learning contents from the internet due to the lack of ICT infrastructure (out of date school network equipment and unreliable government-supported internet connection). Therefore, they could only use the tablet computer for reading static e-book content which is simply the digitised version of the books they already have in the classroom. Teachers also claimed that it would be better if tablet computers can support a broader range of teaching and learning activities instead of just reading [21].

B. Sensing device and UI design

According to the preliminary study, in order to design an effective IoET for primary school students, we need to address several issues including providing a low-cost sensor device and offering a child-friendly mobile application.

1) Designing of low-cost sensing device

Because of the rural schools limited funding provision [2], offering a low-cost learning device can save on the school budget and increase the students' opportunities to access, explore and experience IoT technologies. Additionally, this device needs to be appropriately designed for young students who are growing up in a rural society because most of them come from farming families. Learning to understand weather and the physical environment as a part of everyday life is important. Several life decisions depend on the weather conditions which may inspire them to find out the answers by making observations and conducting experiments. As we found that the majority of students are more likely to learn through seeing pictures and videos, learning through a camera is an important design feature. In addition, to enhancing the students' ability to acquire real-world data conditions, the device will be equipped with a variety of sensors such as temperature, humidity and light sensors. This conjures up an image of an octopus because it has many tentacles which can represent the sensors' connections. The name OBSY is created by the combination of "Observe" and "Octopus" which characterises the key features of the OBSY system.

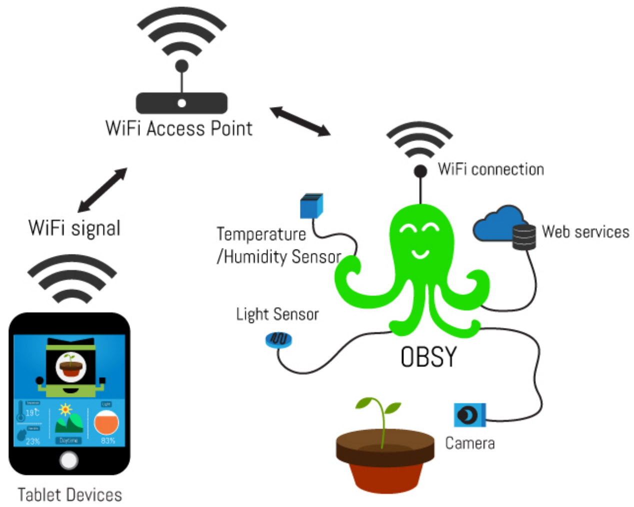

Figure 1. OBSY system diagram

For connecting the sensing device with mobile devices, a local WiFi connection needs to be provided due to the lack of internet connection in rural schools. Figure 1 shows the diagram of the system in which OBSY's sensing device will capture video/ image from the camera and gather surrounding data from sensors and then present the collected data on mobile web service over the WiFi connection.

2) Designing a child-friendly mobile application

Considering our target users are primary school students around 6-9 years old, the interface application is simply designed to be child-friendly with an icon-based and colourful flat style. The theme of the application is presented as the OBSY character where users can interact and see things through its eye. We designed large, simple buttons so the user can easily recognise them and click (touch) with a finger. Additionally, animated gimmicks are designed to hold the children's attention such as the movement of OBSY's character, changing environment background between day-time and night-time and various data visualisations. The page structure of the applications are simplified to contain three main pages including a status page (observe real-time sensors' captured data), camera page (take current picture) and gallery page (see and manage the stored captured images).

Figure 2. OBSY application user interfaces design

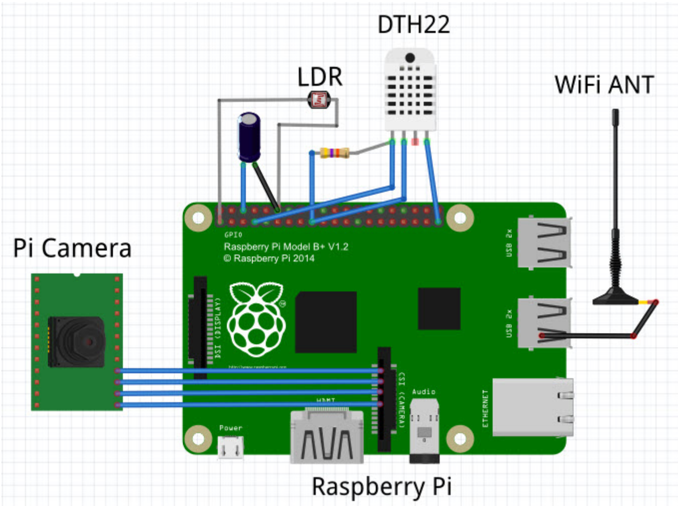

Figure 3. OBSY circuit

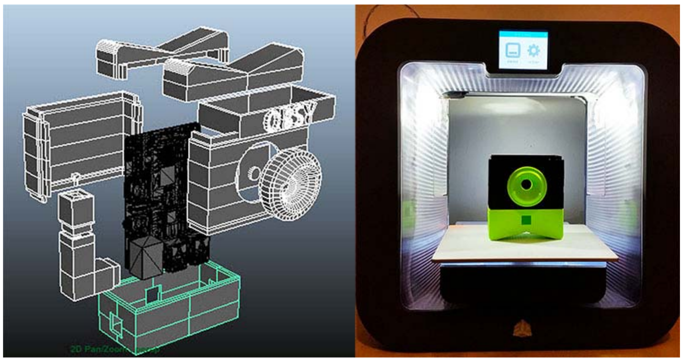

Figure 4. OBSY 3D modelling and printing

C. Prototype development

1) OBSY sensing device

A single-board microcomputer namely the "Raspberry Pi (RPi)" (Model A+) has been selected because it is an inexpensive (US$20), small, low-power device which can run web services and enable developers to build a wide range of software. It was initially developed to encourage young students in the UK to learn about basic computer science and programing [22]. We used RPi (Figure 3) as the "brain" of OBSY which connects to a camera, Wi-Fi USB adapter and sensors (temperature, humidity and light) to enable the students to monitor and acquire real-time data within range of the WiFi access point. Simple, low-cost sensors are used including a Light-Dependent Resistor (LDR), measuring light intensity and a digital humidity-temperature sensor (DHT22), measuring temperature and humidity. Furthermore, with the advancement of 3D printing technology, this allows us to construct an attractive and child-friendly housing for the sensing device by creating models with 3D software (Autodesk Maya) and printing with a personal desktop 3D printer (Cubify) (Figure 4). The OBSY sensing device can be decorated with a variety of 3D printed plastic parts. Students are able to personalise OBSY by changing body parts, accessories and sensors thereby encouraging a sense of ownership of their learning process (Figure 5). A flexible camera tripod is used so that students can easily to adjust the angle of OBSY's camera or hold it in any position.

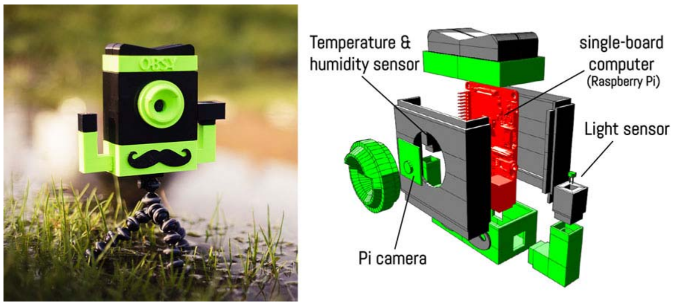

Figure 5. OBSY sensing device with 3D casing

2) OBSY mobile application

The OBSY application (Figure 5) has been developed based on mobile web application technology rather than mobile native application because the system is instantly accessible to users over a web browser across a range of mobile devices. It is developed by using modern web technologies which render applications quickly and with stability on any web browser. The interactive web applications were created by Adobe Edge Suite as an authoring tool based on the foundation of HTML5, JavaScript, jQuery and CSS3. Students can easily observe the video images and real-time data collection from sensors through the application. The application service is owned by Raspberry Pi (Linux based operating system) and is installed with PHP and MySQL database to serve the web application and store collected data from sensors. A Python script is used to communicate between Raspberry Pi and sensors. Video images from the Pi camera are captured and stored in Raspberry Pi by modified scripts of the web-based interface controlling the Raspberry Pi camera (RPi-Cam-Web-Interface) which was initially developed by Silvan Melchior [23].

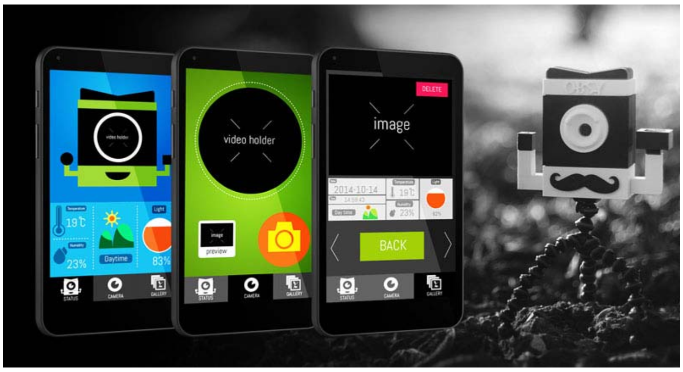

Figure 6. OBSY application

IV. CONCLUSION AND FUTURE STUDY

This paper presents an ongoing research project based on the paradigm of the Internet of Things (IoT) with an educational objective resulting in an Internet of Educational Technology (IoET) platform which promises to deliver great benefits to learners. The rising trend of IoT and mobile technology has enabled the development of an innovative, appropriate, educational learning tool for rural students in underprivileged areas which is compatible with existing low-cost tablet computers in Thai schools. It is hoped that learning through OBSY can empower students to have personalised, rich and interactive learning, anytime anywhere when they need it. Therefore, the learning process can become more active, through collaborative engagement beyond the classroom.

Presently, we are testing the system before planning to conduct a deployment study of the prototype in Thai schools in 2015. The study will investigate how students interact with the OBSY system and how well it supports learning in science experiments. The observation will be conducted with the aim of understanding of how students interact with their peers, teacher and OBSY. Students will learn the topic of living and non-living things by observing real-time sensory data and videos/images of growing beans (living things) and rocks (non-living things) through the OBSY system. Questionnaires and interview sessions will be employed to assess students' engagement in learning and the usability of the OBSY system. Additionally, the reliability, robustness and user-friendliness of the sensor devices, mobile app and local Wi-Fi network will be tested. When data collection is finished, the users' attitudes, perceptions, engagement and learning effectiveness towards tablet computer use with OBSY will be analysed. Then, a final generic design framework, guidelines and applications through tablet computers will be published.

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