

The internet of things technologies in teaching, learning and basic education management

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Abstract: According to the Bill of Rights of South Africa's (S.A.) constitution, the state has an obligation, through reasonable measures, to make education available and accessible to all. S.A.'s push for universal access to education and for improving learning and teaching calls for a number of appropriate measures to be put in place. This paper proposes the adoption of internet of things (IoT) technologies in improving learning and teaching and basic education management. It is an attempt to influence policy on the potential of IoT in improving learning, teaching and management at the basic education level. The paper identifies areas of health in education, teacher education, learner support, social mobilisation and support services, planning and delivery oversight, quality assessment, inclusive education and curriculum policy, support and monitoring as areas where IoT technologies can be adopted. A number of IoT technologies that can be of value in these areas are identified as examples, both from local and international perspectives.

Keywords: Internet of things, education, teaching, learning

1. Introduction

The vision for South Africa is that all people have access to lifelong learning as well as education and training leading to an improvement in their quality of life. This is done through leadership towards the establishment of a South African education system for the 21st century. The strategic outcome-oriented outputs are to improve the quality of teaching and learning, undertaking regular assessment to track progress, improving on early childhood development, ensuring a credible planning and accountability system and improving the capacity of the Department of Basic Education (DBE). In direct support of these goals the key interventions will be teacher development, learner support materials, infrastructure delivery, national assessments and district development. It is with these goals in mind that this research proposes the adoption of internet of things (IoT) technologies in improving education management (The Department of Basic Education, 2012).

The objective of this paper is to showcase the marriage between the IoT and education management. The paper is organised as follows: The next section is the problem statement. We look at IoT concepts in section three. In the fourth section we explore applications of the IoT that can be adopted in teaching, learning and education management. The last section is a summary of the paper.

2. Problem statement

The efforts to improve access to education, the quality of teaching and learning and the management of basic education are issues of topical interest in South Africa. The need therefore arises, to strategise on the way forward. This paper proposes the adoption of information and communication technologies (ICT), and in particular a subset of ICTs that is referred to as IoT in teaching, learning, access and management of basic education. The question that this paper answers is:

“ What role can IoT technology play in improving basic education management in South Africa”.

The approach that is used in this paper is the identification of examples of IoT applications that can be adopted in teaching, learning, access and education management domains. The objectives of the paper are:

- ❖ To showcase the potential role that IoT applications can contribute to basic education management
- ❖ To influence DoE policy on the adoption of IoT in basic education

3. The Internet of Things

The Internet of Things (IoT) is a world-wide network of interconnected objects, uniquely addressable, based on standard communication protocols. The international telecommunications union (ITU) states that the goal of ICT is to connect all objects to form a ubiquitous network which is called the IoT. Using tags, sensors and chips paired with wireless technology, microchips implanted in objects gather loads of data about the location, status and other features of objects. This information is then analysed and passed on to the right recipients who can put it to use. Wireless networks of objects are created using radio frequency identification (RFID), Bluetooth and global positioning systems (GPS) in tandem with cloud computing environments, web portals and back-end systems. In addition, there is telemetry, i.e. the remote reading of sensors and activities with the aid of communication technologies such as global packet radio service (GPRS), global systems for mobile communications (GSM) as well as 3G systems (Raunio, 2009). Then there is systems that are integrated into their surroundings and easily accessible at anytime such as smart/intelligent objects. The final piece is the internet and mobile telephony communications technologies that make it possible to build low-cost internet-based solutions and services.

Communication in the IoT can be in two modes. The thing-to-person communications encompass technologies where things report their status and whereabouts to humans and vice versa. Thing-to-thing communications is where objects can monitor other objects and notify humans. To detect changes in the physical state of things, sensors play a pivotal role.

There are a number of applications of the IoT. Adoption of network-addressable energy appliances could be a key driver of IoT. Network-addressable utility meters, hot water heaters, indoor climate controls could control costs and reduce energy use. Nano-filters in Bangladesh are removing pollutants and ensuring water is safe to drink. Nano-sensors can be used to monitor water quality at reduced costs while nano-membranes can assist in the

treatment of waste water. Special robots have been used for mine detection to save lives in conflict zones (Dlodlo, 2011).

4. Applications of the Internet of Things in education

For each of the sectors of health in education, teacher education, learner support, social mobilisation and support services, quality assessment, planning and delivery oversight, inclusive education and curriculum policy, support and monitoring, a number of potential IoT applications are identified.

4.1 Health in education

Some of the issues identified under health in education are the school nutrition programme and health awareness raising on diseases such as HIV/AIDS.

For supply of food in the S.A. school nutrition programme, supply chain efficiency is necessary. An example can be drawn from Spain. Researchers from the Department of Information and Communication Engineering at the University of Murcia in Spain are working on technological advances for improving supply chain efficiency through tracking, tracing and monitoring (TTM) in order to satisfy requirements for product. The proposed system integrates RFID tracking and tracing through a distributed architecture previously developed for heavy goods vehicles. The system monitors temperature, humidity and light of goods transported through the use of sensors (Castro, 2011)

Health education can also be imparted to learners through IoT. Let us borrow a concept from KIT. Keep in Touch (KIT) is a concept for intuitive human interfacing that uses smart objects and wireless technologies like Near Field Communication (NFC) and RFID. KIT enables people to exchange information with health-related items of their daily life by simple touching those things with the NFC-enabled mobile phones. Closed Loop Healthcare Services allow processing of the resulting data and establishing communication channels between patients, their environment and different groups of caregivers. The combination of KIT smart objects and Closed Loop Healthcare Services add up to an IoT-based infrastructure for pervasive health (Shreier, 2012).

Another concept of imparting health education can be borrowed from the SINGA environment. A digital environment called “SNAP ME” (Dlodlo, 2009), assists in finding entrance points (referred to as “rabbit holes”) for vulnerable children and youths to a digital portal called SINGA. The particular environment introduces the children and youths to science, engineering and technology (SET concepts). A bar code image is captured by means of a camera-enabled mobile phone to reveal a uniform resource identifier (URL) that leads to a ‘rabbit hole’ in the SINGA environment or the SINGA information would then be revealed as a text message. Such a portal can be utilised for HIV/AIDS and other health-related information dissemination. Bar codes are placed anywhere that is likely to attract the interest of the youths (e.g. lamp posts, bust stations, bottle tops, walls, etc). In order to decode any of these bar codes, the child has to ensure the right software application is installed on their mobile camera phone.

4.2 *Teacher education and human resource development*

The teacher is the most important human resource in education. Therefore their training and performance monitoring is vital. An architecture to develop and provide digital content, by taking advantage of the expertise of local teachers and ICTs is described in (Dlodlo, 2011). Teachers in remote locations develop digital content that is transmitted to a department of basic education (DBE) database via networks. The database exists in a private cloud that is sanctioned by the DBE. The content that is submitted is combined to create new content that serves the theme of the day for the learners. The MASHUP application technology that combines these functionalities / content is an interactive web page. Once this new content/ functionality is in place, the system notifies the learners of the updated content via an SMS and learners can access this content via their cell phones.

MyTeaching Partner (MTP) is an innovative , technology-assisted program that provides teachers with support from their own on-line consultant, a teaching expert who assists teachers by observing, de-briefing and extending teachers' educational practice (Kinzie, 2006). MTP also provides a set of web-based resources to support high-quality teaching, including research-based educational curricula designed specifically to support the development of early language, literacy and social relationships in kindergarten learners.

An interactive map can be devised, from which teaching performance figures can be obtained. The data is captured from open-record requests from schools, provincial departments and national departments. The map is updated as new information becomes available. Users can filter data by month, term, year, results obtained, and statistics. Also, a bird's eye satellite view in Google maps can be used to make performance maps. The maps shows a detailed history of performance by province, district and neighbourhood.

4.3 *Learner support*

The following are learner support systems in the IoT.

The Samsung's Engineering academy's prototype solar-powered classroom incorporates laptops and electronic blackboards. It is a climate-controlled structure with a temperate environment for Africa's arid climate. It incorporates an energy-efficient refrigerator, file server, router, uninterrupted power supply, videos and Wi-Fi cameras, designed to interact with 3G, allowing a remote central location such as the DoE to monitor lessons and deliver curriculum-based content directly to the classroom and both learners' and educators' notebooks (Daly, 2012).

IoT can enable interaction with physical spaces for learning purposes or communication. 6 universities in Spain are working on the Mosaic Project to explore new alternatives for using mobile and pervasive technologies in education and to develop middleware technologies to support them. The research is about Touching Learning Scenarios using NFC as the technology to enable interaction with physical spaces for learning purposes or communication (Gonzalez, 2008). Some of the technologies associated are: mobile devices, RFID, Bluetooth, GPS, bar codes, tangible interfaces and sensor networks.

Researchers from the Department of Computer Science at the University of Waseda in Japan are working on an augmented calligraphy system that aims at supporting a calligraphy learner's self-training process by giving feedback. The system monitors the learner's posture by a web camera and notifies them if the posture moves into a bad shape. The system also supports a grading feature so that the learner can improve calligraphy writing skill. The web camera captures the images written on paper and their shape is recognised with OpenCV library (Schichinohe, 2010).

By combining sensor, logic and actuator blocks, young kids can create reconfigurable robots that exhibit complex behaviour. Cubelets are magnetic blocks that can be sapped together to make an endless variety of robots without the need for programming skills and without wires. One can build robots that respond to light, sound and temperature and have lifelike behaviour. Each cubelet has a different default behaviour. There are sensing blocks that act like eyes and ears, action blocks and think blocks. Just like with people, the senses are the inputs to the system (Modrobotics, 2012).

4.4 *Social mobilisation and support services*

For social mobilisation, learners are encouraged to participate in the management of their schools. (Dlodlo, 2012). They take photos of poor state of infrastructure, unhygienic state of facilities, poor maintenance of grounds using their cell phones. This information is sent to a database in the form of an Ushahidi server, which can be accessed by the Department of Education inspectors. The Ushahidi is a crowd-sourcing platform that uses social media and mobile communications to collect information. This information is placed on Google maps to give a visual picture of the state of affairs. The Mobicents platform creates, displays and manages services and applications integrating voice data and video across a range of communication networks.

Education support services include school safety and transport, etc. For safer schools CCTV cameras, perimeter fences, metal detectors and alarm systems need to be in place. An alarm system can have GPS coordinates, so that when it goes off the control centre can easily locate the site. Electronic fences can either be wireless or in-ground. Wireless fences have an electronic base unit that emits radio waves up to a certain range. A receiver and transmitter send an alert to the relevant body. In-ground fence picks up radio waves and beeps once someone crosses the fence. Perimeter security can have fibre optic stretched along the fence. An anomaly such as a bend or twist in the fence, no matter how slight, would show a slight variation in the colour of light (different wavelengths contained in white light reflect at different angles). An optical time reflectometer (a type of radar for light) attached to the fiber optic would locate the spot, within about a meter, where the twist or bend took place and a search light could be instantly aimed at the point (Gruber, 2012).

Automated tracking of transport that takes learners to schools are some of the application areas for IoT in transport. To cut down on accidents, drivers of these vehicles can be enabled to communicate to other road users and each other. There are applications to teach safe and comfortable driving by sensing their behaviour and comparing it with the sensed behaviours of other motorists on the road.

Parent and community participation in education has an impact on learner success. Advantage can be taken of mobile technologies to keep parents informed when their

children play truant, when there are any functions and meetings at the school, of any disciplinary records against their kids and any other developments. Parents can also communicate with the school via the same system.

4.5 *Quality assessment*

An education information management system (EMIS) should be able to electronically link information from schools to districts to the ministry offices. It should be a network of one or more EMIS centres located at central, regional and local levels. It should be a system to provide information and documentation services that collects, stores, processes, analyses and disseminates information for education planning and management. Outputs can include reports (e.g. analytic and diagnostic), personnel management (e.g. salary, promotion, recruitment), resource management (e.g. finance). This EMIS can be linked to Google maps, so that reports can be reflected in the form of maps.

4.6 *Planning and delivery oversight*

Planning and delivery oversight is about issues of school monitoring and encompasses provision of books, library services and national literacy monitoring and performance indicators

As an identifier, the RFID is particularly suited to inventory functions, and a library has a strong inventory component. In libraries, items are taken out and returned many times. This makes the library function an even better use because the same RFID is re-used many times. Second, only to circulation, libraries look to RFID as security mechanism. The RFID tags can facilitate security in a variety of ways. In one method, the tag that is used has a special “security bit” that can be switched from checked-in to checked-out. The exit gates at the library read each tag as the user passes out of the library and sounds an alarm if the bit is not in the “checked-out” state. The check-in function resets the bit. Another method is for the tags themselves to remain the same; as the user passes through the exit gate the system reads the tags in the books in the user’s arm or bag and queries the library database to be sure that the items have been checked out. Additional investment can be made on book return system that automatically checks in items as they pass along a conveyor attached to a book drop. This system can be attached to an automated sorting machine that sorts the items into bins based on their call numbers

One of the problems that South African education is facing today is that of making books available to all learners, including those in remote rural areas. Technology can lessen this burden through the provision of digital books, or e-books, that is, a digital repository of e-books can be accessed by different schools. An e-book is a book in digital form consisting of text, images or both and published and readable on electronic devices. An e-book store is a library of electronic books. An architecture to provide e-books as specified in the South African curriculum for Grade 0 to Grade 12 learners can be made available. Learners can access the Department of Education (DoE) e-books store via MXit on their cell phones. However, Internet access through broadband is not readily available throughout the whole country. Therefore access should be made available both off-line and on-line. Where the learner has real-time Internet access through the cell phone, they can access the e-book store directly. For those learners who cannot have access the books can be downloaded onto digital storage for off-line access. The open source e-book readers for cell phones are downloaded by the learners onto their cell phones since it is costly to develop one’s own.

A number of organisations have come up with their own e-book stores. An e-book store is a library of electronic books. The owners of the e-book stores have their own standards. They have their own application programming interfaces (APIs). Any user who would like to connect to their APIs can put together a java application called the Java Platform Micro Edition (J2ME) which sits on their phone and enables access to the e-book store. Each internet service provider, e.g. Vodacom, CellC, MTN and 8tA has a unique APN or Internet identifier, which enables a GPRS connection to it. By default all cell phones that have browsers connect to a specific APN of each cell provider. Any organisation can also have its own APN number . A J2ME provides a robust, flexible environment for applications running on mobile and other embedded devices, e.g. mobile phones, personal digital assistants, etc

To be able to access an e-book store one has to subscribe. Some of these connections are free of charge, while others are a paid service. An example of a proprietary paid service is Apple's i-book reader. Proprietary services only allow one to connect through their own APN number, through Wi-Fi or landlines. Proprietary service providers provide their own book readers to enable access. A book reader is a tablet PC. The e-book reader is customised for a particular e-book store to keep the customer. The subscriber has a user account in the e-book store with the list of books that one can access. A subscriber can buy books from the book store which can be downloaded and read off line. The connection is not needed all the time. The proprietary service provider keeps track of the books the subscriber has read and recommend new books. To access the service through a cell phone the provider gives the subscriber an e-book reader application. The J2ME sits on the e-book reader. Alternatively free e-book readers can be downloaded from the Internet or purchased. In most cases, where the access to books is free, then its old books.

4.7 *Inclusive education*

IoT can facilitate collaboration between under- and well-resourced schools so that under-resourced schools can have access to laboratory resources that are available in well-resourced schools. It is about using IoT in remote-controlled laboratories (Dlodlo, 2011). A remote operator is allowed access to a central but geographically remote laboratory. The system supports a chemical reaction between water and a chemical. Learners remotely give instructions to actuators in the well-resourced laboratory to pour the chemical into a beaker. RFID tags are incorporated in the remote lab to ensure that the correct chemicals are mixed. Instructions received over the internet are interpreted and acted on by the laboratory controller. The laboratory controller consists of signal conditioning and actuator circuit, an Arduino, microcontroller circuit and various sensors. Sensor data includes ambient light levels, temperature levels, sound and vibration. Cameras in the well-resourced laboratories send images of the experiment to the under-resourced laboratories.

A technological intervention called "Remember me" explored how memories that are attached to objects can affect consumer habits. Oxfam shops linked audio tracks to goods on sale. These audio tapes were linked to two-dimensional barcodes called QR codes and radio frequency identifiers (RFID) tags that were attached to the objects. The QR code is a printed paper bar code that is able to contain an internet address and link RFID tags can easily be associated with information or data files. People browsing the products bespoke RFID readers and iPhone and Android phone-based applications to scan the labels. Once

triggered, speakers located in the shop played back the audio stories associated with the label (Speed, 2011). The same concept can be borrowed into education of learners.

If students are collecting research data in the field, tagging physical objects to find and analyse data about the object and have to feed the data into other programs for analysis is one way the IoT can be used in education. Once the students tag the object, associate certain data and comments to feed that data to other servers for analysis, they can sit back, collect it and run it through various programs for their research. Having to go out to the physical object all the time to collect data on different conditions will be a thing of the past. Learners will have 24 hour data collection, which will make their research more accurate.

A student who wants to learn a foreign language can do so through touching physical objects that are in their vocabulary list. RFID tags can be created and attached by the instructor for each of the physical items in the vocabulary list. When the student places this object on the RFID reader, it will say the word for the item in their native language and in the foreign language. Touching the item will give the student another sense to be engaged and may help, depending on their learning style, them learn the content faster.

A technology based on the IoT for primary school learners to know about various parameters of their environment, that is, the temperature, light, vibration, sound and gas levels. An Arduino is fitted with various sensors that can detect the parameters. It connects to a computer, even wirelessly. The information generated by the Arduino is fed to Twitter social network, which can be accessed via mobile phones (Dlodlo, 2011).

4.8 *Curriculum policy, support and monitoring*

The U.S.'s learning through collaborative visualisation (CoV) is a distributed multimedia science learning environment that uses broadband desktop video conferencing and screen sharing, scientific visualisation tools and distributed datasets, virtual field trips, scientist tele-mentoring and a collaboratory notebook for enabling project-based learning of science in high school using these technical and human resources (Pea, 2002). The project vision is the establishment of collaborative technology learning environments, or "collaboratories" that would enable project-enhanced science learning among remote project partners using advanced telecommunications networks. Collaboration with scientists provide learners with subject matter experts, visualisation tools and vast databases in the various fields.

5. **Conclusion**

This paper identifies applications of IoT technologies that would be handy for a South African environment. The technologies are classified under health in education, teacher education, learner support, social mobilisation and support services, planning and delivery oversight, quality assessment, inclusive education, curriculum policy, support and monitoring and administration. This study is meant to influence policy on the adoption of IoT in education management. This research can also be the basis for developers of such IoT systems to refine and implement the identified systems, customisable to the South African environment. This could involve integrating more traditional and appropriate technologies into each one of these customised solutions.

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