Pervasive Computing in Classroom Environments and Applications

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***Abstract*—Pervasive computing is an advanced computing paradigm which makes computing available everywhere and anywhere. It allows users to interact with computers. Such computers can exist in different forms such as laptops, tablets, a pair of glasses (wearable computers) and clothes or wearable fabrics that are sensor-embedded. It is essential to explore the different applications of pervasive computing to learning in classroom environments, in order to foster learning and promote well-being among students. One of the problems currently confronting some developing countries is a lack of adequate facilities to support proper learning in classroom environments. This has had a negative impact on the performance of students at various levels of educational learning. In this paper, a review of current trends, future trends and applications of pervasive computing was explored, particularly with respect to classroom learning environments, and a generic model of pervasive computing technology was proposed for adoption in classroom learning environments of developing countries, particularly the Nigerian tertiary institution's classroom learning environment.**

Keywords—pervasive computing, classroom environments, pervasive technologies, current trend, future trends

I. INTRODUCTION

The growing trend of pervasive computing in embedding microprocessors in everyday objects for the purpose of communicating information is not uncommon in present day technology. Pervasive computing, also known as ubiquitous computing, implies "existing everywhere" or "around us". The concept of pervasive computing is an interesting one. It implies that chips can be integrated and imbedded into almost any kind of device: these results into the establishment of an infinite mesh of network. These range from shoes, clothing, appliances, homes, cars, and the human body, among others.

The major goal of pervasive computing is to provide and guarantee an environment that has unobtrusive and constant connectivity. Certain network technologies are commonly combined with pervasive computing. These include, among others, voice recognition, advanced electronics, Internet capability and artificial intelligence.

Certain problems are associated with learning in modern classroom environments. Such problems include: an inability of students to understand and assimilate all that is being taught in the classroom, difficulty experienced by students in learning new topics in classrooms, inability of students to retain what has been learnt in the classrooms, and the dynamic nature of the present day education syllabus, among others.

One of the ways these problems can be addressed is by integrating pervasive computing technologies into classroom learning experiences [1]. Thus, conducting a review on various integrations of pervasive computing technologies into classroom environments is a worthwhile and timely.

In this paper, we provide a review on different pervasive technologies applications to classroom environments and the benefits they portend. The structure of the paper is as follows: literature review, current trends and applications of pervasive computing in classroom environments, future trends and applications of pervasive computing in classroom environments, discussion and conclusion.

II. CURRENT TRENDS OF PERVASIVE COMPUTING IN CLASSROOM ENVIRONMENTS

First and foremost, pervasive computing was originally realized as the dream of Mark Weiser [2]. He proposed three basic forms of pervasive computing systems namely: tabs (wearable devices), pads (hand-held devices) and boards (display devices). He also proposed much more useful ranges of pervasive devices such as dusts, skin and clay. Pervasive computing has been largely applied in the health care sector but the educational sector is still lacking behind with respect to pervasive computing research [3]. However, studies have revealed that pervasive computing can be applied in the classroom environments. In essence, pervasive computing can be likened to a borderless education. Few among these studies include:

Yau and colleagues highlighted learning with smart class room technology [4]. Zhang and colleagues applied pervasive computing design to education [5]. Hurson and Sedigh, created a suitable pervasive computing platform for tertiary education [6].

Intelligent and pervasive multimedia systems were analyzed by Grosky [7]. Smailagic and colleagues presented current research trends in wearable computing [8].

Peter Mikulecky conducted a study on recent research of smart workplaces enhanced by advanced smart learning possibilities. The focus of his work was on smart learning possibilities enabled by the research results in smart workplace area [9].

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Finally, Jasmine Norman conducted a study on the impact of pervasive computing in education [3]. In her work, several issues pertaining to education and pervasive computing were considered. Different applications of pervasive computing and their corresponding challenges were analyzed. The roles of a teacher and a student in a pervasive era were listed. In conclusion, an educational framework was proposed by Norman.

According to Johnson and colleagues, emerging pervasive computing technologies that are likely to take stage in the aspects of teaching, learning and innovations within the next 12 months or less were categorized into the following: flipped classrooms, learning analytics, tablet computing and Massive Open Online Courses (MOOCs) [10].

We have studied, and conducted a literature review of these current trends, expanded and re-presented them in a more comprehensive fashion as shown in subsequent sections. Applications, research issues, relevance and examples of the current trends of pervasive computing technologies were highlighted.

A. Flipped Classrooms

Flipped classroom is a current trend of the application of pervasive computing to learning environments. It helps to transform traditional teaching methods by inverting such methods for the purpose of delivering instruction online and helping students bring homework into the classroom by engaging such students in hands-on activities relevant to what is being learnt by students in real life. It has enhanced students' learning experiences. To some researchers, flipped classroom is considered a new teaching model which provides innovative ways of imparting knowledge to students in the classroom [11]. Some researchers have conducted and are still conducting studies on flipped classrooms. Bergmann and Sams presented flipped classrooms as a means of reaching out to every student [12].

An increase in the availability of online videos and an increased access of students to this technology has resulted in the emergence of newer sets of flipped classroom models. In fact, a study highlighted the merits and limitations observed in substituting classroom lectures for videos [13]. Another author, Bill Tucker, highlighted the benefits and possible dangers that can be associated with the use of flipped classrooms [14]. Berret highlighted the various ways flipping classrooms can benefit traditional methods of teaching [15]. Another study revealed how a flipped classroom model helped to improve the performance of Pharmacy students in a renal pharmacotherapy topic module [16].

However, the use of flipped classrooms can cause a digital divide especially when evaluating student's access to technology. The issue of trust is another research issue; is it possible to guarantee that students will actively participate in online lectures and make meaningful contributions to online educational forums? Another issue is the variation that exists in the degree of assimilation by different categories of students. Flipped classrooms have been applied in the University of Queensland English department, University of Albany and the Indian Institute of Business in Mumbai, India.

B. Learning Analytics

Learning analytics is also a current trend that employs advanced tools to improve educational experience and the performance measurement of students. It has helped to improve the learning experiences of students in classrooms based on the analysis of previous learning data. It has also helped to refine classroom learning goals and strategies. It has helped researchers and educationists to gain meaningful insights about students' interaction with courseware and educative online contents. This has resulted into better pedagogies and assessment to ascertain the effectiveness of programs designed to improve students' retention and whether such programs should be sustained. Siemens and Baker studied the impact of learning analytics on fostering research collaborations among educationists [17]. Learning analytics has also been applied in the area of visualization and recommendation [18]. Learning analytics have been applied to increase students' success rate [19]. Scientists have also envisioned it as a solution provider to the numerous problems in education [20].

An issue of concern is the variation that exists in the degrees of assimilation by different categories of students, especially, as they interact with online courseware and contents [21]. Another research issue is the "big data" problem: this represents an upsurge in the volume of courseware and online content users, thus requiring more computing resources [22]. However, part of the research efforts of some scientists in addressing the big data problem was to propose a generic design framework to tackle some of these problems [23]. Some other concerns of learning analytics have been identified by some researchers, and they offer as solution, the social learning analytics [24-25].

C. Tablet Computing

Tablet computing is an aspect of computing that applies mobile computers to solve daily real-life problems. It consists of employing the use of tablets (mobile computers with integrated pervasive computing technologies which are usually embedded within these devices) for day to day learning activities. Over the years, tablet computing has been applied to classroom learning environments [26]. Tablet computing has helped to enhance students' learning experiences in classroom environments and has also supported lifelong learning [27-28].

Tablet computing has also been applied to studying the attitude of students by engaging them in classrooms with respect to computer science curriculum and engineering content development [29-31]. It has been used to foster a more participatory learning environment among students in a classroom [32].

D. Massive Open Online Courses (MOOCs)

Massive Open Online Courses (MOOCs) represents courses that are open and taken by different participants distributed in different locations across the web; course materials are also distributed. MOOCs represent a means to extend technological skills and knowledge to a large

percentage of the world. It also acts as a motivation for promoting online education [33].

A recent study was conducted to investigate how and whether MOOCs will change how teachers teach. MOOCs possess the potential to positively impact teaching and learning in the classroom environments of educational institutions [34]. Researchers have also conducted studies to analyze learners' experiences and performances in MOOCs [35]. Considering both the benefits and drawbacks of MOOCs, some scientists, however, view MOOCs as a disruption in higher education [36].

III. FUTURE TRENDS OF PERVASIVE COMPUTING IN CLASSROOM ENVIRONMENTS

Future trends and applications of pervasive computing to classroom environments have been studied by different scientists in different literature. However, according to Johnson and colleagues, future trends of pervasive computing technology that will be applied within classroom environments in the next two (2) to three (3) years include: 3D printing technologies, games and gamification, virtual assistants and quantified self [10].

The differences and similarities of the future trends in pervasive technologies are highlighted in table 1 below. It should be noted that most of these technologies, apart from 3D printing, share common attributes with respect to the devices on which they operate.

TABLE I. DIFFERENCES AND SIMILARITIES OF THE APPLICATIONS OF PERVASIVE TECHNOLOGIES IN EDUCATION/CLASSROOMS

Differences in future pervasive technologies				
Parameters	***3D Printing***	***Quantified Self***	***Virtual Assistants***	***Games and Gamification***
Brief Description	Technology that can be used to print anything using 3D models.	Technology that helps to monitor daily human activities.	Adopts the knowledge of artificial intelligence to help humans in day-to-day activities.	Technology that uses game theory for designing educative games.
Devices associated with each technology	3D printers, 3D softwares.	Wearable devices, mobile devices, mobile phones.	Digital displays, vehicles, health care management systems.	Mobile devices, Desktop computers, laptops, Mobile phones.

We have taken time to study and conduct literature review on these future trends, their applications, research issues associated with each of them, their respective relevance and examples of where they have been applied. Our review extended and presented them in a more comprehensive fashion.

A. 3D Printing

Known as Rapid Prototyping in industrial circles, 3D printing uses modeling software to design physical objects in the similitude of a three-dimensional shape. Some of the concerns and research issues of 3D Printing include: (i) Cost (ii) Inability to easily print multiple materials on the same machine (iii) Availability (iv) Printing to the finest resolution (v) The printing process is slow (vi) Legal issues [10]. 3D Printing research is ongoing and applications have been developed and are currently undergoing tests in the University of Central Florida, Miami University and University of Liverpool, among others.

TABLE II. EXAMPLES OF THE APPLICATIONS OF 3D PRINTING TECHNOLOGIES IN EDUCATION/CLASSROOMS

3D Printing in Practice	***Description***	***Location applied***	***References***
1.Latest breakthrough in 3D printing	Creation of invisible cloaks and stealth technology.	University of Central Florida	Li Gao et. al., 2014. http://today.ucf.edu/nanotech-leads-break-stealth-technology/
2.Anthropology students	Students study replicas of fragile artifacts that have been scanned and printed.	Miami university	http://www.units.miamioh.edu/anthropology/
3.Scientists	Development of synthetic skin with close resemblance to an individuals' physical attributes.	University of Liverpool	http://news.liv.ac.uk/2013/11/27/developing-convincing-3d-printed-skin/
4. GeoFabLab	Geology students can examine rare fossils, crystals and minerals	Iowa State University	http://www.public.iastate.edu/~franek/gfl/gfl.html
5. Researchers	Creating environmental prototype to study bacterial growth, development and transmission.	University of Texas at Austin	http://www.utexas.edu/
6. Makerspace, The Maker Lab and The 3DLab	Universities have adopted and created dedicated spaces for 3d printing and research	North Carolina State University, University of Victoria, University of Michigan	http://www.ncsu.edu/ http://www.uvic.ca/ https://www.umich.edu/

B. Games and gamification

Gamification is the application of the elements and concepts of game design and game thinking in a non-gaming context [37]. It can serve as a means to provoke creative and critical thinking, develop problem-solving skills and promote collaborative work. It can also act as avenues for solving real-life problems [10], [38]. Games and gamification research have been developed and are currently undergoing application tests at the Stanford University School of Medicine and the University of Washington, among others.

TABLE III. EXAMPLES OF THE APPLICATIONS OF GAMES AND GAMIFICATION TECHNOLOGIES IN EDUCATION/CLASSROOMS

Games & Gamification in Practice			
	Description	***Location applied***	***References***
1. Foldit	Protein folding is an important aspect in Bioinformatics research. This game provides a platform for the implementation of virtual protein folding.	The University of Washington	http://www.washington.edu/news/2011/09/19/gamers-succeed-where-scientists-fail/
2. GLO-BUS	This is a stock-related game. It simulates the global business environment and transactions that occur therein.	Montclair University	http://business.montclair.edu/file/2125
3.The Denius-Sams Gaming Academy	It is expected that this video game will be deployed by 2014 Fall.	University of Texas, Austin	http://moody.utexas.edu/gaming-academy
4. SICKO	This is a medical game that creates a scenario where the game player has to manage the health of three sick virtual individuals. It helps to train medical and aspiring medical students in the art of health care management and medical surgery.	Stanford University	http://cme.stanford.edu/sicko/game/SICKOTitle.html
5. Mentira	This game helps learners to develop their knowledge of Spanish language.	The University of New Mexico	http://www.mentira.org/credits
6. Deloitte Leadership Academy	The game helps to train students in the creation and improvement of curriculum.	Deloitte	http://www.gamification.co/2013/01/11/deloitte-leadership-academy-leads-with-the-gamification-of-training/
7. Find the Future	An educative game that helps people develop the art of writing and composition.	McGonigal with Natron Baxter and Playmatics	http://www.edtechmagazine.com/higher/article/2013/10/awesome-power-gaming-higher-education

C. *Quantified self*

Quantified self applies technologies that monitors data to help people keep track of their daily activities. Privacy concerns, high prices of gadgets and unavailability of equipments are some of the challenges currently facing quantified self [10]. Quantified self research has been developed and are currently undergoing application tests at the University of Texas and the University of Tokyo, Japan, among others.

TABLE IV. EXAMPLES OF THE APPLICATIONS OF QUANTIFIED SELF TECHNOLOGIES IN EDUCATION/CLASSROOMS

Quantified self in Practice			
	Description	***Location applied***	***References***
1. Fitbit	This is a small wristband which helps workers to monitor and keep track of their daily activities.	University of Tokyo	Kota et. al, 2013
2. Health Data Exploration Project	A health project whose ultimate aim is to help individuals track their health profile and overall fitness.	The California Institute of Technology	http://www.calit2.net/hdexplore/
3. The Russ-ome Project	A project to monitor the heart conditions, exercise and sleep profiles of individuals.	Imaging Research Center, University of Texas	http://www.utexas.edu/opa/blogs/research/2013/05/23/neuroscientist-conducts-deep-study-of-a-brain-his-own/

D. *Virtual Assistants*

Virtual assistants apply the knowledge of artificial intelligence to support people in their numerous daily activities. It enhances productivity by providing useful applications to the academia and industry. Language barrier, time difference, trust issues, payment and exchange rates are some of the concerns associated with virtual assistants [10]. Virtual assistants' researches have been developed and are currently undergoing application tests in the University of Cambridge. Other Universities embracing this research and its applications are the MIT Media lab and the University of Virginia Health Systems.

TABLE V. EXAMPLES OF THE APPLICATIONS OF VIRTUAL ASSISTANT TECHNOLOGIES IN EDUCATION/CLASSROOMS

Virtual Assistants in Practice			
	Description	***Location applied***	***References***
1. Zoe	Zoe represents a virtual assistant in the replica of the model of a digital talking head.	University of Cambridge	http://www.cam.ac.uk/research/news/face-of-the-future-rears-its-head
2. Florence	An intelligent medical virtual assistant (to be launched later in 2014)	Nuance Communications	Boston Business Journal http://www.bizjournals.com/boston/blog/techflash/2013/10/nuance-to-launch-virtual-assistant-for.html?page=

Virtual Assistants in Practice			
	Description	*Location applied*	*References*
			all
3. VAGUE	A very important tool for speech recognition.	Carnegie Mellon University	http://cmusphinx.sourceforge.net/
4. BlabDroid	A virtual assistant that integrates with mobile phones to provide weather reports and other useful information to users.	MIT Media Lab	http://upstart.bizjournals.com/news/technology/2013/11/24/blabdroid-to-sell-robot-assistants.html
5. M* Modal	A virtual assistant that helps to manage, maintain and disseminate health records.	The University of Virginia Health System	http://mmodal.com/press-releases/university-of-virginia-health-system-selects-mmodals-speech-understanding

IV. DISCUSSION

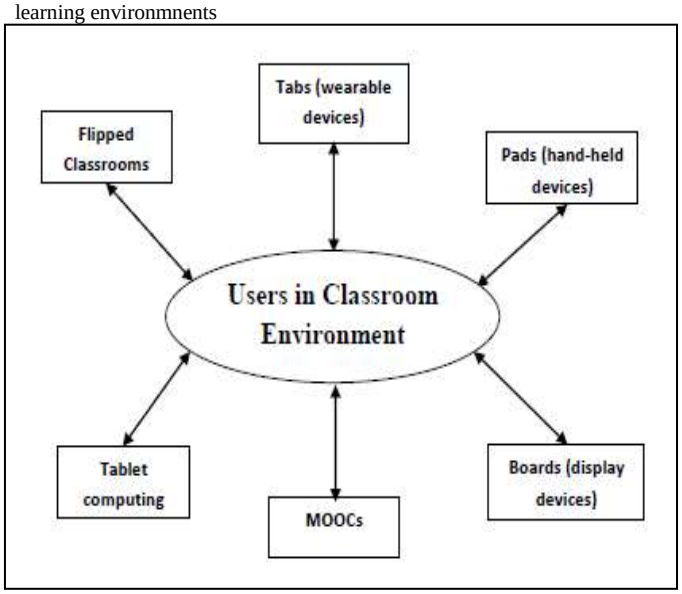
The significance of pervasive computing in classroom environments and its corresponding applications cannot be overemphasized. A review of current trends of pervasive computing in classroom learning environments were presented which included Massive Open Online Courses (MOOCs), tablet computing, flipped classrooms, and learning analytics. These technologies have been applied in some institutions in developed countries, but none of these technologies have been successfully implemented in Nigerian tertiary institutions. Description, research issues, relevance to classroom learning environments and locations where they have been applied were also presented. Examples of these applications with respect to classroom learning environments were presented. These reveal that pervasive computing technology in classroom environments play a vital role in the present phase of classroom education and future of learning. Its areas of applications are very broad and spans primary, to secondary and tertiary institutions respectively.

Furthermore, future trends of the applications of pervasive computing technologies to learning environments were presented. Among various issues of concern was the research issues associated with these future trends of pervasive computing technologies. Examples of their applications were also presented.

A. Adopting pervasive computing technologies in classroom environments of developing countries

Having searched the internet for scholarly articles on the applications of pervasive computing technologies in the classroom environments of West African countries, we discovered that not much work has been done in the application of pervasive computing technologies in Nigerian classroom learning environments. Our focus here is on the Nigerian educational sector with emphasis on Nigerian classroom environments; thus, based on existing literature in other continents of the world, [11-12], [16], [26-31], [34-35], we are proposing the adoption of a generic and viable model that will be useful at implementing pervasive computing technologies in Nigerian tertiary classroom learning environments. The model is as depicted below:

Fig. 1. Proposed pervasive computing tecnologies model for Nigerian learning environmnents



This proposed model, if adopted and implemented, will go a long way in solving some of the challenges inherent in classroom learning environments in Nigeria.

V. CONCLUSION

In conclusion, the numerous benefits and potentials of pervasive computing to our everyday life cannot be underestimated. It's impact on education, particularly, classroom learning environment, cannot be ignored. The need for further research is made evident by the challenges currently been observed in on-going research. Thus, pervasive computing is an interesting field of research that is worthy of further exploration. In this article, we highlighted the current and future trends of pervasive computing technology and its applications to classroom learning environments. A generic model of pervasive computing technology for developing countries, particularly the Nigerian classroom learning environment, was proposed for adoption to enhance learning and improve students' academic performances.

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