Teaching and Learning Chemistry Using Smartphones

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ABSTRACT

Learning in chemistry can indeed be quite difficult and a challenging task as the subject involves creating knowledge about abstract and complex concepts. In this regard, mobile devices became an integral part of the student of the 21st century serving several functions ranging from digital cameras to mobile tablets, from cell phones to mp3 players. These and many more functions of mobile phones are regarded as suitable and could assist learners when properly utilized. To some extent, it is considered that educating matured students without the use of smartphones is similar to educating a doctor without a scalpel. In view of this, the study utilized secondary data from a peer-reviewed and referenced journal articles, conference proceedings and well-authored books from different data-base including scopus, web of science, google scholar, science direct, academia.com etc. A total of fourty-one articles were selected and critically studied. Based on these studies, concepts were defined and described on how a smartphone is considered suitable to make the learning environment conducive and passionate for students as there are various applications found to support their learning of chemistry. The paper also discusses how leaning mobility and access to technology outside the schools could be enhanced using technology. Using smartphones in university and colleges, as instructional pedagogy was also part of the discourse in this paper. Some limitations for full integration of smartphones in learning chemistry such as of lack skills, technical issue and teachers' anxiety were part of the limitations outlined by the paper. The paper finally concludes that, although PCs are the most widely used computer technology with far-reaching meaning nowadays, the use of mobile phone technology is now increasing more rapidly than the PC and, in the future, it tends to restructure traditional classroom systems.

Keywords
smartphone, teaching and learning, chemistry, mobile learning, 21st-century

Introduction

According to Roschelle et al. (2012), most of today's classrooms are not very different compared to the classroom during the 19th century. There is a clear indication that the thriving of smartphones currently provides students with several opportunities to use the mobile app and enhance their learning activities (Wendeson et al, 2011). In line with this, a research carried out by Gaskell & Mills (2012) demonstrated that smartphones have a significant role to play in education generally and teaching and learning in particular, as it provides various opportunities and access to learning environments and resources. This allows many institutions to develop learners there-by supporting them with learning prospects in ways that would enhance current methods, particularly at the level of higher education.

Shuler (2012) reported that smartphones empower students to collect, review, analyze and process data and information which in essence enhances real-world learning. By implication students using smartphones in a collaborative learning environment enjoys better collaboration and communication (which are regarded as crucial for the 21st-century learning). Also, it could support the individual with diverse instructional styles. Evans (2014) claimed that learners develop positive attitude and interest when learning environment involves audio, video or both than in reading notes and textbooks. The audio-visual tools were observed to be helpful to students especially when they could be accessed and used after a lecture to review content materials at the students' pleasure time.

Considering the level of technological advancement all over the world, most especially in this era of mobile technology, using mobile phones in education most especially tertiary education mainly affect students' academic performance. According to Roschelle et al. (2014), with a demanding social nature of society, today's curriculum is expected to encourage students to improve their knowledge lot more than before. As time goes, a rapid increase in technology was noted and becoming more omnipresent.

Learning in chemistry can indeed be quite difficult and also a challenging task as the subject involves establishing meaning about concepts that are mostly abstract; hence, it is noted that collaborating knowledge and co-construction of ideas, focusing the changes in current practices of education are very crucial (Khoo et al, 2012). This means that in the chemistry learning setting there is a need for collaboration and sharing of ideas and understanding concerning the abstract concept for better meaning construction. In this struggle, recent technologies such as mobile phone seem to be of significant function.

Mobile devices became an integral part of the student of the 21st century serving several functions ranging from digital cameras to mobile tablets, from cell phones to mp3 players. These and many more functions of mobile phones are regarded as suitable and could assist learners when properly utilized. To some extent, it is considered that educating matured students without the use of smartphones is similar to educating a doctor without a scalpel. These perceptions of using a mobile phone in the form of technology for teaching and learning made the area of scholars' interest and researches begin to emerge day by day.

Literature Review

Learning Process with a Smartphone

Since recent technologies such as smartphones are accompanied with several functions that could support students' learning by enhancing student involvement (Khoo et al, 2012), it is imperative for students to realize the many possibilities and supports these tools could have on their learning. In this direction, science educationists, specifically in the western world, have seemed to be more informed of the vast possibilities and supports that smartphones are having in teaching and learning science. Thus, these technologies could support science education with a new strategy for presenting scientific concepts and processes most importantly that of chemistry which were considered difficult (Taber, 2015). In the developed world, for example, mobile technologies are abundantly used among young generations. The smartphone is considered suitable to make the learning environment conducive and passionate for students as there are various applications found to support their science learning processes.

Technologies such as smartphones (mobile phones) have made a dramatic alteration on people's behaviour. Most of the adult now days are very dependent on smartphones. A survey conducted by CourseSmart shows that college students keep reviewing their technological devices very frequently in a short course of time (CourseSmart, 2011). This is Indicating that when the learning environment is supported with smartphones, learners' interest and attention are easily captured and retained.

However, to capture students' interest and attention through a smartphone, three stages were discovered in learning using modern technologies which are e-learning, followed by m-learning and deepens to context-aware u-learning. (Liu & Hwang, 2011). Conventionally e-learning is considered as learning using computers and the Internet. Meaning that in modern education and pedagogy, computers play a vital role here. Conversely, with mobile devices and wireless communication, m-learning is possible to be conducted. However, both sensors and wireless networks are required for context-conscious or omnipresent-learning (Liu & Hwang, 2014). These categories of learning can be merged as most of the smartphones are equipped with sensors and wireless networks. According to Alexander, A. (2011) Mobile learning can be divided into three which are devices of mobile learning, communication, and activity of learning. Mobile learning can be defined as learning, study or teaching facilitated by using mobile phones (Huang and Lin, 2014). Any learning environment that is supported with mobile or smartphone is regarded as a mobile learning environment. The smartphones simplify some of the challenges of teaching difficult and abstract scientific concepts such as that of chemistry.

Maldaner (2012) is of the view that the current strategies of the teaching chemistry are pervaded by challenges that showcase even during the initial teacher training when pre-service teachers are confronted with pedagogical practices entrenched in out-of-date sequences of content and techniques that are in contrast with the reality. In Chemistry, only 59.7% of teachers acquired adequate training based on the data obtained in a report published by the Movement for Education in 2016. The report further that one of the strategies to improve the huge gaps in teacher training, especially at the high school is mobile technology-based instruction.

Mobile technology could potentially contribute a substantial part towards an active learning environment, it may be used to supplement teaching and learning processes to support the needed interaction among content, students and teachers. Mobile technologies can also yield better educational productivity thereby expanding the learning experience, supporting students' engagement and motivation and motivation to learn (swan et al, 2012), and accelerating learning (Ronaldo, 2016) support personalized and collaborative learning (Swan & Kratcoski, 2015). Students who use smartphones to collaborate in problem-solving demonstrate a positive outcome on content understanding (Swan et al, 2012). This indeed is part of what the current trend of 21st-century learning is targeting. ` Contrary to many people perception, m-learning is not intended to replace the previous system of learning in the classroom but provides an additional way for learning content to be incorporated into people's daily lives. Schools could use mobile technology in diverse ways to support the teaching and learning processes. Despite the merits already seen in the use of mobile learning technologies in a school setting, expanding it is still a challenge (Ting, 2015). However, if the technologies are properly utilized, the challenges smartly handled, effective learning environment emerges which make the learning conditions acceptable by learners.

Huang & Lin (2012) in a research conducted on m-learning user acceptance observed that m-learning is perceived by individuals as omnipresent and easy to use and is considered very useful by students with the mobility it offers. One example of m-learning can be seen from a competition that required participants to enhance their skills in spelling and reading by playing smartphone-based games. Other than "Learning in the classroom" smartphones can be used in laboratories to develop students learning and empower their knowledge in chemistry laboratories. This seems to enable students to use mobile learning devices like the smartphone to learn chemistry concepts (Khoo et al, 2012), and realize many supports their mobiles could offer them learning concepts most especially the abstract ones.

Squire (2014) argues that while mobile phones are not so much utilize informal school environments, gaming companies are emerging to develop games with the educational context that could be supported with mobile phones. For example, the Brain Age product of Nintendo and the More Brain Training advertising campaigns where one can observe that more gaming companies continue to develop educational games that facilitate some kinds of learning.

Vavoula et al (2013) uphold that students in higher institutions of learning can have real-world activities by smartphone. Abstract concepts of chemistry are learned by simplifying the complex component through a little modification of displaying the real composition. This is crucial for science learning which involves gaining knowledge of the complicated concepts and the ability of students to correlate their knowledge with personal experiences (Vavoula et al, 2011). For example, Google launched a free VLE system called Google Classroom. This environment was mainly for the institutions that possessed the Google Suite for Education account. However, in 2017, it was accessible by any Google user, though with certain limitations of use. Its management system has a simple interface integrated with other Google resources, such as google docs, presentations, spreadsheets, and calendar which swells its possibilities of use. Despite the multiplicity of resources, it is still a modest platform compared to the aforementioned ones (Martin, 2014). Its modesty is proved by its simplicity, flexibility and verities of applications main for learning processes.

Trinder (2015) emphasized that smartphones can be used to present information, write notes, play educational games, listen to recorded audio other files, view images, watch video clips, and take photographs. Recently, some universities have started using smartphones to store information such as e-books, courses, and schedules (Ferry, 2012), which made the documents or data accessible anywhere and anytime since smartphones are mobiles, unlike desktop or laptop computer that may not be at individual possession at all time.

Another research was done by Klopfer and Squire (2014) about smartphones in teaching and learning. Their finding states that most of smartphone and mobile device applications are derived from three major criteria of portability, connectivity, and individuality. This criterion is used to develop an application on education and entertainment.

In addition, Huang et al (2011), smartphone applications support students to learn content conveniently through online collaboration and interaction with peers anytime and anywhere. A study conducted by Williams and Pence (2011) shows smartphones in learning as a potential tool that can be used to learn many concepts in chemistry.

While the use of educational games in learning enables learners to develop curiosity, critical thinking to solve problem, communication, collaboration, responsibility, smartphones are found to be very suitable in facilitating these skills as educational mobile games are easily downloaded and installed in the smartphones. For example, simulations

may represent a more interactive and dynamic way of learning chemistry (Martin, 2013). According to Noh & Scharmann (2016), chemistry teachers need to be aware of the learning affordance of the use of simulations for chemistry concepts at the atomic scale. Some of the online simulations have been widely tested and evaluated to ensure educational effectiveness. The simulations were written in various computer signs and languages such as Java, Flash or HTML5, which can simply be run online or downloaded to a smartphone. The simulations allows for modifications and re-designs by teachers and students.

Methodology

This study involved the use of secondary data from a peer-reviewed and referenced journal articles, conference proceedings and well-authored books from different data-base including scopus, web of science, google scholar, science direct, academia.com etc. A total of fourty-one articles that discussed about “smartphones and the learning of chemistry”, “mobile apps for learning chemistry”, “pedagogies for learning chemistry using smartphones”, “limiting factors for adopting smartphones in learning chemistry” or any article that is well-written on teaching and learning chemistry using smartphones were selected and critically studied. Based on these studies, concepts were defined and presented to aid chemistry teachers and students fully integrate smartphones in teaching and learning chemistry.

Smartphones and the Learning of Chemistry

Some smartphones applications proved to exhibit features that support teaching and learning chemistry abstract concepts. These applications also support chemistry teachers with modalities for evaluating and testing learners’ chemistry level of learning in chemistry (Libman, & Huang, 2013). The applications help disseminate chemistry abstract concepts. In Chemistry, there are mobile applications that may help students learn chemical formulas, provide detailed information on the elements they can examine and take notes on what they learn and then test their knowledge and understanding. Hence, it is believed that smartphones can improve students’ understanding of chemistry concepts alongside facilitating social relationships and critical thinking skills (Karim, 2012). Therefore, the smartphone that many students of higher institution possess could be exploited as an appropriate learning tool to enhance their learning experience.

Smartphones are already used in the chemistry classroom as a powerful tool. The iPhone app from the American Chemical Society enables students to search for more than 850,000 scientific articles. There are periodic tables to study elements or compounds in smartphone apps such as molecular geometry in the iPhone. The RCSB Protein Data Bank also offers 3D visualization of biomolecules on smartphones. Not only for chemistry, but numerous apps also present that can be used in educations by teachers and students. For example, using apps teachers can link "pictures of their students with class rosters, logging observed data, capturing notes from a whiteboard, scanning documents" or mapping smartphones with the concept (Williams and Pence, 2011). These and many more are some of the affordability of a smartphone.

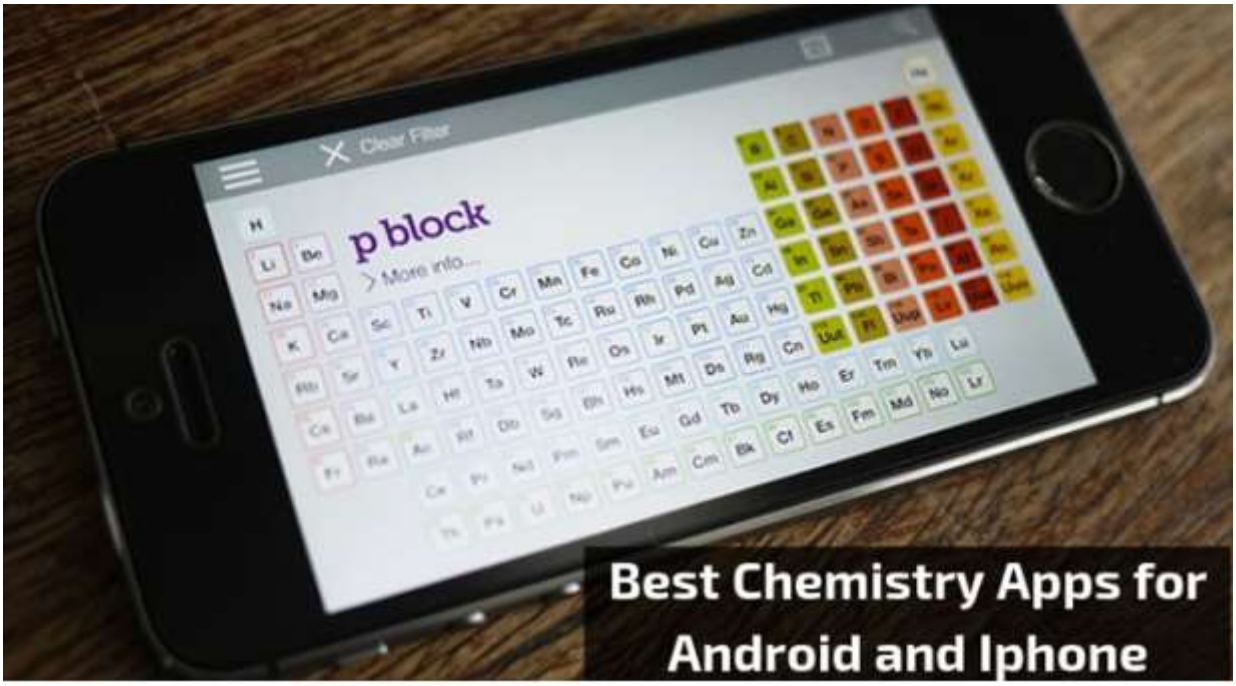

Figure 1. Molecule Geometry for iPhone (Powell, 2019)

It is possible to scan the 2D barcode found in an object such as those on the containers of chemicals using a smartphone which linked to a specific site to derive the information of the product. This can be used by the students to learn more about the products found in the real-world such as at convenience stores which enables them to learn from life experiences (Williams & Pence, 2011). Students at their leisure time can learn about various chemicals and products of chemistry. Some apps present chemical reaction and structures in organic chemistry for proper and better visualization by students compared to that of textbooks.

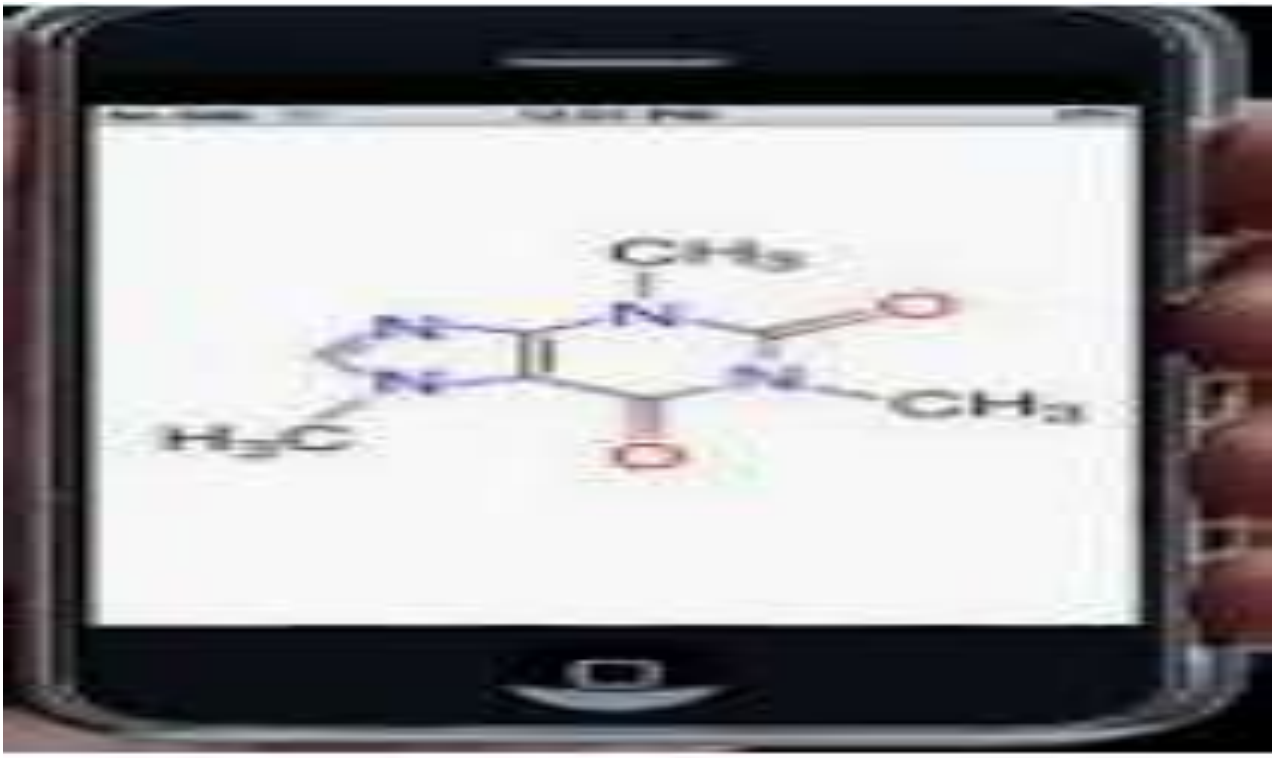

Figure 2. Chemical Reaction Mobile App (Zanoj, 2019)

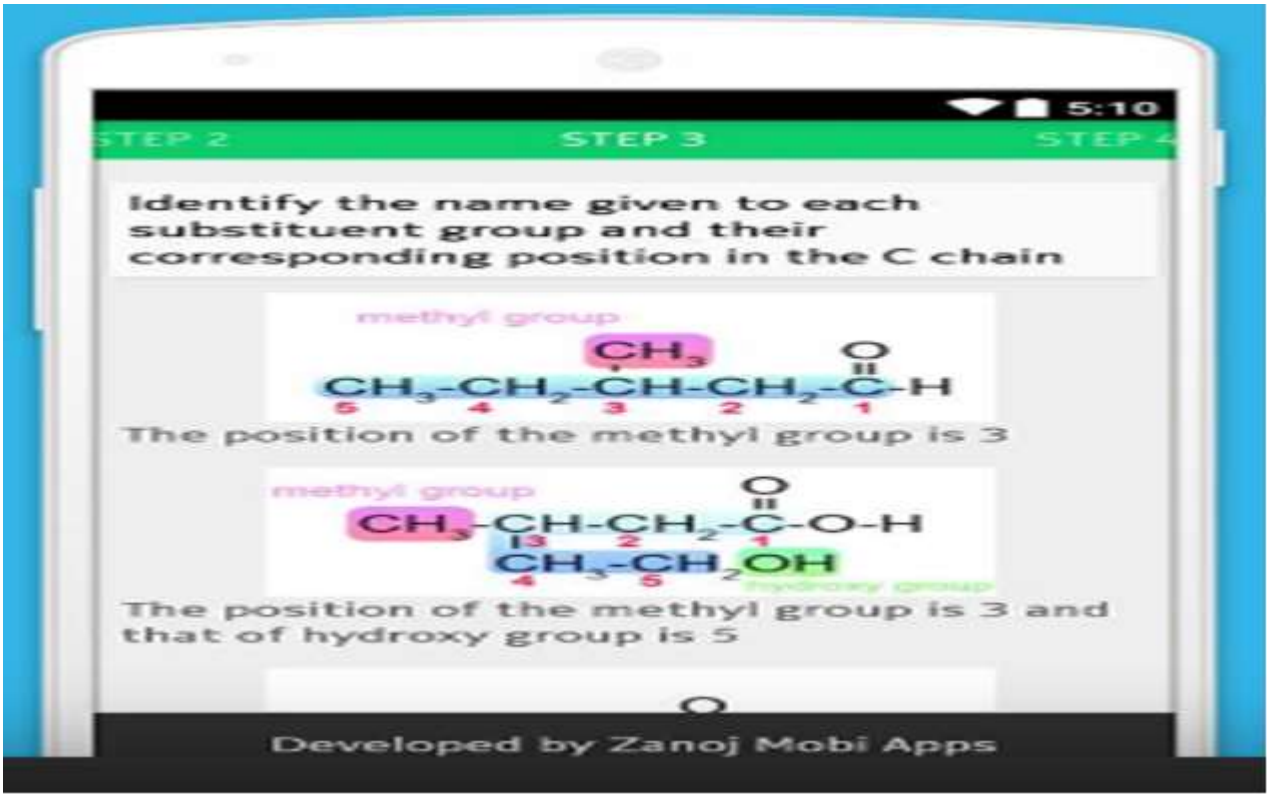

Figure 3. Organic Chemistry Mobile App (Zanoj, 2019)

According to Robert (2016) and Zanoj (2019), currently, the world is full of technologies and applications that enable students to enhance their m-learning, especially in chemistry. Learning using smartphones and the connection that arise together with the collaboration of the real-world makes learning chemistry more effective and prevents the students from isolation.

Access to Technology Outside the Schools

Technology mobility refers to the use of technology which is not restricted to a specific place due to the mobile nature of the hardware and software installed. For better mobility, an uninterrupted wireless internet connection is required. Learning mobility meant the ability of students to learn anywhere. This mobility is supported by smartphones. Learning mobility is the result of technology and learner mobility (El-Hussein & Cronje, 2011). It is of greater influence on students' learning because students need to better utilize every second of their time judiciously.

Currently, there are global challenges that affect the school situations and condition concerning teaching and learning. The challenges include pandemic diseases such Corona Virus, armed conflict, or climate change which lead to closing of school and render students to stay at home. A lot of official school time for lesson activities will be lost as education systems scramble (Martinez). To avoid this lost mobile learning is found to play vital role as students could engage using their mobile phones (smartphones) right away from their homes in the form of online or offline learning. online learning should be used to of school closures, governments should ensure that all children recover missed in-person. Martinez (2020) reported that UNESCO recommended that countries should adopt a variety of mobile technology ranging from hi-tech such as smartphone to low-tech solutions to ensure the continuity of learning even during pandemic, conflict of climate change to avoid damages on students' educational carrier and prospects.

Students Skills Development using Smartphones

In a research carried out by Zurita and Nussbaum (2014) on how computer technologies could support teaching. The results revealed that realization of the importance of cooperation and collaboration among students is integral in developing their dreams which makes a positive influence toward better learning. This technology of smartphones develops social interactions among students. At the same time, it develops the motivation which influences students' learning. Teachers started to believe that these technologies can be used to share lesson notes and exercises to students easily.

Mobile devices are categorized as social connectors as it is readily used to communicate. As a communication tool, smartphones can be used to collect data such as interviews and questionnaires (Pachler et al. 2011). Using mobile devices as an m-learning tool for educational purposes in classrooms offers students and their teachers several advantages and opportunities. For example, in collaborative activities, smartphones can be used to share the knowledge received by students to their friends and teachers. This is aligned with the findings noted by Franklin & Peng (2011) where helping nature is seen among students when two students share their earphones with another student to watch the educational videos using an iPod. This is valuable for the development of the student for their future and crucial skill to be learned

Smartphones in Higher Educations

Smartphones can be used as tools to enhance learning. They are currently being used in three main ways of education. First, the embedded smartphone web browser links to great material wealth. Second, low-cost but useful smartphone applications are used for various reasons. Third, as a scanner of barcode labels provides information regarding the scanned objects. A survey conducted at the University of Colorado and several other universities in 2010 found that text messaging and emailing are two of the most used functions on smartphones among college students, followed by reading news, watching videos and reading books (Dean, 2012).

Turkle's (2011) stated that most of the students prefer to text message compared to phone call conversation as they feel there is freedom in answering were students able to choose whether they want or don't want to answer the text message. This is also related to a psychological explanation that summaries that student's minds consider phone calls as a disturbance in nature (Turkle, 2011). The findings of Turkle are supported by another research done by Brighton

University in the UK finds out that text messaging plays a role in helping students to step into college from high school. Brighton University itself uses messenger to communicate between lecturers and students. This messenger system allows students to receive text messages directly regarding the lecturers.

In the meantime, some colleges are making their way by adopting this kind of technology in their centre. Many universities and colleges already possess their system that enables their students to browse and access information using their smartphones. A modified website-friendly smartphone version has been created from its main website library. The website of the mobile library allowed students to search for library hours, workshop schedules and basic contact information from the library. In 2009, According to research on the experience and expectations of Ryerson University students using the library mobile app, "searching for articles, reading eBooks, checking books, and contacting librarians / obtaining research assistance" was the student's most needed requests. (Wilson & McCarthy, 2013).

There is also a growing number of applications form-learning. An example of such an application can be seen used by college and university professors. Students will be notified the same moment when the professor uploads the assignment on the website (Robert, 2016). Students can view, read and download the assignment using their mobile phones which ensures the assignment reaches the students at that same moment. Since the downloads were done using smartphones, students can read anytime and anywhere they want according to their preferences. This enables students to always to stay connected with educations.

Pedagogy using Smartphones

The applications analyzed in this study exposed different characteristics and features that support the pedagogical needs of teaching chemistry. The use of mobile learning technologies by teachers is generally intuitive and not stuck on what an application can provide to support their teaching practices (Seery & McDonnell, 2013). This intuitive use principally considers the ease and visual appeal of the applications with subtle attention to more erudite features such as note sharing and the possibility of collaborative activities among learners. An interview with the teachers conducted by Hall (2017) indicated that majority of teachers perceived the usefulness of applications is incredible, but when it comes to pedagogical implementation it can at best be classified as modest.

There are varieties of mobile learning strategies in the form of games that could promote students' reasoning skills in science and technology and chemistry in particular which includes Puzzle, Simulation, Scratch, Video Game, Brain Blast and Kahoot (Talib & Aliyu, 2019). Furthermore, there are digital technologies that are supported by smartphone and were found to be suitable for teaching chemistry and general science. Among recent technologies, Augmented Reality is one of the superb strategy of teachingwhich integrates both digital information and graphics with the user's real-time environment through audio-visual and sensory stimulus. The flexibility and portability of augmented reality made it easy to be designed usding smartphone (Aliyu & Talib, 2020). The use of this recent technologies is proved to impact positively on students learning outcomes. Rafiq & Hashim (2018) revealed that utilizing mobile augmented reality in teaching and learning enhances students' academic engagement and foster their understanding. This is indicating that augmented reality possesses certain affordances that enhance the development of 21st-century skills.

The use of m-learning technologies in teaching chemistry is not necessarily an approach well received by teachers (McDonnell, 2013). This behaviour reflects, at least in part, the feeling among teachers for whom the technologies are interesting but involve more work, which is not compatible with their difficult financial situation and long working hours. There is also an extensive debate on the reasons for resistance to the use of learning technologies.

Limiting Factors

One of the main issues at stake is to how to motivate teachers to explore mobile technologies in their teaching activities. Regarding the teaching of chemistry, teachers use almost exclusively traditional methods of teaching. (Ronaldo, 2013). The teacher is already using the traditional approach and have some anxieties to use technologies in their classrooms due to lack of skills, expertise and technological know-how.
However, the challenges they faced were the provision of wireless technology without setting it up by an expert. Every time online-based resources or websites were blocked, the teacher had to contact the expert. It is not uncommon for schools to have technology in their classrooms, but there are inadequate facilities such as experts and

supports for technical issues (Franklin & Peng, 2016). Facilities are inadequate in most of the developing countries and skills to manage technical issues are also a challenge to the common teachers. Teachers required to master the required skills in technologies so that will be able to teach students using technologies without any obstacles. But not all the teachers are aware of the technologies and even some elderly teachers lack technological knowledge due to their childhood background without smartphones

Furthermore, a classroom that supposed to be a fun and entertaining environment with technologies become unrealistic due to limited power supply to charge a mobile phone in the classroom. This also accompanied with crowded classrooms which makes it difficult to implement the use of smartphones in classes (Franklin & Peng, 2016).

The curriculum needs to be rethought. Squire (2013) expresses difficulties for the experts to incorporate the smartphones and technologies in currents conventional teaching in schools. Still, most of the teachers believe that teaching chemistry using smartphones as a foreign idea and concepts (Franklin and Peng, 2008). Some schools are more reluctant to allow technology to be used in schools and the education system. They are convenient in the current teaching practices and educational structure (Roschelle et al, 2011).

Huang and Lin (2013) claim that still lacking adequate research on smartphones and mobile learning. More needs to be conducted to obtain data on learners' perspectives. The behaviour and experience of students using smartphones need to be studied to enhance them-learning.

More studies need to determine the effect of the daily life of students with the usage of smartphones for a better understanding (Scanlon et al. 2015), and also to find the relationship with m-learning. A detailed analysis required to propose the need for the smartphone in chemistry educations in all levels of educations

Conclusion

PCs are by far the most widely used technology with far-reaching meaning nowadays. However, the use of mobile phone technology is now increasing more rapidly than the PC. Experts notice the possibilities and development of m-learning using smartphones. Although it is slow in some schools, in the future it tends to restructure traditional classroom systems.

Most students, who used smartphones in learning, used it for research purposes, in reading science news, books and articles online, some students used their phones Science dictionaries and calculators. Only a few students used their phones' office applications. Researchers have carried out numerous studies, where some of the doing collaborative research with teachers and educational staff to understand and deepens the effect of smartphones in school education systems. Need to be clear in the difference made in formal and informal educations that cater to smartphones.

Therefore, this research gave a better understanding of student's practice and perception towards learning through smartphones and therefore will help to enhance educational activities and aid in engaging students to contribute to their learning. It also provides an insight into students ' type of smartphones and what they can do with them.

Learning no longer depends on the learner's location, but anyone with a wireless mobile device can learn anything, anywhere, anytime. The challenges for m-learning will certainly be easier to overcome by time. Based on previous research and literature, one clearly can conclude that the use of smartphones in education is the future of education in this world. To make it better, skills need to be enhanced in the area of integrating smartphones in education to supply a professional education that can support the younger generation that can strive this competitive world.

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