Synergizing Augmented Reality and Chemistry for the 21st Century Classroom

Mohd Shafie Rosli

School of Education
Faculty of Social Sciences and Humanities
Universiti Teknologi Malaysia
Malaysia
E-mail: shafierosli@utm.my

Abstract: Effective chemistry classroom remains a persistent and pervasive challenge. In many institutions, chemistry is taught in practice that by now seem to be ineffective. Traditional practice such as lecture, content delivering, and rote learning render chemistry being perceived as memorizing facts. Situation has become even more acute with the rapid changing of student from z and y – generation. The classroom should have substantive understanding of how the new generation of student learn. Short span of focus, difficulties in visualization are among the characteristic of this digital native. As content is now made available in the web, the new role of teacher continues to be the centre of debate in academic researches. To solve a myriad of challenges in chemistry classroom, augmented reality seems to have a tremendous potential in creating the 21st century classroom for chemistry. Finding from author's and several other researchers are being discussed in this paper. It was all the positive side of augmented reality that attract further application of augmented reality in chemistry classroom, but it is doubtful if the cascade got much further. The fact that student get deviated by augmented reality is too obvious to be ignored. Thus, argument that augmented reality is time consuming is not really tenable. As countermeasure, a strategy on how augmented reality can be applied with exploration and knowledge construction hang in the balance is being suggested.

Keyword: Chemistry Education, Augmented Reality, 21st Century Classroom

Education is imperative for every nation. Education serve as engine that fuel economic progressiveness by generating workforce capable of catalysing the national vision. Nation with manpower skilled in higher order thinking and complex thinking have a better prospect. Therefore, todays education had transformed from emphasizing knowledge to featuring thinking skill in learning (Siti Zubaidah Omar, 2018).

Although learning is the centrepiece of education. Learning might be effective and ineffective as well. If effective is good, ineffective learning give unfavourable impact to the education itself. It led to low achievement among students, especially in thinking skill (May and Winnie, 2011). Siti Zubaidah Omar, Mohammad Yusof Arshad & Mohd Shafie Rosli (2018) reports students who learn chemistry through the traditional method is prone toward low skill in thinking. The finding authenticates finding of other researchers such as Mohd Shafie Rosli, Baharuddin Aris & Maizah Hura Ahmad (2015) in chemistry, Ahmad Fakharudin Mat Zin (2018) in mathematics and Emir Nashriq Kassim (2017) in science. Therefore, what is the solution to this problem? Let's have a review on the current practice.

THE CURRENT PRACTICE

Among the factors that contribute toward ineffectiveness of chemistry education is the pedagogy being used. Contemporary approach to teaching chemistry has been critiqued. Chemistry has been long being associated with lecture-based teaching and learning. It is a norm for science subject to be teaching using lectures and tutorials (Chui-Man & Kwan-Yee, 2018). Yet, this traditional method of teaching fail to address the difficulties in learning chemistry faces by the student (Marzabal et al., 2018).

The common practices in school in teaching chemistry is a teacher-centred classroom as reported by Tan Yin Peen & Mohammad Yusof Arshad (2014) and Lim Tzyy Chyun (2007). In this situation, teacher serve as fundamental element of learning with students sit silence, observe and receive information from the teacher in passive manner (Winnie Sim Siew Li & Mohammad Yusof Arshad, 2010). Teacher imparting all the knowledge he or she know about a chemical concept to the students with assumption that students able to digest the knowledge easily – without problem or difficulty, yet, it is not always the case (Mohd Mokhzani Ibrahim, 2018).

Some teacher has the idea that our role is as the source of information and the task is delivering the content. When the information is delivered in mass lecture format, its foster learning by memorization (Watters & Watters, 2007). Teacher assume students as an *"empty vessel"* that only obeying and instruction from teacher (Tan Yin Peen and Mohammad Yusof Arshad, 2013). Huges & Wood (2003) argued this as "the bottle theory of education" as not the correct way of teaching. The assumption that students in a vessel to be filled up with information and once it is filled, student is ready to work. In addition, some information might not be captured by the bottle and even it might be computer, the information might not actually the information that student need.

Figure 1: Illustration of The Bottle Theory of Education by Huges & Wood (2003)

The result of this practice is, student is learning through rote learning (Latifah Abdul Raub et al. 2018). By depending on rote learning, students are unable of obtain conceptual

understanding of a phenomenon (Lamba, 2008). They unable to understand the underlaying concept for the chemical problem occur.

THE INEFFECTIVENESS OF CURRENT PRACTICE

The current pedagogy being practice is totally no longer relevant. Especially toward the z-generation and y-generation. They just have a very short span of focus. Both the z and y - generation are known as Digital Native (Mohd Shafie Rosli et al. 2018). Generation who never experience life before the era of Internet and born from 1977 to 2012 (Roblek et al. 2018). Generation who lived in an era of technology being handy to young people (Turner, 2015). They born with all sort of electronic and digital devices around them. Due to this nature, the way how they think, their preference as well as how they learn had radically changed from the generation before them.

For a highly literate IT generation, lecture that require intense focus is totally contradicting to their character. According to research conducted by Mohd Shafie Rosli et al. (2018), digital native need graphic and gratification as found by Teo (2013). They need active learning, not a passive one. Thus, mass lecture is highly unlikely to attract them.

Despite being IT literate, they always found themselves lack interest in content-oriented learning environment. Yet, these generations are still prone toward weak visualization skill. Siti Zubaidah Omar (2018) reports this weakness is not limited toward ordinary students, students from high performing school are also weak at visualization. Siti Zubaidah Omar et al. (2017) reported that among the visualization problem faces by the student in chemistry are:

i. Inability to understand the conservation of mass
ii. Inability to mastering the concept of atom
iii. Inability to understand the concept of chemical reaction

The current practice also neglects the importance of the multiple representation in chemistry. The idea of multiple representation in chemistry was pioneered by Johnstone (1991). Student should master three level of thinking which are macroscopic, microscopic and symbolic to be a competent learner in modern classroom. However, this concept is not easy to be mastered (Mohd Mokhzani Ibrahim, 2018; Siti Zubaidah Omar et al. 2018).

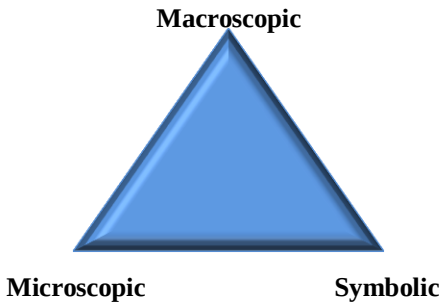

Figure 2: The Multiple Representation in Chemistry

In traditional method of teaching, the concept of multiple representation is being overlooked. In some case, the implementation is not in the right sequence (Tan Yin Peen & Mohammad Yusof Arshad, 2013). As concepts in chemistry is beyond human sense and

students have little or no experience in constructing such abstract information. Sooner or later, student prone toward misconception and alternative concept.

21st CENTURY CLASSROOM, NEW TOOL IS NEEDED

To ensure an effective education for chemistry, the current practice need to be revised. It is no longer enough for teacher to deliver the content (Siti Zubaidah Omar, 2018). Based on discussion above, researcher concluded that there are three main problems that need to be emphasized in the 21st century classroom.

First, to serve the need of digital native that consist of the y and z-generation. They need graphic and gratification in learning. A static text book never appeals to their nature. Something graphical in nature and able to give them pleasure of exploring around is needed instead.

Second, to facilitate student with weak visualization skill. Most of the concepts in chemistry need high level visualization. Such as the concept of valence electrons, atomic structure, stoichiometry, redox and ions. Such concept never being seen by naked eyes, it needs specialized instrument which is normally absent in our classroom.

Third, a tool is also needed to facilitate student to think at macroscopic, microscopic and symbolic levels. The ability to make connection between these three levels is paramount in ensuring an effective learning could be materialised. The question is, what is the tool that could overcome this problem? How it can be done?

THE NEED FOR A BETTER ROLE OF TEACHER

Teacher is no longer the source of information, the centre of the classroom or the only one talking in the classroom. With the emerging of new technology, teacher is no longer teaching but we have a bigger role to play as instructor that moderate and facilitate students process of information seeking and knowledge construction. Based on research conducted toward chemistry student, Mohd Mokhzani Ibrahim (2018) states that teacher's role had shifted from teaching to becoming supervisor, thinking activator, simulator of student's prior knowledge and challenger of student's understanding. The question is, what is the tool that capable of fulfilling all the stated teacher's role?

THE POTENTIAL OF AUGMENTED REALITY FOR CHEMISTRY CLASSROOM

Augmented reality is a set of technologies that was invented as a mean of overlaying the digital world or information and the real world with the purpose of giving user a better perspective experience (Berryman, 2012). It constructs a superposition display by combining the real scene and virtual scene (Zhang, 2018). Augmented reality compliment the content-oriented book and able to interact with user via video and audio linkage (Fan, 2018). Information display that was before not visible to human eyes is now observable with the support of devices such as computer, smart phone, tablet and HMD. It does not eliminate the reality but improve the reality with its digital information. Its main goal is, supplementing three dimensional stereoscopic into the real world as mean of enriching user's perception (Maqableh & Sidhu, 2010).

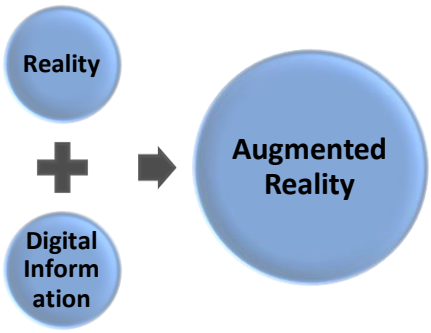

Figure 3: The Fusion of Reality and Digital Information to Form Augmented Reality

Potential in Teaching

As stated before, chemistry is abstract (Chittleborough & Treagust, 2018) and intense visualization is crucial. The application of augmented reality technology is just right for teaching and learning chemistry. Fan (2018) had enlisted three advantages of teaching with augmented reality which are:

First, synthesis of the virtual and reality. This feature enable user to experience the virtual in reality (Fan, 2018). Concept such as the movement of ions during electrolysis or the molecule arrangement of a solid object are now observable. Student no longer have to spend their time trying to digest teacher's explanation nor struggling to imagine it in their mind. The static figure in the textbook is thing of the pass. Supplying students with augmented reality not only enrich their learning experience yet stimulate senses and reduce propensity toward misconception.

Second, natural interaction. Augmented reality eliminates the need for special gear such as VR glass. It can be rotate at 360 degree, move freely, zoom and observes from multi angle (Fan, 2018). Amalgamate the need for visualization aid and hands-on activity to construct knowledge in chemistry. In fact, in learning science student rely on 360-degree rotation and multi angle viewing as one of knowledge construction mechanism (Emir Nashriq Kassim, Mohd Shafie Rosli & Azri Syazwan Atan, 2018; Emir Nashriq Kassim, 2017).

Third, three dimensional stereoscopic. Augmented reality not only facilitate student with visualization. It also gives 3D output that give a clearer understanding of a phenomenon (Fan, 2018). The 3D output of augmented reality has been proven effective in escalating user's visualization skill (Mohd Shafie Rosli, 2018).

Advantages in Learning

The positive benefit from using augmented reality has being well documented. Mohd Shafie Rosli (2018) reports that augmented reality improve sample's spatial visualization skill significantly. Samples uses lots of tracking features with male showing higher focus than female. Lighting condition was reported as an important parameter that concerning user's interaction. Augmented reality nurture higher level thinking among student in science (Emir Nashriq Kassim, 2017). Science process skill was reported being improve tremendously after using augmented reality for two continuous weeks and 360-degree rotation is among the most

vital feature that construct student conceptual understanding (Emir Nashriq Kassim, Mohd Shafie Rosli & Azri Syazwan Atan, 2018).

Ming-Puu and Ban-Chieh (2015) reports that static augmented reality improves student's comprehension on electrochemical concept. It not only improves user's knowledge but satisfaction toward content as well (Kularbphettong, Roonrakwit & Chutrtong, 2019). Augmented reality video gives higher learning efficiency (Yip et al., 2018). From the aspect of hands-on procedure, Ribeiro, Martins and Garcia (2018) conclude that augmented reality is beneficial for training of medical equipment.

Yet, augmented reality still relying on reality object to act as anchor. For example, a tracker, building or physical structure. Rapid development of mobile terminal equipment and advancement in digital publishing technology render mobile technology as a new tool of supporting teaching and learning even in the area of augmented reality (Fan, 2018). Augmented reality is now mobile through the usage of mobile application designed to support augmented reality.

HOW TO DEVELOP AUGMENTED REALITY FOR CHEMISTRY CLASSROOM

Today, augmented reality is available to user and teacher in abundance. Several options are available. Teacher can develop their own augmented reality application using software such as Unity and Aurasma @ HP Reveal.

Unity is a powerful software platform being uses widely to develop games and augmented reality application as well. It is also popular among augmented reality researchers for example Erra (2018), Kim, Huh & Kim (2018), Diao & Shih (2018) and Amaguana et al. (2018). Unity uses Vuforia, SDK package for Unity to develop augmented reality for smartphone and tablet that using Android and iOS (Nguyen & Dang, 2017).

Figure 4: Unity, a powerful platform to develop Augmented Reality

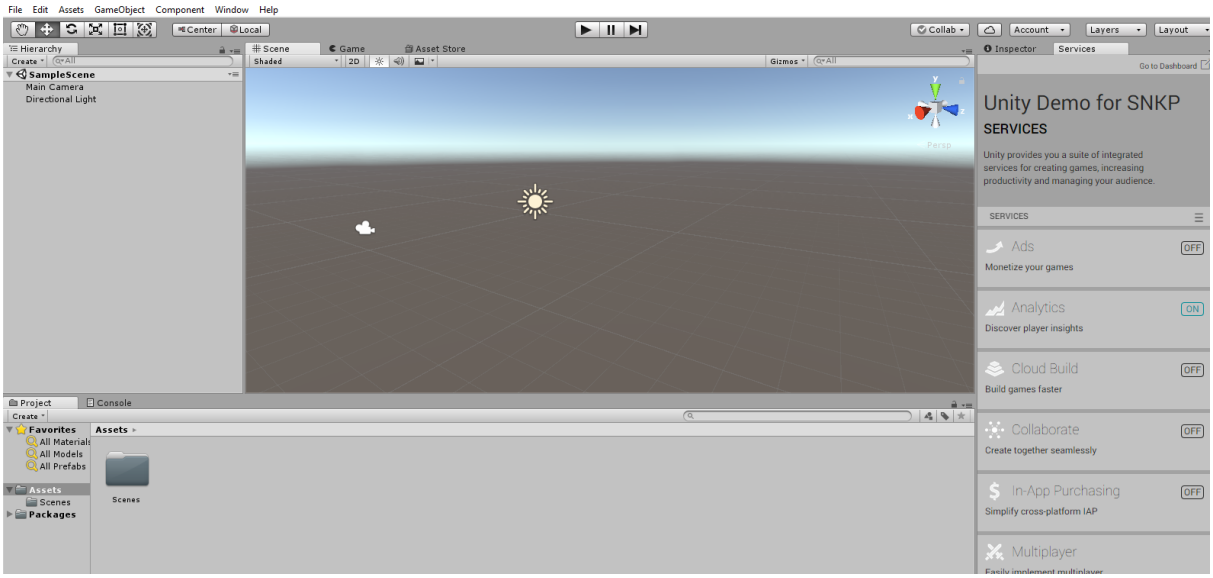

Figure 5: Interface Display of Unity (Source: screenshot of installed Unity Software downloaded from https://unity3d.com)

By using Unity. There are three types of account to choose. Which are Personal, Plus and Pro. Each account has their own purpose. You may access Unity at https://unity3d.com. Please refer to author's slide for the procedure of developing augmented reality using Unity.

Aurasma orHP Reveal is another powerful augmented reality development platform among researcher. Various researchers such as Holzschuh & Bogoni (2017), Opris et al. (2018) and Norkhamimi Zainuddin & Rozhan M. Idrus (2018) already uses Aurasma in their augmented reality research. Aurasma was later rebranded as HP Reveal. The advantage of Aurasma or HP Reveal is it is highly portable in nature and developer can share their augmented reality product with others using the platform making this technology assessible to large portion of user and educators as well.

Figure 6: HP Reveal known before as Aurasma

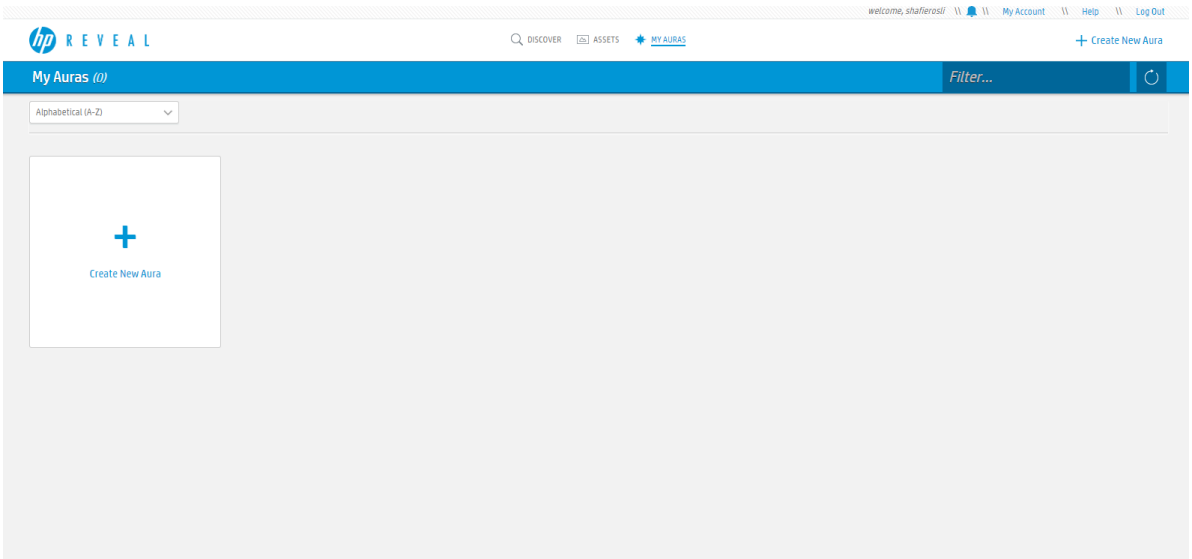

Figure 7: Interface Display of HP Reveal (Source: screenshot from https://studio.hpreveal.com/home)

HP Reveal provide user with free trial. HP Reveal site is https://www.hpreveal.com. Please refer to author's slide for the procedure of developing augmented reality using HP Reveal.

For educator that might not familiar with design and development process of multimedia, they can use numbers of augmented reality mobile application that available at Google Play Store and Apple App Store. Numerous augmented reality mobile applications are now available for free. Thanks to the generous developers and educators for their work.

Figure 8: Google Play Store and Apple App Store are suitable for educators without development knowledge

HOW TO IMPLEMENT AUGMENTED REALITY IN CHEMISTRY CLASSROOM?

Even though augmented reality is well accepted as beneficial to learning. There is still a concern that student assumes augmented reality as tool of play rather than a formal knowledge construction tool. Result in long engagement, deviation and eventually content sound insignificant during the engagement (Mohd Shafie Rosli et al., 2018).

To ensure optimum augmented reality engagement in chemistry. 5E Modelling model is highly suitable. This model was developed by Siti Zubaidah Omar (2018) to facilitate modelling skill nurturation among students in chemistry classroom. It was constructed through infusion of 5E Model by Bybee et al., 2006, modelling skill by Dori & Kaberman (2012) and multiple representation in chemistry. The model is as below:

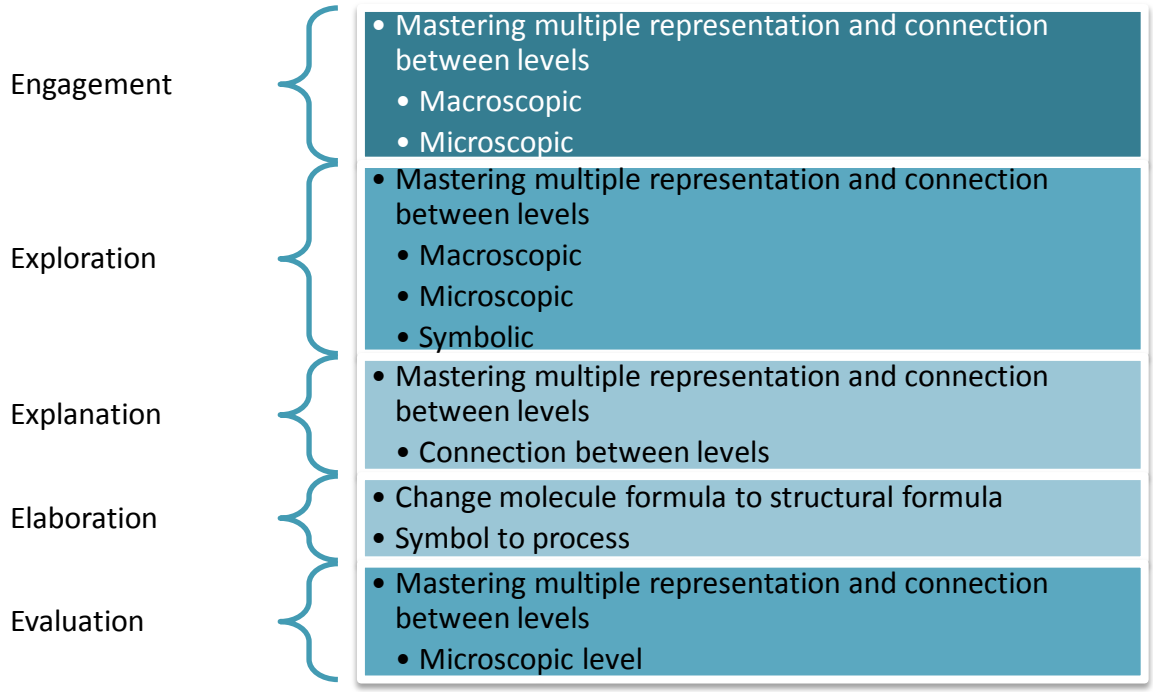

Figure 8: 5E Modelling Model, the result of doctorate study by Siti Zubaidah Omar

In Engagement, teacher start with an engagement video about the topic. Here, teacher show how the augmented reality work and explain the concept from macroscopic and microscopic level.

During exploration phase, student is not exploring without purpose. The three level of multiple representation must be the centrepiece of the exploration. They explore the concept from macroscopic, microscopic and symbolic level. Using spreadsheet that provoke students toward finding the answer at each level might be useful. Online database and survey form are also applicable especially for students with high IT literacy. Hands-on and minds-on activity as well as group work take place here. The roles of teacher are as supervisor and moderator.

At Explanation phase, student communicate with each other and brainstorming. To direct or correct idea constructed by student, teacher act as idea challenger and stimulate prior knowledge. A discussion is a must. The augmented reality application is no longer being use actively here but just as source of reference. To boast understanding, self-reflection is crucial.

Student then extend the new knowledge into much complex situation in Elaboration phase. Yet, if the new situation is too complex most probably student tend toward confusion. Thus, Siti Zubaidah Omar (2018) suggest student change the molecule formula to structural formula and from symbolic to process.

At the final phase, to evaluate how much has been learn it is highly recommended for teacher to probe into the most difficult skill which is student's understanding at microscopic level. In case the knowledge constructed is wrong, the augmented reality application is beneficial in correcting their knowledge.

THE BENEFITS OF AUGMENTED REALITY TOWARD CHEMISTRY CLASSROOM

After almost a decade augmented reality being introduced into chemistry classroom, its efficiency in facilitating student learning is beyond argumentation. Researches show the visual prowess of this technology increase student's conceptual understanding and cognitive skill as well. A few of researches on the benefits of augmented reality as indexed by SCOPUS is as follows.

Researcher(s)	Research Scope	Findings
Cai, Wang & Chiang (2014)	Application of Augmented Reality simulation in Chemistry Course	Increase in cognitive performance Low achiever shows higher gain than high achiever
Yang, Mei & Yue (2018)	Investigate pre-service chemistry teacher perception toward mobile augmented reality	Useful for display of toxic and unstable chemical such as Hg Reduce chemophobia and create positive attitude toward laboratory
Hou & Lin (2017)	Combine augmented reality and virtual laboratory on mobile device to create educational games	Increase in learning performance
Al Qassem et al. (2018)	Probe into how mobile augmented reality can enrich student's learning environment and attract student to learn chemistry	Higher enthusiasm than traditional classroom Better performance in organic chemistry than traditional classroom

Author's research provides the answers to our quest on the effectiveness of augmented reality for educational purposes, especially toward the mind and skill of y and z – generations who will be our future economic catalyser. Author suggest that there is no doubt that augmented reality is beneficial to its user's learning. User's visualization not only being augmented, other skills such as visualization, spatial-visual and scientific skills are tremendously escalated by this technology. Currently, it is one of the frontier technologies in learning. Promising impact of eliminating learning difficulties in 21st century classroom renders it as a must have technology today. Teachers and educators need to raise awareness about the usage of augmented reality in classroom.

SUMMARY

In this paper, a solution toward the ineffectiveness of current classroom is offered. Previous studies have been conducted regarding the current approach. Most of it show negative consequences of such practice. An alternative to the problem is imperative as the newer generation need active and engaging classroom. The role of teachers now is getting bigger and important. In comparison to teaching and delivering content, they now act as facilitator to the knowledge construction process. Lack of visualization skill and the need for learning that engage multiple representation of chemistry further contribute for the need of a better alternative.

For this reason, the implementation of augmented reality into chemistry classroom seem to be a right move. Student become prowess in visualization, active engagement, exploration through hands-on and minds-on and creating the link between each level in multiple representations are among its advantages. Yet, student still tend to treat this technology as a tool to play rather than the tool to explore. To crack such limitation, author had suggested the application of 5E Modelling model during engagement with augmented reality.

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