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An Augmented Reality System for Malaysian STPM Students Studying Chemistry

Mohammed Ameen Faisal Salar and Naresh Kumar Appadurai

Abstract--- *Chemistry based laboratory experiments for upper high school level also known as Sijil Tinggi Persekolahan Malaysia (STPM) chemistry education has been a staple subject for the past 27 years as outlined by the Malaysian Higher Education Ministry. Even though safety standards and utilities have progressed throughout the years, the fundamental issue of student safety remains ever-present and remains the only major avenue of learning these experiments. Even though technological advancements have taken place, the lab experiments have been unchanged. The aim of this research is to justify the necessity of an alternate safer and practical avenue for learning chemical lab experiments using an Augmented Reality System. The paper discusses methods to create an Augmented Reality system for chemistry laboratory education that not only allows the students to learn experiments safely outside the boundaries of the chemistry lab but also teaches laboratory safety and tests their abilities. The research encompasses case studies and other research to support the above stated.*

Keywords--- *Augmented Reality, Chemistry, Laboratory, Safety.*

I. INTRODUCTION

Chemistry laboratory experiments have remained a cornerstone for the subject of chemistry for STPM students. This is both the bane and boon of the problem. It is the boon because it instills hands on and tactile experience to the students on not just the knowledge but also safety procedures in a lab if taught well whereas it is a bane because students are restricted to the limits of the vicinity in order to learn or perform said experiments. There is no outer platform for students to possibly practice these experiments because of the lack of equipment and chemicals which are not available to the students. If for any reason be it an illness, disability or any other reasons to be missing in action, compensating for said experiments is a hassle due to the immense amount of coursework and sheer time adequacy. Most students are in school for more than half the day and generally tend to go for extra tuition after that leaving little to no time for self-nourishment let alone do an entire experiment.

Augmented reality has been on the rise in its applications especially in the field of education. While not the most tactile way of learning, content for it is easy to produce and is accessible through most just through the camera on the phone. An Augmented Reality System for chemistry experiments will offer students a much better holistic approach to learning these experiments outside of the lab compared to other mediums like videos. The system will also allow students to test themselves in the form of games. This will not only allow them to learn better but also be safer compared to the hostile environment of a chemistry lab where human error is a big factor.

Mohammed Ameen Faisal Salar, Asia Pacific University of Technology and Innovation, Technology Park Malaysia, Bukit Jalil, Kuala Lumpur, Malaysia. E-mail: faisalsalar@gmail.com
Naresh Kumar Appadurai, Asia Pacific University of Technology and Innovation, Technology Park Malaysia, Bukit Jalil, Kuala Lumpur, Malaysia. E-mail: naresh@apu.edu.my

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II. BACKGROUND

Augmented Reality has progressed immensely throughout the past few years while the chemistry laboratory has stuck to its roots and the mass availability of phones in the hands of students leaves the untapped potential of using Augmented Reality in Chemistry Education.

2.1 State of Augmented Reality

According to (Azuma et al., 2001) an Augmented Reality System consists of three properties which consist of coexistence of both real and virtual objects in the living environment, allows users to interact and provide instant feedback for user inputs and seamless spatial integration of both virtual and real objects. These fundamental pillars of Augmented Reality have helped shape their use in education and separating it from other conventional forms of learning. Augmented Reality is meant to aid learning and not replace the conventional teaching method completely.

Through their algorithm (Cipresso et al., 2018) analyzing literature on Augmented Reality discuss that the direction the Augmented Reality is heading to in the future in unclear, the disciplines under it are interdependent on progression and development. While Virtual Reality and Augmented Reality are researches more on the clinical side it is also applicable to engineering, computer science, applied sciences and is a novel way to support learning and training.

(Radu, 2014) that a major section of the papers they surveyed using their algorithm found that students learn better with Augmented Reality compared to other conventional media like papers or personal computers.

2.2 Augmented Reality in Education

(Sigitov, Hinkenjann and Roth, 2013)talks about the disadvantages of Augmented Reality in terms of needing physical objects or markers for it to work, not being able to compare Augmented Reality to real life experiments in the case of chemistry where they won't be any haptic feedback or the ability to perceive smell. The complexity of the system and the need for assistive technology like Heads Up Displays would lead to more costs. Then talks about how Virtual Reality is better than Augmented Reality in terms of being less complex, easier to use and has basic haptic feedback. Their proposed system is Desktop VR due to its lower cost which consists of a computer of medium specifications, two Novint Falcons as input devices and 3D display. (The guy who hates VR). The proposed system would not work in Malaysia due to just the high cost of the Falcon input devices which are 250$ apiece and the impractical utilization for thousands of Form 6 students here

(Cai, Wang and Chiang, 2014) in their research paper, made an Augmented Reality system consisting of 6 markers that visualized some molecular structures and made some on their own with mixing and matching. Junior-high students were tested once before they were presented with these markers and once after they used it over a 8-10 min per marker. In their questionnaire they found that students showed a positive response towards the Augmented Reality system and is beneficial for cognition. It also found that the system had a greater impact on low-achieving students compared to high-achieving students. This primarily could be due to high achieving students being inherently better at paper and pen tests leading to very small area of improvement compared to low achieving students.

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(Weng et al., 2019) made an Augmented Reality system for Form 4 Biology students covering the topics of mitosis, mitosis and both aerobic and anaerobic respiration and allowing the students to interact with their augmented reality visualization. They found that their Augmented Reality system enhanced the learning experience of Form 4 Biology students and provided a safer and more interactive learning environment

While (Cai, Wang and Chiang, 2014) did get positive feedback from the students as discussed above, students also concluded the ability of the Augmented Reality tool to offer accurate results lead to discontent due to the Augmented Reality system requiring accurate lighting for image tracking and reproduction on the markers and any such variation in lighting can mess with the appearance of the virtual object in the real world

(Akçayır et al., 2016) made an Augmented Reality laboratory manual for a group of students in their first year at the Kirikkale University in Turkey taking the course General Physics Laboratory 2. The application was made using the Jintao browser app on the phone and content was made using the Metaio software. The content consisted of the experiments that are part of the curriculum. Students were assessed based on the mid-term test taken before the implementation of the Augmented Reality manual and the test final test after. They found that the students who had access to the Augmented Reality manual not only had better performance academically but also were able to do the experiments faster allowing them more time for question and answer session with the teacher. They also found the students felt more comfortable and could do the experiments more easily compared to the group that used the regular manual. (Akçayır et al., 2016) also made an interesting find was that students were not studying the regular manual at home and relying too heavily on the Augmented Reality application. This can be a potential drawback of the usage of Augmented Reality learning tools in the future but it's just speculation as of now.

(Sigitov, Hinkenjann and Roth, 2013) found that most Augmented Reality content creators lean on making solutions that emphasize on the visualization aspect over the interactivity which leads to expensive systems that only a few students at a time have access to such as Virtual Reality system.

From the above there is a novelty in what the proposed is which is an Augmented Reality system for chemistry that will be easily accessible and affordable to all students with the touch of a fingertip allowing them to learn at their own convenience to little to no cost and won't require the use of markers as some of the above Augmented Reality solutions do.

III. PROBLEM STATEMENT

"As of today, there is no other avenue for students to learn or perform chemistry lab experiments safely outside of the boundaries of the chemistry lab itself"

(Goh et al., 2018) in their case study of lab safety in schools for students from Form 4 and 5 in urban and rural areas in Pahang found that the selected schools for their study had adequate laboratory safety in place in terms of work procedure, safety equipment, undertaking experiments, chemical waste management and response plans in situation of emergency. Even though 51.8 % students did not agree that their school had adequate laboratory goggles or laboratory coats, majority of them agreed that the equipment was ideally labelled, and they were comfortable in conducting the experiments on their own and were well aware of lab protocol.

On the contrary (Ali et al., 2018)case study in Cameron Highlands found that most of the students from Form 4 and 5 in the rural areas were obsolete to basic laboratory protocol in terms of not keeping things on higher platform in order to prevent it from following, the necessity of goggles and lab coats while performing experiments, the knowledge of discharging chemicals like Naphthalene correctly instead of throwing it down in the sink which clogs it, the knowledge of using an eye washer in the scenario chemicals go into the eye because there was no eye washer in the lab itself, the procedure to take place in case of an emergency or spill. These basic protocols are lacking potentially due to lack of supplies and not necessary a student knowledge related issue.

(Hassan et al., 2017) also concluded that while staff in school laboratories have a basic understanding and practice of safety protocols, they are not mentally or physically prepared to deal with an emergency case due to lack of training

There have been reported cases of mishandled equipment leading to hazards and loss of money and property like "Port Dickson school laboratory closed off after chemical spill" (Zakaria, 2016)

"Chemical explosion causes scare at KL school" (Camoens and Hamid, 2013)

While it's not possible to eradicate human error entirely and improve lab safety to or more than the standard already set. It is possible to make the students feel more comfortable and familiar with environment with an Augmented Reality system which can potentially mitigate the human errors, help students learn in a safe environment without the risk of potential harms and help perform better both in and out of the laboratory. In summary:

1) Make an Augmented Reality system based on the syllabus of Form 6, STPM 962 Chemistry
2) Collect statistical data on the usage and impact of the system to understand if the usage of the system has led to lesser accidents and better performance of students.
3) Analyze the collected data to see how the system can be improved and potentially push for it to be a legitimate support material.

IV. RESEARCH QUESTION

Why is there a need for an alternative learning platform for Form 6 Chemistry students?

What problems does the proposed system solve in terms of a chemistry laboratory?

What is the relation between safety standards in a school and the student knowledge?

How does the proposed system affect learning experience compared to conventional methods?

How does the proposed system affect the relationship between the student and teacher?

How much of a difference does this system provide to the students' academic performance?

V. SIGNIFICANCE OF THE RESEARCH

The proposed augmented reality will solve the problem of chemistry lab experiments being restricted to the walls of the school's chemistry lab. Its usage is not only restricted to students who are in Form 6 but also students who

wish to be informed and learn before-hand. The system will be easy to understand and operate for even the layman and still be highly informative.

Its implementation is not only limited to the usage as a supplementary tool to the conventional learning methods but can potentially be used as a replacement for students with disabilities, illnesses, allergies and other issues that might prevent someone from learning the conventional way in a lab. It has the potential to be a legitimate application that is certified and promoted by schools not just for Form 6 but can be scaled to accommodate the syllabus of other Forms also. It adds to the already existing usage of Augmented Reality in different fields.

Researchers will see it adds value to the spectrum of uses of Augmented Reality in its application and chemistry and can be a step towards more and more schools and multiple locations adapting this to their needs.

VI. Research Methodology

For the purpose of this research both Qualitative and Quantitative tools will be used. For the qualitative part, Stratified Sampling will be used to determine which Form 6 students around Malaysia from the different strata which in this case would be schools, will be part of the group that gets to use the app. Surveys will be implemented within the app itself to further collect both objective and subjective data in a timely manner in order to understand the students opinion on its usage and to form a statistical back bone to formulate where the app stands in terms of opinions and the objectives it set out to achieve. It is important to collect data on the stated objectives in terms of how much more safer the students feel and how the incident report of the school has changed, if it promoted autonomous learning to move up and beyond just the walls of the syllabus and to test if they performed better on the laboratory experiments and the course overall.

Students who had negative feedback from the survey will be interviewed in order to understand better as to why the negative feedback was there and what can be changed and improved to make the learning experience even better. Prefer using lab or AR system as a testing methodology.

VII. Overview of Proposed System

The system will be in the form of a phone application made using Unity and Google ARCore. Google AR core is at the fore front of augmented reality and making regular advancements to stay ahead of their counterparts especially in the field of spatial tracking. Unlike its well-known counter-parts like Vuforia which needs physical objects/images/markers to bring the Augmented Reality virtual object into the real world, (Google, 2019) Google AR core uses its own motion tracking technology that doesn't need any physical object present and can produce the AR on any surface it has successfully tracked, uses environmental understanding to detect any surface and light estimation to gauge the lighting condition in the surroundings, hence the choice of Google ARCore so it can be used by everybody who has a phone with a camera.

The system will have a simple user-interface that would be easily understandable by all but also be loaded with information in a graspable manner in order to give the best learning experience to the students. The app will consist of simulated experiments based on syllabus to adhere to the curriculum, provide a virtual chemistry lab for the students to be able to interact with the chemicals and equipment that they would see in their chemistry lab but

wouldn't be able to do so to their curiosity and hearts contentment, at the comfort of their home and phone and the app will also have laboratory safety instructions implemented not just as pop ups during the experiments in the application but also as a subsection to constantly remind the students the importance of safety in the lab and also notify the students when they are mixing potentially dangerous chemicals and explain the chemical reactions behind it.

This will allow students to not only have a more holistic and spatial learning but also test out their curiosity which they wouldn't be able to in a chemistry lab due to safety restrictions. The system will also have certain testing games, that will provide students with situations on which they have to act and perform experiments accordingly. This allows learning more than just the syllabus and teaches situation-based problem-solving experimental skills which are not necessarily taught in a conventional chemistry lab due to the students just repeating experiments that are taught by their teachers or prescribed in the syllabus making it a mere performing art over creating or discovering something tangible.

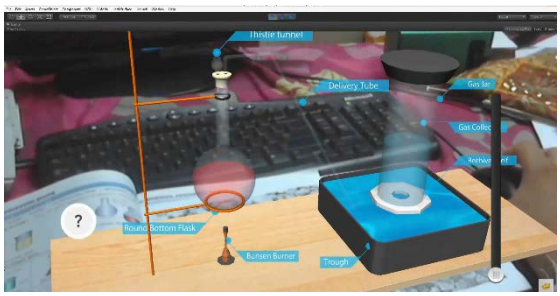

Fig 1: A Sample of what the Proposed Augmented Reality System would look like

VIII. CONCLUSION

In conclusion, the proposed Augmented Reality system is a step in the right direction to enhance the age-old ways of using chemistry labs. While this may not give this most tactile results, it still gives students a sense of familiarity to the tools and chemicals and make them more comfortable in that environment and potentially motivate them more to learn and perform better academically. The system is not meant to replace the conventional chemistry lab. It is meant to be an aid or tool that can be used side by side with the conventional learning to enhance the experience. A safer, less tactile, more immersive and holistic experience is what the system aims to provide the users apart from the just the knowledge it transfers. The potential of this system to be an education standard in the future is one that in uncertain but in the likely scenario would lead to a lot less incidents and safety hazards that may potentially arise.

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