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Use of Augmented Reality for Learning Chemistry

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***Abstract*— Augmented Reality (AR) has been rapidly spreading out through the younger generation because it is providing capability of combining virtual objects on a real-world image towards cognitive processes. There are many applications related to different domains such as medical, tourism, urban planning, marketing, which are based on AR. Specially AR is affected on education sector which can be used to improve students' understanding towards subjects. Learning chemistry is also based on conceptual things like microstructures, composition of substances and atoms. Therefore, imaginative ability is the most important things in chemistry. In this review discusses about use of AR for learning chemistry to improve students' capability of imagination. Furthermore, it describes about the key challenges which are existing in chemistry towards AR.**

Keywords*— *Augmented reality, Virtual Reality, Learning chemistry, Imaginative ability

I. Introduction

At present human beings are living in a technological era which has been changed day by day with the enhancement of Information Technology. Augmented Reality is a technology that have been rapidly growing for past two decades. AR is an enhanced version of virtual reality which provide ability to generates three – dimensional (3-D) virtual objects on real world while provides an interactive interface between virtual and real objects [6]. There are two main approaches of utilizing AR technology, which are namely image-based AR and location-based AR. The main three characteristics of AR technology are, integrate virtual and real objects, intercommunicate in real time and put record in 3-D. In addition to that AR technology provides capability to allow technologies of computing hardware, software architectures, and tracking [3]. At present augmented reality is used to accomplish many objectives in different fields such as education, marketing, navigation and path planning, tourism, urban planning and civil engineering [1]. AR is still in developing phase.

Learning is important to change thinking and actions by experience and storing knowledge [6]. There are many different types of learnings available. In this review paper has been focused on academic learning. Students who are learning chemistry in schools and universities should have go through the micro-world to gather particular knowledge. To accomplish this, potently students have to use their imaginative ability [5]. During the beginning stage of chemistry has been focused on composition of substances, atoms and their microstructures, organic chemistry, chemical bonds and inorganic chemistry [5]. Furthermore, students are required to perform practical related to above mentioned knowledge areas. However, student's capability of imagination related to micro-world is not enough for learning advance chemistry, finding an innovative method for that is necessary.

To overcome issues which are arisen while learning chemistry, AR technology can be used. Student's perception is enhanced and interaction with the real world is done by utilizing AR [3]. Specially Augmented reality brings a whole new dimension for learning chemistry. It provides innovative learning methods. When consider about learning chemistry, with the use of AR components is more than twice as effective. Students can perform experiments in virtual laboratories, and they can understand theories, reactions and set of knowledgeable things efficiently through the 3-D environment.

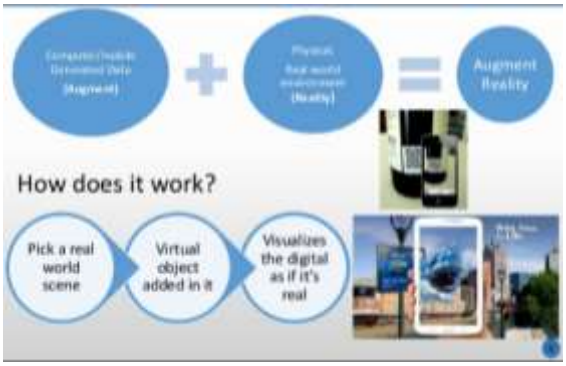

Figure 1: Augmented Reality and real world

II. Overview

Augmented Reality is a technology which has been emerging rapidly for the past few decades. It becomes more customary among new generation due to cognitive and interactive features which has capability of combining virtuality and reality together. AR is a form of virtual reality which provide the clear view of real world under three aspects such as combining real world with virtual world, real time interaction and accuracy of 3D registration [19].

At early stage of AR technology, there were several application domains related to AR can be identified like medicine, manufacturing, entertainment, visualization, military and robotics and also at present, new application domains are recognized such as marketing, navigation,

tourism, education, geospatial, path planning, urban planning and civil engineering [6]. Through these application domains AR has been provided powerful user interface to computer environment while Mobile Augmented Reality also has been becoming more flexible and user interactive application among the people.

Education is more important for the society which is affected towards development of country. Therefore, learning is a platform to get knowledge and improve deepen perception of students. At present some students face uncomfortable situations due to lack of understanding during learning period. To overcome this issue, AR has been used. Specially in chemistry field, students should be imaginative. According to many surveys, at present most of the students are getting failures over the learning chemistry. Learning environment, course content, student related, and staff related factors are mainly affected on those learning failures [17]. Therefore, it is important to have cognitive systems to improve students' perception towards chemistry experiments and related research works can be identified.

III. Major Researches in use of augmented reality for learning chemistry

Possibilities of Augmented Reality in Science Learning: Propositions for upcoming research was done by Kun-Hung Cheng and Chin-Chung Tsai to identify existing learning supporters which are related to image-based AR and location-based AR and considering drawbacks of existing, provide propositions for upcoming research are suggested [3].

According to AR Chemistry: doing chemical experiments with enhancement of AR focuses on experiment learning of chemistry which is based on AR and tabletop interface which was done by Daiki Nishihama, Tatsushi Takeuchi, Yosuke Horiuchi†, Tomoo Inoue and Ken-ichi Okada [5].

TUI for Chemistry Education: Visualization; Portability; and Database was done to extend the Augmented Reality (AC) system with the aspects of enhancing interaction, accessing internal/external database and keyboard free configuration [8].

A new smart device which is utilized in junior high schools' science education for better understanding of Chemical Reaction Formula based on AR is proposed by Rina Ashida1 and Mitsunori Makino to visualize the atoms and molecular structures with the purpose of students to contribute their deep perception towards chemistry [9].

Augmented Chemical Reactions research work was done to build an application by P. Maier and G. Klinker, which has capability of visualizing the molecules using direct manipulation and dynamical behaviors of molecules can be shown [12].

According to Augmented Chemistry: An Interactive Educational Workbench research work was done by Morten Fjeld and Benedikt M. Voegtli about tangible user interface called "Augmented Chemistry" which provides capability of working with single or multiple users at one time [13].

Figure 2: AR work bench

Collaborative Augmented Reality system was developed to introduce an AR based system in order to solve students' problems related to inorganic chemistry at the university level. Mainly focused on showing material and compound structures in 3D, allowing students to manipulate and move them [24].

A new inquiry-based AR visualization learning model was proposed to improve students' problem solving and critical thinking abilities towards chemical experiments. System was designed to learn about properties of gas in natural context [25]. Students are able to do experiments of three level according to worksheet after login to the system via tablet computer [25].

IV. Current issues in use of AR for learning chemistry

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A. *Technological Issues*

Concerning about technological issues, to achieve the particular task using AR, students need to use head-mounted display and backpack with computer equipment which are more expensive. Since there are multiple devices are available, issues of interfacing, device break downs and issues of stability can be happened due to lack of knowledge regarding AR technology [2].

B. *Inflexibility*

Inflexibility of the system and fixed sequence of teaching also make some issues during learning time. Since system

cannot be changed as they want, students are not able to accomplish their educational tasks [20].

C. *Location Dependency Issues*

Additionally, location dependency issues can be happened while using AR for learning chemistry. Although location-independent AR applications do not require students to be present in particular location, others should pay attention about location [2]. And also, connectivity of internet can be recognized as key challenge of usage of technology.

D. *Portability Issues*

Applications of AR are function on average number of PC regardless its type. But the system uses Windows® and a DirectX® 10 are enabled graphics card [12].

V. Applications of Augmented Reality

A. *Medical field*

Main purpose of the using AR for medical is visualize the medical data such as heterogeneous data and the patient utilizing same physical space [4]. AR has been used in various domains in medical such as ultrasound imagine which is used to search features of abdomen, X-ray vision and corporative surgical systems.

B. *Urban planning*

Architectural education also has become advance with the use of AR. Several domains like country and town planning, development processes and green concept architecture are done through the visionary city applications which has capability to improve imaginary construction using 3D graphics [14].

C. *Marketing*

To accomplish advertising purposes, motorized industry has been using AR applications. They get used to produce computer games, movies to promote shoes and furniture [4]. And they provide a chance to select shoes according to color or pattern by wearing virtually. QR- code is another simple example for application of AR.

VI. Conclusion

This study is done to recognize the different applications of Augmented Reality for learning chemistry. Mobile augmented reality and computer-based augmented reality applications are mainly discussed in this paper.

Review paper is identified major difficulties of students that are mounted during learning chemistry, based on learning environment, course content, student related, and staff related. According to many surveys, most of the students' perception towards learning chemistry is backward.

Few areas that could be used to improve students cognitive thinking over the imagination towards learning chemistry were described in this paper. Mainly focused on experimental activities in inorganic chemistry, imaginative methods for learning compositions of subsistence, atoms and their microstructures. Then reader can identify the concept of the augmented reality and its technologies and how AR was implemented to overcome students' difficulties over the above-mentioned areas.

There are some limitations that were arisen when the AR was using for learning chemistry are discussed such as inadequate resources in learning environment, higher cost, poor technical knowledge and takes more time. Excepting this limitation augmented reality make such an interactive environment for students to improve their imagination towards cognitive learning.

Findings of this research can be summarized as follows;

Table 1: Summary of Relevant Researches

	Title	Aim & Problem(s) addressed	Limitations/Challenges
1	Augmented Reality simulation system application in a chemistry	develop an inquiry -based AR tool for inspecting how effects on law-achieving and high-achieving students to imagine how atoms are composed.	Students are unsatisfying in stability and them curious, exited and discourage to adapt the system.
2	Current status, opportunities and challenges of AR in education	present current situation, opportunities and challenges of AR related to educational field.	To overcome the lack of evidential validity and poor designing, large sample and valid instrumentations are needed.
3	A brief review of augmented reality science learning	To motivate students towards science learning, develop studying environment using AR.	This paper focused only, how to achieve cognitive expressions of multimedia and constructivist

			theory using AR.
4	A User Study Trends in Augmented Reality and Virtual Reality Research	identify the user studying trends regarding virtual and AR research projects published in ISMAR and IEEE conferences competed in past three years.	Considering only research projects published in two conferences completed in past three years, did not review the all papers during this time period and low number of independent coders involved.
5.	Augmented Reality Applications , Challenges and Future Trends	This survey is focused on current state of AR and its different applications as well as major challenges.	Challenge is to construct a pervasive middleware to support the AR system.
6.	Use of augmented reality in education	problems that are arisen during learning and application of AR in education field which is based on Fiducial markers.	Users feel real environment is not present during learning period.
7.	Applying Augmented Reality Technology to E-learning	This paper is emphasized the benefits of AR products which are related to science-learning and possibilities of applying AR to e-learning.	Particular experiments cannot be evaluated using kids because they get this as entertainment rather than learning tool.
8.	Augmented chemistry: An interactive educational work bench	develop tangible user interface called "Augmented Chemistry" which provides capability of working with single or multiple users at one time	AC system cannot distinguish stereoisomers and no general way to compare such complex structures generate on authors' knowledge
9.	Augmented Reality as an Educational Tool of M-Learning	utilization of AR as an educational tool for mobile learning considering architecture and urban planning.	This paper focused only, usage of AR for mobile based learning in education and covers only two different areas on educational field.
10	Augmented Reality Laboratory for High School Electrochem istry Course	investigate the effect of AR learning tools on performance and motivation of high school students towards electro chemistry.	Students haven't adequate knowledge regarding AR to do experiments.
11	Affordances of Augmented Reality in Science Learning: Suggestions for Future Research	identify existing learning supporters related to two types of AR and considering drawbacks of existing, provide prepositions for upcoming research are planned.	Used number of selected research papers and there is an option to change the current theoretical frameworks in future.
12	AR Chemistry: Building up AR for Learning Chemical Experiment	develop a learning system for chemical experiments using AR and tabletop interface.	some students are not interested in doing chemical experiments, needed to motivate for working with this tool.
13	Tangible User Interface for Chemistry Education	extend the Augmented Reality (AC) system with the aspects of enhancing interaction, accessing internal/external database and keyboard free configuration.	Challenge is an exploration of intelligent, physical balls and sticks.
14	An AR-based	A new smart device is	this system is limited for

	Support System for Learning Chemical Reaction Formula	proposed to visualize the atoms and molecular structures with the purpose of students to contribute their deep perception towards chemistry.	junior students who have to cover basic compositions of the atoms and molecules
15	Augmented Chemical Reactions: 3D Interaction Methods for Chemistry	This research work was done to build an application which has capability of visualizing the molecules by using direct manipulation and dynamical behaviors of molecules.	Applications of AR are function on average number of PC regardless its type. But the system uses Windows® and a DirectX® 10 are enabled graphics card
16	What makes chemistry difficult	Investigation about students' difficulties which are arisen during learning chemistry in university.	Survey was done by using only students of the Dire Dawa and Haromaya universities in Ethiopia
17	Augmented Reality and its technologies	explain technologies which are implemented together with AR.	Described only about selected key technologies which are implemented together with AR.
18	Designing and developing an AR application: A sample of chemistry education	develop an AR application to learn about periodic table and atomic structures.	Supportive material had been to comprise of analogies, metaphors and high-fidelity visual components.
19	Why should my students use AR? A Comparative review of the	reveals the positive and negative effects of AR on learning through the comparison	coding was limited to corpus sentences that related to learning,
	educational impacts of AR	of 32 AR publications.	cognition, or usability.
20	An interactive 5E learning-cycle based AR system to improve students 'learning achievement in a microcosmic chemistry molecule course.	develop an AR based system to improve students' understanding related to microcosmic structures based on 5E learning cycle.	System was developed mainly focusing on 5E learning cycle.

VII. Future Directions of Augmented Reality for learning chemistry.

Several possible future directions are suggested by researchers.

A. *Enhancement of Technological Equipment*

Specially to overcome the issues that arise related to technological equipment need to be developed. Head-mounted devices and wearable equipment need to be created as more light, small and easier to work with user [4].

B. *Location Independent Applications*

Location-dependency is another challenge for learning purpose. To avoid this problem, location independent applications which has benefits in flexibility and portability, should be used [1].

C. *Authoring Tools*

To overcome the inflexibility in AR application, authoring tools can be used [1]. These tools allow users to manipulate AR activities and application as they wish.

D. *Development of Dynamic Augmented Reality*

Dynamic augmented reality needs to be developed to improve learner's performance on electro chemistry [15].

E. Vocal Enhancement

Need to be developed a method to combine text study and experiment using chemical considering" Which procedure"," Who", and" What operation" aspects under teacher's guidelines. Vocal enhancement needs to be added [5].

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