

A Review of Augmented Reality Elements in Science Learning

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Abstract—The integration of technology in education or learning domain makes a huge transformation in human wisdom and also in the way of thinking and learning. Augmented Reality is increasingly used for learning purposes as it may provide the learners what they have learned and what should have learned. This article reviews on literature concerning the elements of augmented reality which may be implemented for scientific practices in order to make science learning more motivating. The integration of multiple media in educational materials may influence learners' motivation towards the learning process. Thus, the instructional strategy of learning materials is equally important as the content does. Content analysis of 47 articles reveals that 3D models are popularly used in augmented reality for science learning. This article further discusses the importance of multimedia elements in representing information, especially for science learning through the use of augmented reality (AR) technology.

Index Terms—Augmented Reality; Multimedia; Science Learning; Multimedia Learning Principles.

I. INTRODUCTION

The integration of technology in education or learning domains makes a massive transformation in human wisdom and also in the way of thinking and learning [1]. An ideal teaching and learning process escalates students' innovative thinking and understanding towards the importance of reaching the objective in education for own sake without any compulsion [2]. According to [3] variety in instructional strategy will keep the learner's engaged with the learning.

Moreover, the presentation technique of learning materials in the classroom is very salient because its influence student's perception towards subject matters whether it is easy or difficult to learn and score [4], [5]. As known students have a big wall of the misconception in their mind regarding science-related subjects [6] thus, an effective teaching and learning process should comprise with several attributes like fun [7], easy to understand the content [8] and able to stimulate the creative thinking [9].

The goal of augmented reality is not only to present the knowledge, but also to provide guidance on how to process the presented information. According to [10], there are two goals of the multimedia learning; to remember and to understand information. Remembering is the ability to reproduce the presented material through a retention test.

The use of multimedia depends on the designer's underlying conception of learning. There are three metaphors of the multimedia (MM) learning in a multimedia learning environment [11]. The first metaphor is the multimedia

learning as a response, strengthening which involves strengthening or weakening a combination between a stimulus and a response. The second metaphor is the MM learning as information acquisition, which involves in adding information to one's memory. The third metaphor is the MM as knowledge construction which is based on sense-making activity where a learner builds a coherent mental representation of the presented material. Then, the presentation of multimedia content depends on the view of the content [11]. There are three views of multimedia contents, namely delivery-media view, presentation-mode view and sensorial modality view [11].

These views depend on the devices utilised to present the multimedia content. The delivery- media emphasises more to the technology over the learner [11]. Meanwhile, the presentation-mode and sensory- modality view focus on information processing system of the learner and assume that human process the information through view and hear [11]. Although our definition of multimedia is more on presentation view and sensory-modality view to process the information, the delivery-media also has been considered crucial to deliver the content efficiently. Hence, Augmented Reality (AR) technology has been included so that the learners have opportunities to know what they have learned and what should have learned. Moreover, AR technology has reduced the limitation of multimedia learning involves from aural and visual material from words and images. Through the use of AR elements in science learning, it is proven that the learning content and the delivery- technology provides the crucial combination.

Regarding assessment, the common tests include recalling such as instant writing after a lesson and recognition such as questioning learners regarding the presentation content and usually in multiple choices. Then, understanding is based on the ability to build a coherent mental representation of the presented material. In a transfer test, the learner's knowledge will be tested by providing an advanced problem that has not included in the presentation. The learners have to practically apply what they have learned and understand the presented learning material. These both goals are crucial in multiple media integrated teaching and learning [11]. Therefore, this paper aims to review existing augmented reality elements in science learning; and to review whether previous studies have proven there is a significant relationship between them.

II. METHODS

In order to review existing augmented reality elements for science learning, we applied content analysis where we used keywords such as augmented reality and science learning to identify the literature. Google Scholar and open access journals are referred as primary databases to search the literature. There are several inclusion criteria proposed by [8] has been adopted; (a) main content related to AR and science learning, (b) focused on human learning, not for robot or machine, (c) focused on normal students without any disabilities or special requirements, and (d) only English articles were selected throughout the study.

Based on the inclusion criteria, we have identified 47 papers. Those retrieved papers are from 2003 till 2016. The findings did include books and apps that have been utilised in science learning comprise of physics, chemistry, biology and pure science through the use of AR.

III. RESULTS AND DISCUSSIONS

This review aims to evaluate the most preferred elements which have been used to deliver meaningful AR-based science learning environment and to determine the relationship between these features and science learning.

A. Augmented Reality Elements for Science Learning

The text, audio, video, graphic, and animation are five multimedia elements are able to provide a practical and multi-sensory learning experience. Additionally, a 3D model also delivers an in-depth and an interactive learning experience. Each element has its unique characteristic which is able to provide attractive and interactive science learning experience. According to [12], for an average human, the majority of the knowledge is gained through seeing (75%), listening (13%) and other sense (12%). Other than that, the learning is prominent, and it would be more useful and long-lasting if certain senses, such hearing, sight, touch, and emotions are involved in a learning process [13], [14]. Therefore, an intervention of multiple elements such as 3D models, animation, graphics and audio display in a technology-integrated learning environment is crucial.

As shown in Figure 1, from 47 articles, it is found that 42 articles reported on the implementation of three-dimensional (3D) models; hence, it probably the most critical multimedia element in an AR science learning environment [15]-[56]. The usage of three-dimensional (3D) models is given this level of priority because providing the opportunity to experience the learning content from the 3D view and the transparency of the content enhances the understanding of learners. Even though 3D models can attract learners, yet a static model is not able to continuously engage learners in the learning process [32], [57]. Therefore, the animation is added to 3D models to deliver meaningful content to learners.

Among the total papers were reviewed fifteen papers suggested animation among the important MM elements [15]-[19], [26], [30], [35], [38], [41], [42], [45], [54], [56], [58].

Other than that, twelve studies proposed learning contents in the format of video in a learning environment [18], [22], [23], [32], [46], [48], [53], [58], [59], [60], [61], [62].

Followed by the utilization of graphics proposed in eight papers [19], [20], [22], [23], [38], [53], [58], [60].

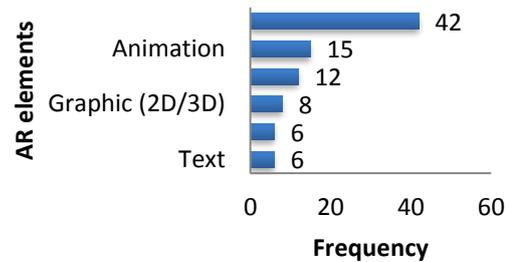


Figure 1: Frequency of preferred elements of AR in science learning

Finally, there are six papers respectively suggested text [15], [28], [32], [38], [53], [60] and audio [18], [22], [28], [32], [46], [62] also important to deliver a content.

Basically, text and audio are utilised to present information. Also, through the use of AR technology, it may be possible to include the elements like 3D models with animation in a learning environment. AR is immersive technologies that bind together the original and authentic environment together and present them in parallel. Moreover, 3D models, animation, video, and graphics with the addition of text and audio can enhance the understanding of the content and persuade students to engage with learning longer which eventually leads to motivation [63]. Other than that, it reduces the cognitive overload in an AR learning environment [64]. This is due to the number of materials and complexity of tasks [64]-[66]. The multimedia elements are fundamentally important to represent information efficiently.

Further, through the use of augmented reality elements, it could enhance the interest and curiosity of students towards the science learning. It cultivates critical thinking, ability to visualise and lead their learning independently without solely being dependent on teachers' knowledge. This attitude would improve their confidence in their skills and knowledge and eventually would assist students to score in science learning.

B. The relationship between Augmented Reality Elements and Science Learning

Based on the literature, there are plenty of suggestions for designing and developing useful and practical supplementary learning materials such e-book, web-based learning, courseware, and e-notes. According to [67], an effective learning material solely depends on how the learning material being presented to the learner. Meanwhile, the method of representing the information is equally important as the content of the learning material and end of the process; the presentation method will leave the impact among the user to learn the subject matter more deeply [63]. Content is a hub for any presentation. The content must be precise, realistic, and well-ordered in a learning process [63]. The presentation should suit all levels of students in the classroom because they are from various families and knowledge background. Hence, motivating adult learners are more challenging and more robust rather than students from primary schools. The relevancy of the content is prominent to attract students' attention towards the presentation. This presentation design factors may be categorised into (i) information representation, and (ii) pedagogical issues.

Representing information effectively and attractively will enhance the intrinsic and extrinsic motivation among the user [68]. For instance, the elements such as the fonts, images, colour combination, audio, and animation should be taken

into consideration [68], [69]. Moreover, the usage of uppercase fonts and lower case should be standard and clear. Meanwhile, the selected images should be clear and applied on purpose while the selected colour combination should not be too bright or too dark while audio and animation integration assists to reduce stress [68]. Multimedia in learning presents the learning material in the form of texts and images simultaneously to simplify the content, to make easy to understand the content and make an effect on the learner's knowledge retention [10], [70]. Learning is a process of acquiring the knowledge and skill while the memory is a form of expression of what learners have gained. The human mind is limited in the amount of information that it can process [71]. The human brain does not interpret words, pictures and auditory information in a mutually exclusive fashion, but these elements are selected and organised dynamically to produce a logical model of the MM presentation [10]. Thus, presenting the information through verbal (written text or audio) or pictorial (animation or pictures) produces a productive learning process [11]. After the thirty seconds, the information is transferred to the long-term memory which stores the knowledge for an indefinite amount of time [72]. Besides that, students learn more and deeply with word and graphic together rather than word alone [63].

To resolve aforementioned pedagogical issues, there are cognitive principles of multimedia learning proposed by [63] consist of three cognitive processes [63]. Three kinds of cognitive processes are reducing extraneous processing, managing essential processing and foster generative processing [63] as listed in Table 1.

Table 1
Category of Cognitive Principles of Multimedia Learning

Cognitive Processing	Description	Instructional Goal
Extraneous	Instructional goal is not achieved due to the poor instructional design.	Reduce extraneous process
Essential	The aim is to present only the essential material and is realised due to the complexity of the material.	Manage essential process
Generative	The aim is to make sense of essential material, caused by students' effort.	Foster generative process

Table 1 depicts the categories of multimedia principles. Text and graphic are crucial elements indeed; hence the placement of these elements to represent information should take into consideration. Perhaps it could be effective or vague. Through the use of the extraneous process, it removes the text and also presents text and graphics closer to hinder overloading. Then, the essential process aims to break the lesson into several parts to overcome the complexity of the learning. Finally, the generative process aims to make sense of essential materials caused by students' efforts.

The employment of elements of multimedia in science-related subject matters could provide more fruitful achievements in gaining more comprehensive and more in-depth knowledge. This is because science has a lot of complicated procedures and intuitive processes which are hard to imagine and understand it correctly. Therefore, a supplementary element with the addition of technology tool is needed to extract the intuitive and unseen learning contents to understand it correctly. This is in line with the characteristics of AR technology that assist to see-through the

instinctive virtual information and present it in an authentic environment. AR is recommended for educational settings and also has been tested in real circumstances [65], [73], [74]. This is due to the comfort with the less cognitive effort it is produced to fit into a learning process [17], [30], [51]. Moreover, AR and science learning had a positive relationship and made a positive impact on students' academic performance [73], [75]. In developing AR projects, many elements have been applied to make the project more effective. The elements in previous AR projects categorised based on the multimedia elements comprised of text, audio, graphic, video and animation and also three-dimensional (3D) models as an additional element.

Based on the literature, it can be concluded that there is a definite relationship between the information presentation and science motivation as well as pedagogical issues and science learning.

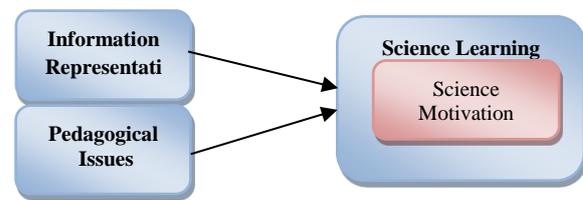


Figure 2: Relationship between augmented reality elements and science learning

Figure 2 shows that representing information such as in image and 3D models may resolve the cognitive overload, and eventually, trigger students' science learning and science motivation. Pedagogical issues such as instructional strategies may also contribute towards science learning.

C. Critical Design Factors of Augmented Reality for Science Learning

Students might experience cognitive overload in an AR learning environment due to the complexity of tasks and learning material [64], [66] and should be given more priority. Meanwhile, an inappropriate instructional strategy leads to frustration and decrease their motivation in learning [16], [76], [77]. Previous studies identified a major impediment in a flexible and appropriate instructional strategy in the AR system [78]. AR textbook for science learning [32] obtained similar results that AR and science learning have significant and positive relationships. For AR textbook, students choose to focus on 3D models with animation [15]-[19] and video [18], [22], [23], [58], [59] over the text, audio, static graphics.

According to [10]'s temporal contiguity principle, [67] implemented image and text simultaneously for an inquiry-based AR in their online learning activities. Moreover, this kind of activity might assist students to achieve more profound phases of knowledge construction and inquiry abilities [60]. Similar findings have been reported by [79] in web-based learning activities. When learning with the AR-based mobile learning system, the students learned from scenarios which presented real-world targets and supplementary digital materials in an integrated and organised way. According to [38], based on these findings, AR is accepted as a beneficial learning tool in enhancing middle school students' cognitive test performance on corresponding content and has a significant influence on low-achieving students.

Students prefer images over text for an AR simulation system application in a chemistry course. Other than that, students had a positive attitude toward the AR technology as a learning tool and enjoyed the exploration experience. Similar to previous studies, 3D models with the addition of animation should be given priority in science learning. Also, the right technique for elements utilisation in learning materials could turn ordinary learning into extraordinary and meaningful learning experiences. The meaningful learning experience could cultivate the intrinsic motivation among students. Intrinsic motivation is a behaviour that is driven by internal rewards. Students with higher levels of intrinsic motivation express extreme theoretical learning, better memory, and soaring overall attainment in education [80]. Even the learning is tough, the brave students will face and succeed the issue because of their inner willing power is high and strong enough to fight with the difficulties in learning. These students are more likely to experience a state of meaningful task concentration and uttermost presentation [81]. Otherwise, students with low intrinsic motivation could be frustrated because of the situation or lost their interest in the learning. Apart from that, intrinsic motivation is a dominant factor in presentation, determination to learn, and efficiency [82]. Some researchers also considered emotional engagement as intrinsic motivation and researchers have found that emotional engagement in a learning experience predicts the development of behavioural engagement [83].

IV. CONCLUSION

Through the use of technology, it is hoped that students feel the richness and enthusiasm of science through knowing about and understanding the natural world. The scientific processes and principles would assist students in making personal decisions. Later, the scientific knowledge makes them engage wisely in public discourse and increase their economic productivity through the use of the knowledge, deeper understanding, and skills of the scientifically literate person in their careers. It is prominent that students foster interest and enjoyment in science learning. Science does not only guide to think critically, but it also teaches on how to live a civilised life because the content depicts all about the way of living. In this context, stimulating and motivating students towards gaining scientific knowledge is critical. Once students are stimulated and motivated, they can achieve in every aspect of the learning process. Learning materials are necessary because they can significantly increase student achievement by supporting student learning. Learning materials can also add relevant structure to lesson planning and the delivery of instruction. Particularly in lower grades, learning materials act as a guide for both the teacher and student. Teaching materials can support student learning and increase student success. Ideally, the teaching materials will be tailored to the content in which they are being used, to the students in whose class they are being used, and the teacher. Teaching materials come in many shapes and sizes, but they all have in common the ability to support student learning. This paper reviews existing literature on augmented multimedia elements for science lab practices to provide meaningful experience in science learning. From this review, it is found that rather than just using text and images, the assistance of audio or three-dimensional models with animation as well as the two-dimensional or three-dimensional video would provide a deeper understanding and

cultivate interest. It is evident that the knowledge, as well as engagement in learning, are also retained longer than those with standard practice. The knowledge assists students in choosing their future path. Finally, science is the fusion of several other subjects indeed a strong visualisation, and critical thinking provides the enjoyment and fun in the learning process.

Future work may focus on augmented reality-based science laboratory experiments notably for Physics learning. It is quite well known that Physics comprised of plenty of complex procedures and abstract processes to follow. It does also require a good visualisation ability to visualise the non-figurative processes. Hence, this study utilised three-dimensional models with the addition of animation to reveal the processes that are impossible to experience in factual circumstances. Hands-on and practical skills are prominent, especially when it is related to science (physics, biology, chemistry and pure science). The fusion of technology integrated learning leads to a participatory learning process where student gain opportunity to construct their learning based on their learning experience.

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