Designing Mobile Augmented Reality (MAR) for Learning Chemical Bond

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Abstract- **This research study is about the designing of Mobile Augmented Reality (MAR) applications for learning the Chemical Bond. Due to the emergence of the MAR in education field, the authors take this opportunity to adopt the advantages of the MAR in Chemical Bond. This is due to the effectiveness of MAR in visualization, which is believed to be helpful in reducing the problems of visualization in the topic of Chemical Bond. In order to ensure the learning process is successful as the author needed, the instructional Design Model which is ADDIE has been used in the development of the MAR applications for learning Chemical Bond through their learning environment. There were five phases involved in the model to make sure that the process of before, during and after using the MAR applications has achieved the objectives listed. This study discusses on how each phase takes place.**

Keywords—Mobile Augmented Reality; Chemical Bond; ADDIE; Visualization

I. INTRODUCTION

Martin et al. [1] stated the new technology trends in education with seven years of forecast. There is a stage in which the technologies are grouped according to their similarities. This approach is used to determine the direction in which educational technology is progressing. In the next stage, the evolution of the technologies is being studied and the meta-trends and evolution flows of the technologies involved are analyzed. The prediction technologies include social web, semantic web, learning objects, immersive environment (games and virtual worlds), ubiquity and mobile device and augmented reality (AR). However, the most potential technology highlighted by Martin et al. [1] that needs to be developed is Augmented Reality. The research predicted that the technologies of Augmented Reality will be developed by the year 2014 and above because the ability and advantages that AR has, especially in visualization, meet the requirements of the students in their learning.

Accordingto the research by Lee [2], the term of Augmented Reality (AR) is first coined by Tom Caudell. However, the technologies were believed as already existed since the 1960s, which were first used by systems, AR and Virtual Reality (VR). The difference that clearly seen between VR and AR is, in VR, people are expected to experience the computer generated in virtual environment. While in AR, people can experience the real environment which is extended by the information and imagery via the system. Besides, AR also renders three-dimensional (3D) virtual objects and allows people to interact with virtual and real objects at the same time [3]. Yuen and Johnson [4] stated that, the 3D virtual objects which include the digital media such as audio, video files, textual information also can be incorporated into user's perceptions in the real world.

The exciting developments and various functions of AR made many researchers in all fields interested to work with the technology. In Educational field, the researchers also believe that AR has a vast potential in the augmentation of teaching and learning [4]. The potential of AR in education is being explored and it is widely being used recently, especially on the topics that contain abstract concepts including Chemistry.

II. PROBLEMS OCCUR IN CHEMICAL BOND

A. Difficulties to Visualize Abstract Concept in Learning Chemistry

According to Taber [5], Chemistry is a very conceptual subject which contains abstract concepts. For example, the chemical terms, the materials that can manipulate (solution, sulphur) the process, cannot be observed directly and also the ideas or concepts cannot be easily demonstrated and seen with our naked eyes. Peterson, Treagust and Garnett [6] found that in a group of secondary school students, 74% were unable to answer conceptual questions about electron repulsion in valence shells, but 78% were able to successfully answer test questions designed to test this understanding. Similarly, Yarroch [7] found that in"A and B level" high school chemistry students, virtually all could balance the equation, but half could

not draw a correct molecular diagram to explain this result. This was happening because they did not understand the concept of the subjects that resulted in this misconception.

Moreover, Driel, Verloop and Vos [8] found that Chemistry teachers seem to focus their practice on the content of specific models, rather than on the nature of models and modelling. In order to teach Chemistry in the way that students will understand, teachers need to have a clear and comprehensive view of the nature of a model in general, how their students construct their own mental models and how the expressed models can be constructively used in class. It is very important that students realize that no model is entirely correct and that they understand that science is more about thinking than just describing objects [9].

From the research by Tasker and Dalton [10], it shows that visualization by using technologies like animation is one of the learning strategies that encourage students' new skills with new situations and also access to their visualization skills in the assessment given, which then help them to understand properly. In addition, Trindade and Fiolhals [11] found that the students in the research have a clear data on the structure and molecules of ices when using computer visualizations. This is because computer visualization has an ability to represent the structure and images in 3D which then make the students see and understand the unseen things or concepts clearly. When talking about representing the 3D structure, in Chemistry, the synonym topic is Chemical Bond. This is because Chemical Bond requires visualization skills in order to make the students understand the concepts. All the above problems show that this kind of problem has already arisen a long time ago and yet the problems still exist.

B. Chemical Bond one of the Subject Required Visualization

Unal, Costu and Ayas [12] explored student's misconceptions on the fundamental concept of covalent bonding in the topics of Chemical Bond because there are comments from the students on the presence misconception that exist in their learning. Misconception can disturb the students' learning which makes a lot of researchers worried. Nowadays, with the existing of technologies, these problems can be lessening down by using the visualization advantages. In a research by Stotts and Conceicao [13], there is visualization of pure covalent, polar covalent and ionic bonds in compounds. It showed a great result which the representations provide better insight into the nature of each type of bond. This shows that visualization is needed in order tohelp preventing the misconception in Chemical Bond. There is also another example from the research by Garcia-Ruiz, Santana and Molina [14], which from the research visualization shows that it is worthwhile in using it for teaching and learning chemistry. This is because the traditional teaching has limitations in terms of facilitating the understanding of the precise properties related to the structure and molecules in a chemical bond. Therefore, students should rely on visual information that is displayed to the students with a practical and pay.

There are a lot of examples of research that used technologies in visualization for Chemical Bond. The list of the related researches is listed in the table below.

Table 1. The Visualizations Tools that Used for Chemical Bond

Author/s	**Visualization Tools**	**Used**
Ventakaraman [15]	Commercial molecular modelling software package, Spartan Student Edition	Emphasize basic chemical concepts, and guide students using the software to build, visualize, interact, and simulate molecular-level systems and processes.
Frailich, Kesner and Hofstein [16]	Web-based learning environment (website)	Visualize the structure of the substances (metal, ionic, or molecular), provide information about the physical properties of different substances, shows a connection between the structure of the substance and its properties
Garcia-Ruiz, Santana and Molina [14]]	Computer-generated three-dimensional spaces (PyMOL)	The user can interact with the graphical representation generally using desktop and laptop computers, used to display a molecule, display of molecules as Anaglyphs, enhancing their 3D structural perception.
Wu, Krajcik and Soloway [17]	Computer-based visualizing tool (eChem)	Build molecular models, and view multiple representations simultaneously.
Hanwell et al. [18]	Computer-based visualizing tool	Semantic chemical builder and

	(Avogadro)	platform for visualization and analysis

From the Table 1 above, it shows that technologies for visualization are really beneficial to be utilized in learning Chemical Bond in order to help solve the problems of misconception. This is because an illustration and visualization are needed when dealing with something that involves abstract concepts in learning process. That is why there are a lot of visualization tools being developed nowadays.

III. VISUALIZATION USING MAR

Over the several years, AR has been developed and become portable and available on themobile devices as the effects of the rapid development of the technologies in tablet computing. The convergence of AR and mobile devices delivers an innovative experience that is more exciting for users to explore the physical world easily because it is handheld and its portability if compared to PCs [19]. Therefore, all these advantages make AR different from MAR, where MAR can easily be moved with the users. Table 2 shows the recent research in MAR in fewer fields.

Table 2. The recent research on MAR

Author/s	**Areas**	**Purpose of MAR Use**
Chao,Pai and Parker [20]	Geography (Campus Event App)	To help users find daily campus events by visualizing events over the real world and showing the map and route to the event in real time.
Pundit, Zaibon& A. Bakar [21]	History	To help visitor conducting enjoyable informal learning at the cultural heritage site.
Kim et al. [22]	Health/Medical (Calory Battle AR)	To promote physical activity among children, but it can also be enjoyed by adults.
Chen [23]	Design Drawing (3D Model Visualization System)	To identify user requirements and to aid builders and engineers to have a better under-standing of real structure.

From the Table 2 above, it shows that MAR which incorporated AR technologies in mobile devices mostly been used to visualize the concept or process that cannot be seen by our naked eyes. In the educational field, subject of science is an example that required students' visualization skills because it always involves abstract concepts and processes. Moreover, in the literature, most of the researchers stated that Chemistry is a subject which is famous with the vast topics that contains an abstract concept which leads to misconceptions. This misconception will create difficulties in the studentsin understanding the concept.

Therefore, this research is going to develop MAR for Chemical Bond topic. Although this technologies is widely been used by a lot of research nowadays, but this research is more suitable for Malaysia context. The novelty of this research is the development of MAR on the topic of Chemical Bond will be followed the syllabus of *Kemahiran Bersepadu Sekolah Menengah (KBSM).*Thus, the developed MAR will help them in understanding more based on what they learn in class.

IV. IMPLEMENTATION OF ADDIE INSTRUCTIONAL DESIGN MODEL IN MAR DESIGN

From the aforementioned discussion regarding the problem in learning Chemical Bond and further the needs of technologies that encourage visualization skills to visualize the abstract concepts, the researcher has taken this opportunity to develop a MAR to help in visualizing the abstract concept in Chemical Bond.Therefore, in this study, ADDIE Model has been used as an instructional design model (ISD) to develop the MAR. This is because ADDIE model is simple and is also the basis of other instructional design models [24]. Furthermore, according to Jeuring, Rooij and Pronost [25], ADDIE is widely used in the instructional system development, especially for teaching methods, books, educational games and other technologies in education. There are five steps in the process of the ADDIE model, which are analysis, design, development, implementation and evaluation as shown in Figure 1.

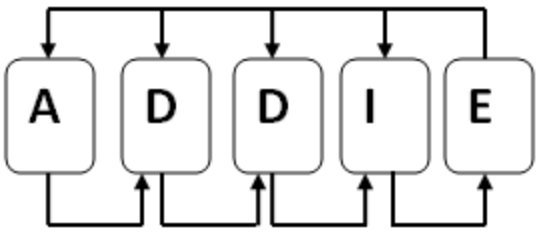

Figure 1. The ADDIE method (Jeuring, Rooij and Pronost, 2013)

Figure 1 above is the ADDIE process that is provided in the research by Jeuring, Rooij and Pronost [25]. It shows the flow of how the ADDIE process takes place. The tasks of each phase are highlighted in Table 3.

Table 3. The task of ADDIE model (Jeuring, Rooij and Pronost, 2013)

Phases	Tasks
A (Analyse)	Determining learning goals Analyze the learning materials and background Analyze teaching method Analyze related educational games
D (Design)	Design learning task Sequences task classes Set performance objectives Design supportive information Design procedural information Design challenges and levels
D (Develop)	Create artistic content Program the game Debug
I (Implement)	Implement in test environment Implement in a teaching environment
E (Evaluation)	Internal Testing Public Testing Gather Feedback

TheTable 3 above is the clear version of the tasks highlighted in the research by Jeuring, Rooij and Pronost [25], which they developed an educational games for their research. These tasks can be the guidelines on how the MAR designs in Learning Chemical Bond will be develop. Below are the detailed explanations on how every phase takes place.

A. Analysis

In the analysis phase, there is a process of analyzing the need of the MAR development for the visualization in the topic of Chemical Bond. Next, the instructional analysis is conducted which involves the study and analysis of the learning goals, objectives, learning materials and teaching method. The aspects related to the learners such as target group, prior knowledge, curriculum, and learner level also being analyzed.

The analysis of the tool that been used in developing MAR is also conducted. The tool that will be use is Unity which its consist of Unity3D Packages that used for developing application in AR. The tool is suitable to be use in developing applications in multiple platforms such as PC, MAC, Android and iOS.

B. Design

The design phase includes the aspects such as learning outcomes, teaching strategies and test items. In the research by Rio, Sabrina and Guan [26], it is stated that in designing learning materials, principle of sound learning theories and pedagogical aspects of teaching and learning should be taken into consideration. The storyboard is one of the processes in designing phase, which is similar to the designing of the learning task. For the MAR design, there are three parts of designing, which are the design of the storyboard for MAR application interface, storyboard of the visual when user point on the marker and lastly, the draft of the mini-book that is needed as a kit in learning the Chemical Bond.

1. The MAR application interface

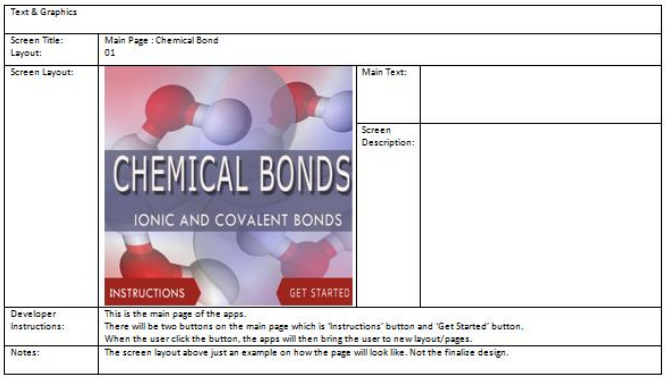

Figure 2. The MAR application interface

Figure 2 above is the example of the storyboard for the MAR application interface. There are few sections provided in the storyboard such as the screen layout that shows the interface on how the application will look like. Other than that, there are also other sections such as developer instructions, notes, main text and screen description. In the developer instructions, there is an explanation on how the MAR application functions. This is required to make sure that the MAR application will fulfill the learning outcomes that are required for the application. While, the 'Main Text' in the Figure 1 above is the section of the text that is going to be displayed on the page of the MAR application. This isdoneto ensure that the text is clearer rather than writing directly on the screen layout of the MAR application design. Last but not the least, the notes provided isexisted to stress out the important things for the developer to take into account, when developing the MAR application.

2. The Visual When User Point On The Marker

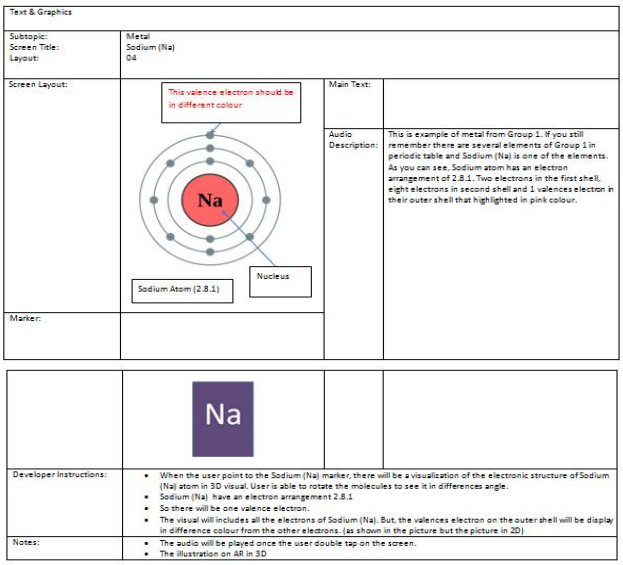

Figure 3. The Visual When User Point On The Marker

Figure 3 above is the visual of when a user point on the marker of MAR application. In the MAR design process, this process should be provided in order to explain how the 3D visual will be displayed when users use the application. It is same as the previous storyboard, but the difference is the addition of two new sections, which are the audio description and the marker. The audio description is included because, when the users double tap on the screen, the audio will be played. Accordingly, the user will be able to hear the explanation clearly while they are exploring the Chemical Bond in the MAR Application. The reason why the marker section is shown because in AR, in order to make the visual presented is by point up the devices on the marker. Differences marker will presenting differences visual depends on what we developed for the specific markers.

3. The Minibook

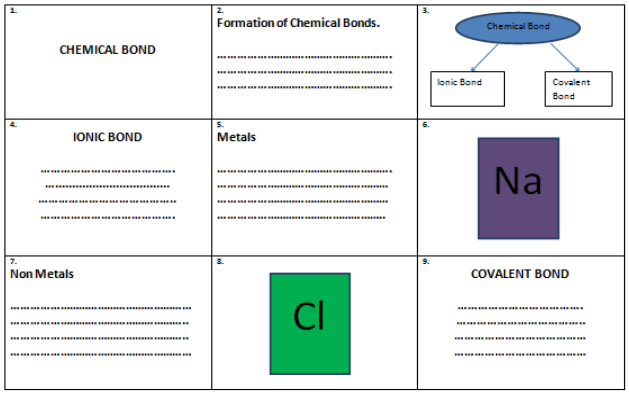

Figure 4. The Minibook

Figure 4 above shows the design of the draft of the minibooks that is needed in the MAR application for learning Chemical Bond. This draft is provided to make sure that the learning process will be systematic and the student will be able to understand what they are learning. In this MAR application, the Chemical Bond topics consist of two parts, which are the Ionic Bond subtopic and the Covalent Bond subtopic. Text also provided in the minibooks to make sure that the input acquired by the user could last for their long term memory.

C. Development

1. Development of MAR application

For the development of MAR application, the previous two phases which are Analyses and Design phase can guide the user on how the application should look like. There are three pages being developed in the MAR Application, which are the 'Main' page, the 'Instructions' page and 'Start' page.

2. The development of Minibook

While for the minibook, the books created are based on the draft of the minibook that is provided in the Designing phase. The process and the flow of the books should exactly follow the draft to make sure the minibook make sense of their users' learning.

D. Implementation

The Implementation is the phase where the MAR application is tested in the learning and teaching environment. The MAR application is tested to the user which is Form 4 students who are taking Chemistry subject.

E. Evaluation

In the evaluation phase, it involves the process of evaluating the MAR application that was developed. The evaluation process is done by gathering feedback from the users who are the teachers who are instructed the learning, and the students who are learning the Chemical Bond using the MAR Application.

V. CONCLUSION

Overall, it is important to design before the development of the learning application in order to ensure that the user learning process will be successful [27]. However, before designing, a number of analyses should be conducted to find the problems that really exist in the learning environment. Besides, an innovative way like learning using MAR should be implemented in the students learning environment in order to help them learning in a fun way instead of learning in traditional ways that they used before.

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