Development of Augmented Reality application for learning the concept of molecular geometry

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Abstract. This research aimed to develop and measure the usability of the Augmented Reality App used for learning Chemistry, focusing on the concept of molecular geometry. AGILE model of development was employed to step by step development, starting from the analysis of the curriculum and need assessment, followed by design, development, deployment and evaluation. Some computer software such as Vuforia (database), unity (App generator) and blender (3D object maker) used at the development stage of the app. 17 students took part in the testing phase of the app. The students evaluated the ease of use of the app using the System Usability Scale (SUS). The SUS score of the app was 92.7, which means the app is easy to use, and most of them would recommend the app for other students. The result indicated that the app is user-friendly, light, and useful to learn the concept of molecular geometry.

1. Introduction
Student engagement in the classroom is a crucial point for successful learning [1]. Teachers should pay attention to acquire the focus and attention of students to achieve the goal of learning in the classroom. However, student engagement in the school tends to decline from time to time because students may feel bored with traditional stereotypical learning style where the touch of technology is ignored [2]. Instead of adopting the rapid change and development in this digital era, most schools, especially in Indonesia, even ban smartphones and gadgets from being used in the school area. The educators seem to be allergic and close their eyes to the massive use of mobile apps in daily student activities outside the schools. Millions of mobile app both paid and free are available to help students learn subject matters [3], but school might have to control and manage them to be on the track by integrating the use of mobile phone to the school curriculum [4].

Augmented reality is one of the emerging advanced technologies currently used in many sectors such as robotics[5], medical surgery [6,7], medicine and infrastructural design [8]. The main advantage of AR is the encouragement of people to experience enhanced artificial reality to represent the real object by using technology devices like smartphone, tablet, and personal computer through the camera feature [9]. By using this technology, abstract concepts can be modified and presented in more realistic models. Since the understanding of abstract concepts is crucial for students, involving computer software to guide students in learning, thus become very important and helpful.
This research focuses on the development of an android app that makes use of augmented reality technology to view the abstract concept of molecular geometry. The app was expected to help the student understand the concept of molecular shapes through augmented virtual visualisation. The AR app is currently under evaluation in a small tasting group before implementation in the field to ensure the ease of use of the app. Therefore, the paper focuses on the process of app development.

2. Method
This work was a research and development (R & D) adopting the AGILE model, which consists of 5 stages including Analysis, Design, Development, Deploy and Review [10,11]. In the analysis phase, a need assessment was carried out by delivering seven questions related to the AR application and chemistry subject matter. We asked students about their experience in learning molecular shapes, their interaction with learning media, and their knowledge of using AR technology. In the design stage, based on the assessment results, all components needed for the development of AR, including markers, 3D objects, and computer software, were determined. App markers were prepared with a blender software, while 3D objects of molecular shapes made using Unity and construction of an android application created with the collaboration between Unity and Vuforia. The final product was APK extension executable by an Android operating system. In the testing phase, a trial was carried out to a small volunteered group (17 students) from the Department of Chemistry Education, Faculty of Education and Teacher Training, Universitas Syiah Kuala. The data of system usability of the app obtained by using the System Usability Scale (SUS) questionnaire consisting of 10 statements developed by Brooke [12] due to its validity compared to other methods [13].

3. Result and discussion
3.1. Analysis
At this stage, a review of the school curriculum was conducted to determine the appropriate chemistry concepts that can be represented using AR Media. Since there are many abstract concepts in chemistry which promote misconceptions among students, all abstract concepts should be introduced in a more real and easy way to gain students’ understanding[14]. The molecular shape is among abstract concepts in chemistry where students tend to misunderstand due to lack of proper representation. Currently, textbooks are only capable of representing molecules and atoms in two-dimensional figures, while the concept of modern chemistry revealed that both atoms and molecules are three-dimensional creatures. Therefore, AR which capable of augmenting 3D object could help learners understand the concept of molecular shapes better. In addition to curriculum analysis, seven questions related to the development of this media were also prepared and handed to the participants to gain their opinions and suggestions regarding the AR development. Table 1 below shows the respondent's answers regarding the need for AR media in learning chemistry, especially in the concept of molecular shapes.

| No | Questions                                                                 | Answers (%) |
|----|---------------------------------------------------------------------------|-------------|
|    |                                                                           | Yes | No  |
| 1  | Do you use specific learning media to study the concept of molecular shapes? | 82.3 | 17.6 |
| 2  | Do you think you can easily understand the concept of molecular shapes by studying using figures represented in a textbook? | 5.8  | 94.1  |
| 3  | Do the figures illustrated in textbooks attract you to learn the concept of molecular geometry? | 100  | 0.0  |
| 4  | Did you know about Augmented Reality?                                    | 0.0  | 100  |
| 5  | Have you ever used Augmented Reality as learning media?                  | 0.0  | 100  |
Do you think AR is exciting to be used as learning media to study molecular shapes? 100 0.0
Do you think molecular shapes would be more interesting to study using 3D AR compared to 2D figures? 100 0.0

The table 1 shows that most students do not easily understand the concept of molecular shapes if they only rely on images displayed in a textbook because the image does not show a real angle. The students argued that the pictures in the book could attract their attention in learning, in line with a question no. 6 and 7 where students feel AR would be a great choice as media to help them in learning molecular shapes, but most of them do not have experience of using AR as media of learning as reflected by their answers (no. 4 and 5). After students answered question number 1 to number 5, we briefly introduced AR technology to gain their attention since they had no idea at all about AR, then the students continued answering the rest of the questions. Therefore, the last two questions illustrated their interest in AR.

3.2. Design
The stage of design includes three components e.i markers, 3D objects, and the activity scheme of the AR application that explained the operation of the app. The app markers and 3D objects of 9 different molecules according to the VSEPR (Valence Shell Electron Pair Repulsion) theory were prepared using CorelDRAW® and Blender. The molecular formulas included BeCl₂, BF₃, BrF₅, CH₄, H₂O, NH₃, SF₄, SO₂ and XeF₄. Figure 1 depicted the example of markers and 3D objects.

![Figure 1. Sample of NH₃ marker and 3D model.](image)

Fig-1 shows the marker for NH₃ molecule, the common mistake made by students that they could draw NH₃ as planar while the correct shape of the molecule is trigonal pyramidal due to pair electron repulsion provided by two electrons own by a nitrogen atom. To better understand this concept, the student should be able to draw Lewis structure so they can realise the presence of electron pair in the molecule. This such abstract concept and many more would be more straightforward for students to understand if they are allowed to experience the AR app more often in the classroom.

3.3. Development
Upon the completion of components design, all components required for app development uploaded to Vuforia® as a database. Collaboratively, by using unity®, the app was then developed to obtained executable file as APK to be installed on android® devices.
Fig.2 depicted the view of both markers for specific molecule 3D model in the computer software of unity. All designed molecules integrated along with marker files in the unity software. After proper size and view have been set up, the app was then built to obtain the APK, installable extension for the android operating system.

Fig-3 depicted the built application named “AR Kimia” showing molecular shapes of some compounds at the same time, the app also displayed the bond angle of each molecule, and electron pair repulsion based on VSEPR theory. By showing the bond angle and paired electrons, the students were expected to have more comprehensive knowledge regarding molecular geometry. Besides, the real app shows the dynamic movement of molecules instead of static that can only be observed by operating the app on the physical devices.

3.4. Deploy
At the stage of deployment, 17 students were involved voluntarily to an early trial of the app. They were asked to install the app on their devices and use the app for half an hour. Their experience regarding the ease of use of the app was investigated by answering SUS questions.
Figure 4. SUS scores obtained from 17 users.

Fig 4 shows that the app was found to be very easy to use, and generally, all users feel confident and would recommend others to use this app. The usability is an essential factor for a computer program or android app to be effectively distributed and to reach more users [15]. The smoother the app operates, the wider audience the app can reach. Therefore, we believe that this app will be able to target a wider audience since the usability score reached 92.7, which is grade A, i.e. best imaginable criteria [16].

4. Conclusion
The Augmented Reality app for the topic of molecular geometry has been successfully developed and tested to a small group of students at the department of chemical education, Universitas Syiah Kuala. Based on app evaluation using the System Usability Scale, the average score was 92.7 indicating that the app is easy to use.

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