*Research Article*

# The Use of Augmented Reality 2.0 (AR 2.0) Application in Assisting Students to Draw 3D Orbitals

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***Abstract:*** *The study aims to promote students' independent learning by implementing the use of AR technology in Chemistry concepts, particularly in the topic of 3D orbitals. The AR 2.0 app "3D Molecular Shape" is an interactive mobile app which was developed using UNITY with C# language and further modified into version 2.0. It can be found and downloaded free of charge from Google Play Store. The upgraded AR 2.0 application provides QR code for scanning and user manual to follow. The process involves scanning the pre-generated QR codes via smartphones and enables students to visualize the 3D orbitals in AR views. This helps students to understand and draw the accurate 3D orbitals successfully. The analysis was carried out based on the pre- and post-test among pre-university students cohort 21/22. Respective sets of pre- and post-test questions were administered to the students. The data was collected and analyzed quantitatively using bar chart. From the analysis, a significant improvement shown by the students' performances convinces that this AR app is able to assist students to understand better and draw 3D orbitals more accurately. Interviews and questionnaires were distributed and collected among the candidates to acquire their perception towards the use of AR 2.0 app "3D Molecular Shape" in supporting them to draw the 3D orbitals.*

*Keywords: AR app 2.0; 3D orbitals; QR code.*

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## 1. INTRODUCTION

Most of the educators have made progression and gradually familiarize themselves with the uses of online platforms such as *Google Classroom*, *Google sites*, *WhatsApp* and *Telegram* to interact with their students. However, the advancement of the technologies imposes some challenges to the educators on how to incorporate the subject content knowledge into various teaching methods; how to motivate and captivate students, who are more IT proficient, to learn the subject content in a more creative and interesting way. Johnstone (2000) stated that Chemistry is found difficult to comprehend due to the complicated integration between the information of macroscopic, microscopic, and symbolic domains. For examples, students were asked to visualize 3D molecules in spatial space and draw them out onto papers. This is indeed a huge challenge especially teaching the STEM subjects which require the teachers to explain the conceptive and abstract topics.

### *1.1 Problem Statement*

Based on Teaching and Learning (TnL) reflection, the idea of the project started when from the lesson related to SK015 Chapter 2 Atomic Structure and DK014 Chapter 5 Electronic Configuration. During the lesson, we observed that several students could hardly understand and visualize the 3D

orbitals (1s, 2p, 3d etc). They were unable to draw the 3D orbitals correctly onto papers. After several discussions, we have agreed on and outlined three problems.

Based on the Candidate Script Report Semester 1 2015/2016, 2017/2018 and 2018/2019, about 65% candidates were unable to draw the 3D orbitals precisely in the examination PSPM 1 and hence did not granted marks in that question. This indicates that those students who had failed to answer the questions might be due to lack of understanding on the 3D orbitals.

Due to the pandemic, we experienced since March 2020, classes and lessons are forced to conduct virtually via online platforms such as Zoom, StreamYard or Google Meet. As such, some of the lecturers have encountered difficulties and challenges to teach and guide their students to visualize and understand the spatial 3D orbitals. Furthermore, an additional challenge they have stumbled upon is how to make sure their students are able to draw the 3D orbitals correctly in this topic. Figure 1 shows the orbitals that can be found in students' notes. Based on these diagrams, we can clearly see that the orbitals are in 2D and flat in view. In fact, these orbitals are in 3D and it is very challenging to guide the students to draw in 3D. The difficulty increases if students are unable to acquire correct interpretation.

*1.2 Research Objectives*

The general objective of the research is to create an augmented reality (AR) mobile app to assist students to perform better in drawing 3D orbital diagrams in Chemistry subject. The specific objectives are:

- To facilitate students' imagination in visualizing 3D orbitals.
- To assist students in understanding the 3D orbitals.
- To ensure students can draw 3D orbitals correctly.

## 2. METHOD & MATERIAL

The mobile app and augmented reality 3D orbitals were developed using UNITY and the function of the app was programmed using C#. Then the app was uploaded into *Google Play Store*. In order to view the 3D orbitals via this AR app, QR codes were generated beforehand. Students will then use the AR app to scan each QR codes and its respective 3D orbitals, in AR view, will appear on the screen of their smartphones.

The research involved 80 students from four semester program. Version 1.0 involved 20 students from LS1 and LS2 each whereas for version 2.0 it involved 20 students from LS3 and LS4 respectively. These students were selected among those who did not achieve a satisfactory mark during the topical test topic 5, which related to solving problems involving orbitals.

*2.1 AR 1.0 – Molecular Shape 3D*

The AR app version 1.0 is named "Molecular Shape 3D" with some of the weaknesses which have been overcome into version 2.0. The Figure 3 shows the three simple steps to use the AR app 1.0.


**Figure 1**. Three easy steps for using the AR app 1.0.

However, there are some deficiencies in version 1.0 which require improvement. Table 2 shows the weaknesses and the consequences that it causes.

**Table 1.** Weaknesses of AR app version 1.0

| | |
|---|---|
| i. No QR code | No QR code is enclosed in the AR app. Therefore, it is difficult to share with other lecturers or students. |
| ii. No user manual | Impractical for some of the users which is new to this AR app |
| iii. No colour label for the axes | Difficult for students to differentiate between x-, y- and z-axes |

*2.2 AR 2.0 – 3D Molecular Orbital*

After figuring out the weaknesses of the AR app 1.0, some modifications have been done and we came out with a new version 2.0. Figure 4 shows the latest logo for version 2.0 AR app which named as "3D Molecular Orbitals". The latest version 2.0 has improved from the previous version which includes the QR codes, user manual and colour axes. In version 2.0, the application manual is available and students just need to click at the "ABOUT" button to access the QR code and manual (refers to Figure 5).

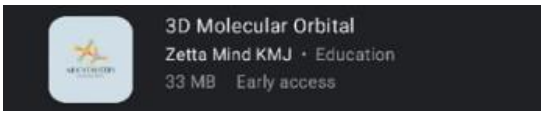



**Figure 2**. Version 2.0 of AR app


**Figure 3.** User manual in AR app version 2.0

**Table 2.** Comparison between AR app version 1.0 and 2.0

| | Version 1.0 | Version 2.0 |
|---|---|---|
| **Name of AR app** | Molecular Shape 3D | 3D Molecular Orbitals |
| **QR code** | No | Yes |
| **User manual** | No | Yes |
| **Axes label** | No colour | With colours |

## 3. FINDINGS

### *3.1 Effectiveness of the Innovation*

From our study, the data was collected using qualitative and quantitative methods. The main instrument for quantitative measurement is by using pre- and post-test questions with similar and comparable difficulties while for qualitative method, the data was collected using interviews. A pre-test was given to the 40 students to identify their achievement before and after the implementation of the method.

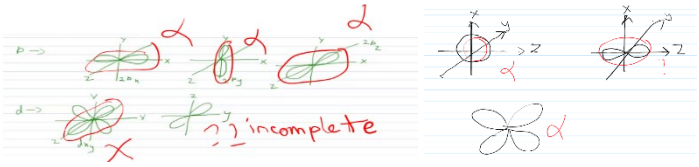



**Figure 4.** Examples of students' answer during pre-test

The findings from pre-test showed that students incapable to draw the most of the orbital's diagrams correctly. They can't distinguish the correct axis pass through certain area. During interviews, researcher used open ended questions to give the students more freedom to give answers without feeling restricted. The question was what the difficulties in drawing correct orbitals diagrams were. Furthermore, a few students with score range (0-4 marks) during pre-test and obtained (8-10 marks) during post-test were selected and the outcomes of the interviews are recorded and are available at https://tinyurl.com/ARappresult.

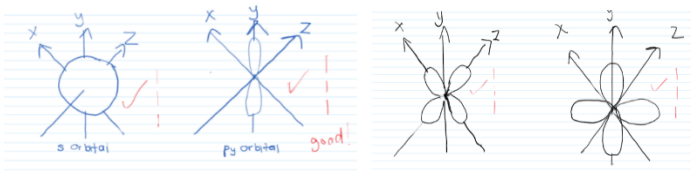



**Figure 5.** Examples of students' answer after the use of the AR app

Based on the Chart 1and 2, both AR app version 1.0 and 2.0 reveals that students show a significant improvement in their post-test result after applying the AR app.

**Chart 1.** Comparison between pre- and post-test from sample LS1 and LS2 (Version 1.0)

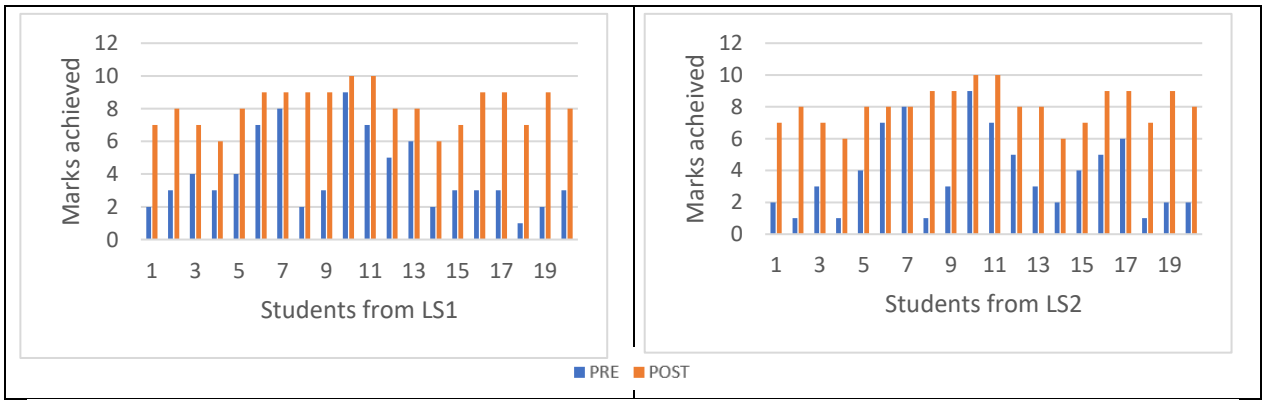
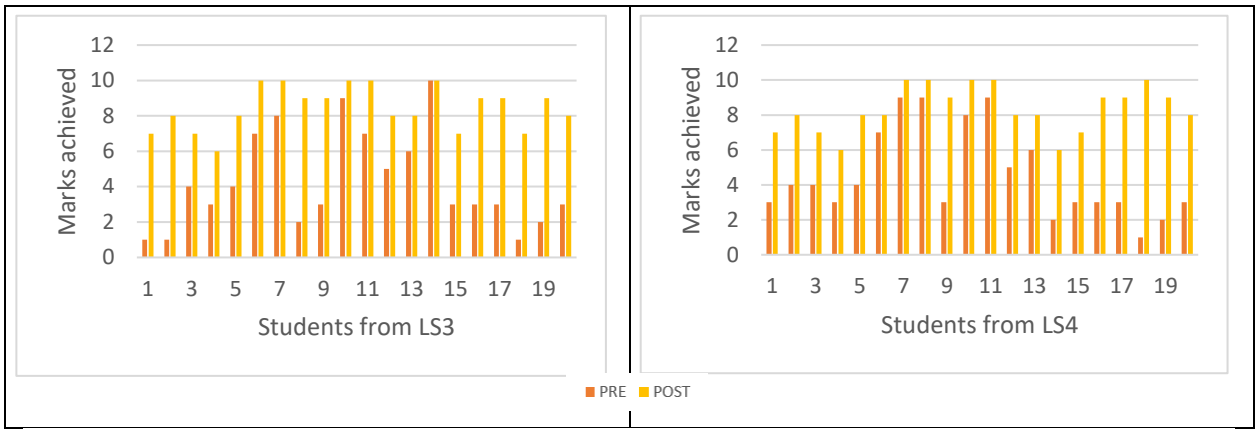


**Chart 2.** Comparison between pre- and post-test from sample LS3 and LS4 (Version 2)




*3.2 User Satisfaction*

Perception of the students towards the practical use of the AR app was collected using Likert level determination scale, which ranges from 1 – strongly disagree to 5 – strongly agree. Table 5 below shows the average mean of the study. It reported an average high value of the average mean. Most students think it is helpful in learning orbital diagrams and should be used in other subjects as well. This further convinced the applicability of the AR app in assisting the teaching and learning process. The overall high marks indicate that our main users, the students, are satisfied with the AR app.

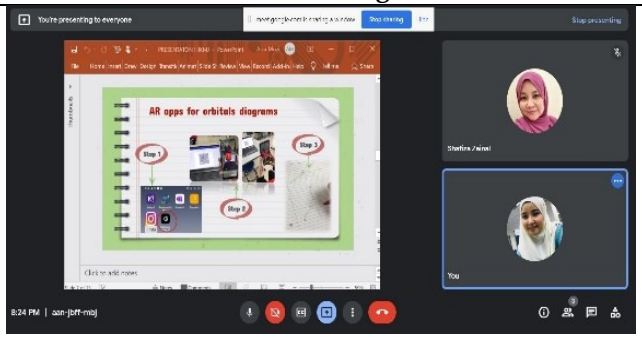
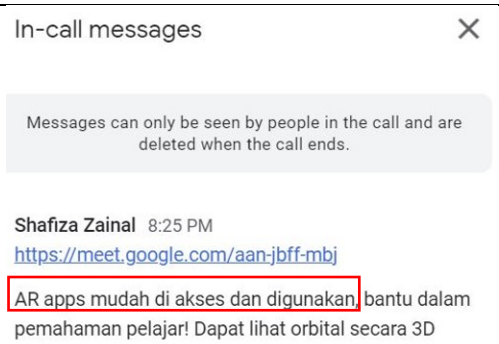
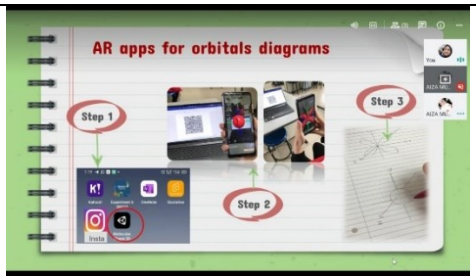
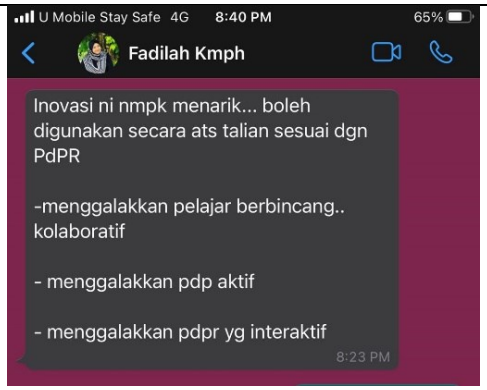
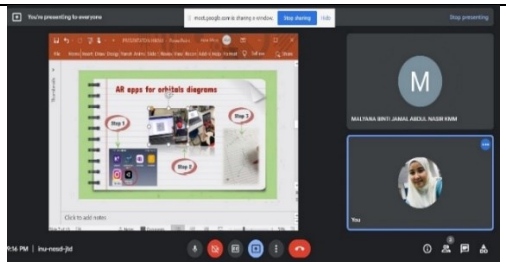
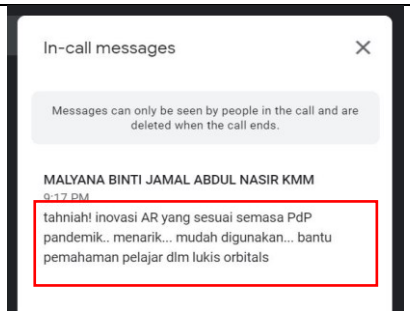
**Table 3.** Average mean value of students' perception towards AR app

| No | Item | Mean |
|---|---|---|
| 1 | AR app is helpful in learning orbitals diagrams | 4.834 |
| 2 | AR app allow students to learn at their own time and pace | 4.689 |
| 3 | AR app promote self-directed learning in students | 4.620 |
| 4 | AR app should be used along with traditional teaching method to improve educational outcomes | 4.768 |
| 5 | AR app is easy to use and user friendly | 4.900 |
| 6 | AR app should be used in other subjects as well | 4.820 |

*3.3 Feedback collected*

The following shows some feedbacks given by a few Chemistry lectures from several matriculation colleges. They also agreed that this AR app is user friendly and once the app is downloaded it can be accessed anytime and anywhere without internet.

**Table 4.** Sharing session with lecturers from different matriculation colleges.

| Innovation sharing session | Feedbacks |
|---|---|
|  Sharing session with Pn Noor Shafiza binti Zainal, Chemistry Lecturer from Kolej Matrikulasi Selangor. |  |
|  Sharing session with Cik Nur Fadilah binti Zulkiflie, Chemistry Lecturer from Kolej Matrikulasi Pahang. |  |
|  Sharing session with Cik Malyana binti Jamal, Chemistry Lecturer from Kolej Matrikulasi Melaka. |  |

## 4. DISCUSSION

4.1 *Relevance To Teaching and Learning Process*

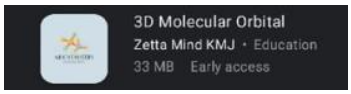
The AR mobile app is relevant and can be applied in module SK015 Topic 2 Atomic Structure for two semester programme and DK014 Topic 5 Electronic Configuration for four semester programme. It can also be used for Sixth Form and foundation programme that offer similar module. Table 8 below shows the comparison between the teaching method before the innovation and after the application of the AR mobile app.

**Table 5.** Description of the innovation

| | **Previous method** | **Innovation** |
|---|---|---|
| **Content** | 2D diagram available in the lecture note and reference book | Create a mobile app which shows the 3D orbital via AR application |
| **Strategy** | Chalk and talk about the 3D shape, merely through self-imagination | Promote student-based learning as the AR mobile app is very easy to access and it enables them to discover the fun way to learn the 3D orbitals. |

In comparison to the conventional way, the use of AR application is more efficient in delivering the content knowledge. It shortens the time in teaching and at the same time promotes student-centered learning.

**Table 6.** Comparison between conventional method and AR innovation

| | **Conventional Method** | **AR Innovation** |
|---|---|---|
| **Time saving** | ~30 minutes | Less than 15 minutes |
| **Cost saving** |  <br>Expensive orbital models |  <br>Free |
| **Improved productivity** | Boring<br>Need more explanation | Fun and creative<br>Can be replayed and reused |
| **Convenience** | Need to bring book or models | Can be accessed anytime and anywhere with only smartphones |

4.2 *Impact for Education*

The AR 1.0 mobile app has been presented at the 3rd International Conference on Science with other competitors at international level on 13th and 14th September 2021.


**Figure 6.** Letter of acceptance and certificate of participation

We also participated in the Virtual Innovation Competition 2021 (1st June - 29th September 2021) and won a silver award at international level with the innovation AR 1.0. The certificate of achievement is as shown in Figure 7. Figure 8 shows the participation in sharing of research project in SeDAR'21 at international level.


**Figure 7.** Silver Award VIC 2021


**Figure 8.** Participation in SEDAR'21

With the upgraded version of the AR 2.0mobile app, we won Platinum award in KonPPi-2 2022 (Figure 9) and Gold award at iCompEx 2022 (Figure 10). Both innovation idea has been presented and competed at national level.


**Figure 9.** Platinum Award KonPPI-2 2022


**Figure 10.** Gold Award iCompEx 2022

Our innovation idea AR 2.0 has just recently been granted Gold award and a special recognition, the second best overall project award in PIITRAM 2023 (Figure 11).


**Figure 11.** The second best overall project awards and gold medal won in PIITRAM 2023.

## 5. CONCLUSION

The implementation of the AR app was shared with a few lecturers from different matriculation colleges. They are very positive about the application and the feedback is shown in Table 6. We plan to further sharing the idea and the application with high schools that offers Chemistry subjects in the sixth form and officer from District Education Office Tangkak. The AR application that was uploaded into Google PlayStore is available for all Android users to download for free. Besides the students in matriculation programme, the app is also open for the use to sixth form students, Science diploma and A-level programme which offer Chemistry subject.

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