M-Learning: Atomic Orbitals of Elements in Periodic Table using SPATO

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Abstract. Recently, student’s enrolment in science and health studies has shown a downward trend. This may jeopardise the successful implementation of government's agenda in alleviating Malaysia's performance in the world stage. In this report, the focus is on a mobile application named SPATO, a teaching aid in the learning of atomic orbitals of elements in the Periodic Table. SPATO is developed with the aim to spur the interest of students in studying the science-related subjects in the guise as a mobile-learning tool. The Waterfall Model was used to fulfill the aims in the development of this mobile application. Students and education’s staffs were involved in the testing of this mobile-learning tool. From the results, SPATO had shown to be well accepted by the users. Users found that it is easy to use, even though initially they might not familiar with the m-learning application. These results indicated that SPATO can provide an alternative and another approach for user in understanding the chemical elements.

1. Introduction
Recently, the Ministry of Education Malaysia reported that the number of student enrolment in the field of science and health studies had decreased [1], indicating the interest in the study of science in Malaysia is at its lowest ebb. Since Malaysia aims to become a developed country by the year 2020, and the agenda forwarded in the TN50 plan, the importance of the science, technology, engineering, and mathematics (STEM) studies cannot be overstated [2, 3].

Due to the rapid advancement of mobile technologies, there are new opportunities to incorporate the latest innovation in the digital front for teaching and learning. Compared to the computer-based educational software and simulation, studies using the mobile application is still new to the education world. However, some of the educational apps had shown to contribute and enhanced the effectiveness in teaching and shaping the students’ characteristics [4, 5]. Mobile application can be used to attract science students by providing a flexible platform in learning a topic of interest. It is an alternative way to support the traditional methods in teaching, in which the amount of time spent on a topic could be increased [6].

One of the widely used basic information in pure science education is the atomic orbitals of the chemical element. In the current report, a mobile application SPATO (SPatial ATomic Orbitals) with certain properties will be presented. This mobile application will allow the user to view image of the

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atomic orbital surface. The size of the orbitals can be compared between the elements of the Periodic Table (PT). Different type of orbitals can be analysed using this application.

2. Literature Review
Understanding the elements in PT is an important part in science education. PT is an organized form of sorting the chemical element according to the atomic number. It was introduced in 1869, and has undergone many changes before it exists in the form as it is known nowadays. The modern version of the PT was created by Nobel Laureate Glenn Seaborg during 5th decade of 20th century [7].

PT is widely used due to the important information that are usually incorporated in it. There are many types of printable PT that are available in the internet and text books. However, due to the space limitation, not all properties of the elements can be included. One of them is the atomic orbital. Atomic orbital is a space where the electrons have a chance to be found. It is a standard topic usually taught in the introductory chemistry classes [8, 9]. For some other countries, atomic and molecular orbitals are part of the secondary school syllabus [8]. There have been many approaches in generating the atomic orbitals, ranging from using marbles and papers [10], software [11, 12] to the 3D printer [13].

Mobile learning, also known as M-learning, is defined as the learning process by using the mobile devices, such as smartphones. It is also known as “e-learning using mobile devices” [14]. Learning the elements in the PT through M-learning can be considered as an interactive aid to the existing methods. M-Learning is supported by variety mobile communication platform such as communicate using voice, surfing to the learning portal on the Internet and learn on platform Short Message Service (SMS) [6]. This shows that M-Learning could be interactive learning platform with the combination of audio, portal web and mobile phone technologies in the one package.

Atomic orbitals can be had from performing quantum-mechanical calculations (e.g., using software Gaussian [15]) or drawn from the hydrogen-like equations of the orbitals. One of the innovations using M-learning, related to atomic orbital is developed by Bonifácio [11]. In the work, labelled QR-APTE, which is based on quick-response (QR) codes, the information of the chemical elements in the PT can be retrieved in the audio form by scanning the given QR codes. It focusses on the usability for the visually-impaired people.

3. Methods
To fulfil the aims of this study, Waterfall model was used, where the model consist of analysis, design, implementation and testing phases, as shown in Figure 1 [16]. To proceed to the next phase of the Waterfall model, the previous phase need to be completed [17].

![Figure 1. The waterfall model.](image-url)
3.1. Analysis
In the analysis phase, the information for the development of the mobile application were collected and recorded in requirement specification document. The information was collected from the online sources, article, journal and online databases.

3.2. Design
Based on the requirements, the designing of the interface for the android application was made. The storyboard was used as the guidance on the real interface design before implementing the interface design prototype using the Android Studio, Genymotion, Balsamiq and Adobe Photoshop CS5. The interface was designed by referring to the existing interface of another application that is being used for the PT in order to fulfil the users’ requirements. It provides two different options to compare the atomic orbitals.

As shown in Figure 2(a), two different buttons were developed to indicate different options. “Explore” button would provide the detailed information about the chemical elements and the atomic orbital of the element. The “Explore” button will lead to page with 18 different buttons indicating 18 different elements in PT as shown in Figure 2(b). All of these 18 buttons would lead to another page with the information of the chemical elements (Figure 2(c)). The atomic orbital and information is placed side by side. The atomic orbitals include in this page also has a button to go to another page. Figure 2(d) shows the interface of the atomic orbitals for the chemical elements. This interface provides the zooming option of the molecular orbital. The name and coordinates was overlapping the atomic orbital for better understanding of the size of the atomic orbital of the chemical elements.

![FUN ORBITAL]

**Figure 2.** Interface of the application in (a) front page, (b) elements provided, (c) details of element and (d) molecular orbital of element.

The “Compare” button as shown in Figure 2(a) would lead to another interface where a list of chemical elements will be shown. To compare two different elements, Figure 2(b) would appear for second time after second element can be chosen to compare to. Last interface would show the two
different elements put side by side as in Figure 3. Same zooming option was provided to the users. The coordinate scale is similar for a better comparison of the atomic orbitals.

![Figure 3: The comparison of molecular orbital page.](image)

The atomic orbitals viewed in this mobile application are generated using Gaussian 09 [15] and Multiwfn [18] software. The Gaussian 09 is used to generate the atomic orbital of the chemical elements through the quantum mechanical calculations. The outputs from the calculations were fed Multiwfn, which provides the coloured atomic orbital with scales overlapping the atomic orbital.

3.3. Implementation
The project was then developed based on the input collected during the analysis and design phases. Java language was used as the writing source code to develop the mobile interface link and function. The library used is based on the Android library provided by Android Studio software.

3.4. Testing
The mobile application uses functional and acceptance testing test for any fault and failure. Functional testing is to ensure the application is working as planned while acceptance testing is to ensure the acceptance of the user to the applications. The mobile application is deployed on the user environment which involved the students as a target user, to identify the effectiveness of the mobile application.

3.4.1. Functionality testing.
Functional testing is applied to validate the functions of the application where it is aimed for a better performance to meet the requirements. There were several modules used for the functionality testing as shown in Table 1. The module for this system consists of the list of 18 elements based on the PT, the list of each kind of orbital available for viewing and zooming option of the atomic orbital image.

| Test ID | Modules                                      | Expected Results                                      | Results |
|---------|----------------------------------------------|-------------------------------------------------------|---------|
| 1       | Show list of 18 elements based on the PT.    | Users choose an element to learn the atomic orbital shape and information. | Good    |
| 2       | List type of orbital.                        | The user chooses the type of orbital.                 | Good    |
| 3       | Zoom image atomic orbital.                   | The user is able to zoom the image to view more clear the shape and coordinate of orbitals. | Good    |
3.4.2. Acceptance Testing.
The questionnaire was constructed to examine the m-learning interest of the research participant on this mobile application. The Technology Acceptance Model (TAM) was used to understand the implementation of the mobile application from the users’ perspective [19]. TAM questionnaire was divided into four different categories, which are, perceived usefulness (PU), perceived ease of use (PEU), attitude toward usage (ATU) and behavioural intention to use (BIU).

PU section was constructed to understand the extent of the system satisfying the user needs. Meanwhile, PEU is the extent of user’s understand ability and their ease when using the system. ATU discussed the attitude toward usage which is the extent of the effectiveness of the system to the users. Lastly, BIU is asking about the intention of users for adopting this system in future.

4. Results and Discussion
Two preliminary evaluations were carried out to evaluate SPATO. The first evaluation is about the functional testing of SPATO. The second one is to gauge the student’s understanding on the atomic orbitals after using SPATO.

From the results of the functional test, it can be concluded that SPATO is easy to use. The user found it easy to handle this mobile application even though majority of them are not familiar with the M-learning application. From the observation, there were no users facing any problem when using the application in the testing phase.

The overall mean was classified in three scales which was negative, neutral and positive as shown in Table 2. The range of this scale is between zeros to five.

| Table 2. Range of mean |
|------------------------|
| Category | Range of Mean |
| Negative | 0 – 1.66 |
| Neutral | 1.67 – 3.33 |
| Positive | 3.34 – 5 |

From table 3, results shows that, the overall mean for the acceptance test using TAM is 4.16. This concluded that for each category tested, positive feedbacks were obtained from the users. This also means that the users accept SPATO mobile application.

| Table 3. Acceptance testing TAM result |
|----------------------------------------|
| TAM Category | Min | Max | Mean | Mean Category |
| Perceive Usefulness (PU) | 3.9 | 4.2 | 4.05 | Positive |
| Perceived Ease of Use (PEU) | 4.1 | 4.5 | 4.3 | Positive |
| Attitude Toward Usage (ATU) | 4.1 | 4.4 | 4.25 | Positive |
| Behavioral Intention to Use (BIU) | 4 | 4.1 | 4.05 | Positive |

5. Conclusion
SPATO mobile application was developed to provide effective learning of atomic orbitals of the elements in the PT, with the aim to spur the interests of more students to study science courses. Generally, this mobile application has achieved the objective as to develop a convenient and suitable mobile learning of atomic orbital for elements 1 to 18 in the PT. The preliminary evaluations the effectiveness of the mobile learning among students of sciences and technology in UiTM Perlis. The limitations of the SPATO should be improved in the future.

Acknowledgment
The authors would like to thank Institute of Research Management & Innovation of Universiti Teknologi MARA for providing the Academic & Research Assimilation (ARAS) fund (project code 600-IRMI/DANA 5/3/ARAS (0194/2016)).
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