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Design, Development, and Evaluation of CHEMBOND: An Educational Mobile Application for the Mastery of Binary Ionic Bonding Topic in Chemistry

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Abstract The integration of information and communication tools in education has been a common trend in the last decade which resulted in increased student engagement, motivation, and even achievement and learning. Despite these improvements, science teachers still report challenges with its use in science education. Several abstract topics in chemistry are still not This research aims to develop, design, evaluate a mobile application that can be used to teach and master binary ionic bonding topic in chemistry. The research utilized a design and development research design for the app development while a quantitative-descriptive research design was used to evaluate the app. A researcher-made rubric (Krippendorf's alpha = 0.82) was used to evaluate the app and it was found out that the application is interactive and attractive. Intrinsic motivation was also determined using an adopted instrument and was modified to fit the objectives of this research. The respondents agreed that, in terms of their intrinsic motivation, the application had some value in it and that it increased their concentration towards learning. This implies that the developed mobile application developed can be used to teach and master binary ionic bonding topic in chemistry.

Keywords: *chemistry education, educational intervention, educational gamification, ICT integration, innovative teaching, innovative learning*

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1. Introduction

The principal goal of science education is to produce a scientifically literate community [1,2,3,4]. This can be achieved during this era by integrating different Information and Communication Tools (ICT) available to make the teaching and learning of science more interesting, versatile, and goal oriented [5]. This rapid development paved the way for increased student engagement, motivation, and learning [6].

Despite the advances in ICT development and the great level of improvement in science and technology, science teachers still report that they are facing many challenges and also opportunities with regard to science education [7]. One of the problems found in the literature is that most countries integrate ICT only routine type of tasks like sporadic and mechanical retrieval of information from the internet [5]. This highlights the fact that the use of ICT in education do not necessarily transform science education for the better. More so, there is a huge responsibility put unto teachers in how they select and evaluate appropriate ICT tools to integrate in their teaching and learning process.

One of the ICT tools used widely in education are mobile applications [8]. Mobile technologies for learning are handheld devices that support individual and collaborative learning [9]. The use of mobile technologies is currently revolutionizing and transforming traditional and conventional classrooms into a more interactive one through applications that enhances students' learning [10]. In addition, mobile learning provide opportunities for students to engage in problem-solving based learning activities. The features of mobile applications include time and place flexibility, ubiquity, and easy accessibility which make it valuable in science education [11]. Moreover, mobile applications can be effectively used in the classroom when they are used as part of a blended instruction [12].

Students often find chemistry to be very challenging rite of passage on their way towards achieving various science, technology, and mathematics fields [13]. The same authors also posited that students experience difficulty since they simply memorize facts and formulas instead of understanding the concepts and developing fundamental problem-solving skills. More so, students also find chemistry difficult due to its abstract nature [14]. In addition, chemistry deals with a number of abstract concepts which are necessary to explain the physical world [15]. In response to this, many chemical educators have already utilized mobile phones for education purposes [16].

There are currently a good number of chemistry mobile applications that can be used in educational setting or even by chemistry professionals. A review by Libman and Huang [17] summarizes the different mobile applications for chemistry as reference/study guide, molecular viewer, research, utilities, and as periodic table. Currently, there is no mobile application yet available on binary ionic bonding thus this study aimed to design, develop, and evaluate an offline mobile application called CHEMBOND.

2. Methods

2.1. Research Design

The study employed a design and development research design [18] and quantitative-descriptive research design [19]. The research process is summarized in Figure 1. A mobile application that can be used as instructional material in teaching Binary Ionic Bonding was designed based from the different recommendations found in the literature. Based from the interface and features of the app design, the application was developed by software developers from the university. It was then alpha- and beta-tested by experts in IT, chemistry, and chemistry education to determine glitches and inaccurate concepts found in the application. After validating the app, a one class of students in a nearby high school was asked to evaluate the app.

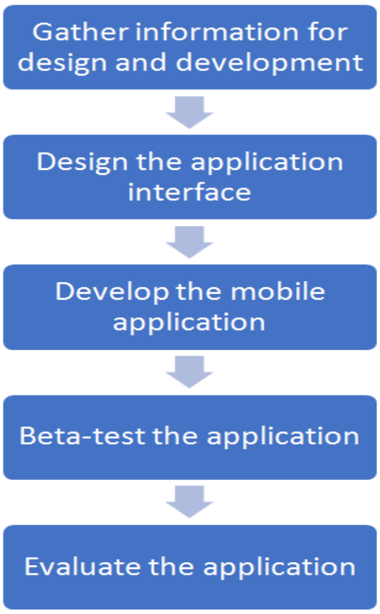

Figure 1. Schematic Diagram of the Research Flow in the development of CHEMBOND Application

2.2. Gathering Information for App Design

The CHEMBOND Application was designed to test how mobile application may enhance students' understanding of some concepts in Binary Ionic Bonding. Before this was designed, an informal random survey was conducted to determine the possible features of the application from chemistry teachers and high school students. Based from the gathered data important features like being an offline application (an app that no longer requires active use of the internet), use of interactive icons, can be manipulated for trial and error, and has a student record of student scores which teachers can view using designated webpage. These features were then integrated in the design together with the information gathered from the literature.

2.3. Application Interface Design and Mechanics

The interface design of the application is shown in Figure 2. Once students open the application, they will be welcomed by a message as shown in Figure 2a. Once the app has completely loaded, the students will be directed to the page shown in Figure 2b. Figure 2c shows the contents found in the application when students chooses the Practice mode. They will be provided with the concepts, examples, and practice exercises.

The application mechanics is summarized in the following steps:

1. The students is prompted to choose whether they will do Practice or Assessment as shown in Figure 2b.
2. Once a student chose Practice, important concepts and rules in ionic bonding are shown for students to learn as shown in Figure 2c. After learning these concepts and rules, the student will be directed to page where they can manipulate the application by choosing which elements to pair with and determine correctly the subscripts. After doing some trial and error and based from the element's charges, the student will submit their answers or attempts by clicking the icon "combine" as shown in Figure 3a.
3. If the incorrect details are inputted in the application, the app will show a prompt "Try another compound" in the screen. Once the user correctly determines the correct compound, he can proceed to the next stage. The next activity will require the student to choose whether he or she will give the compound name, molar mass, and the uses of the compound.
4. If the user chose the naming icon as well as the molar mass icon, he/she will have to answer what is the name and the molar mass of the compound from the 3 choices provided.
5. If the user is not sure how to name the compound and calculate the molar mass, the student can directly click the question mark icon located on the left side of the screen to be provided with the rules in naming ionic compounds and the steps in calculating the molar mass.
6. The user can also click the application icon to know what is the function and uses of that certain compound.

7. After practicing, the user can proceed to assessment part wherein they can input their name and class code to register as shown in Figure 3b. The scores will be then directly connected to a website wherein the teacher can have access to the students' score.
8. After answering the 15-question assessment, the students can then get their scores.

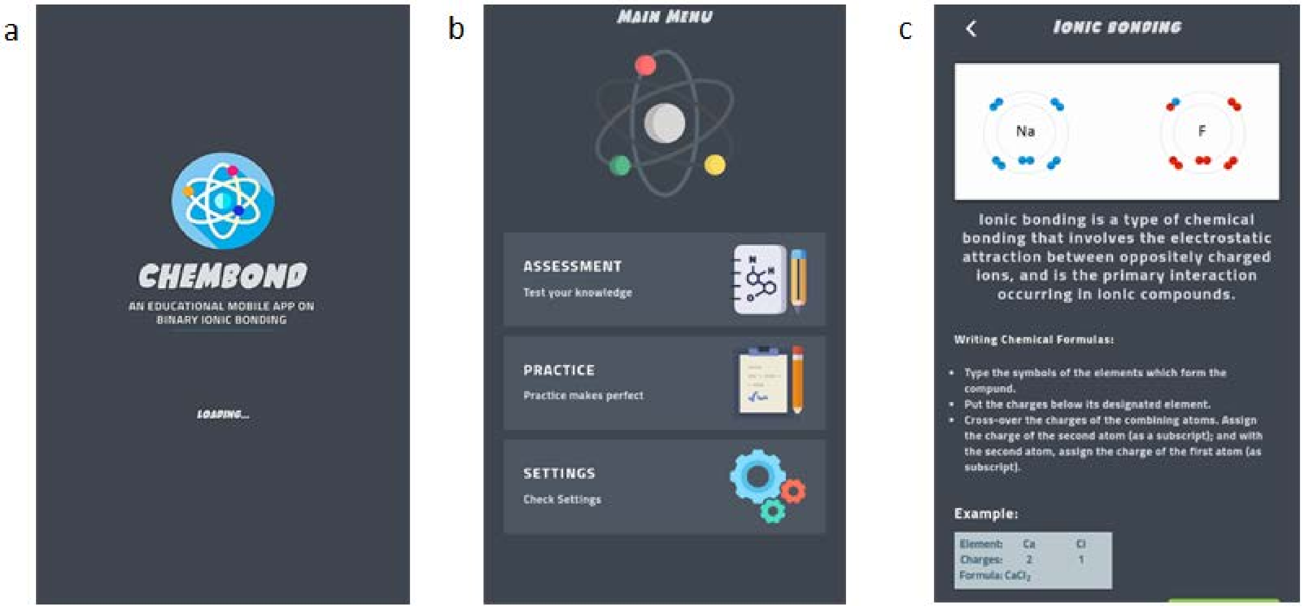

Figure 2. CHEMBOND Application Interface

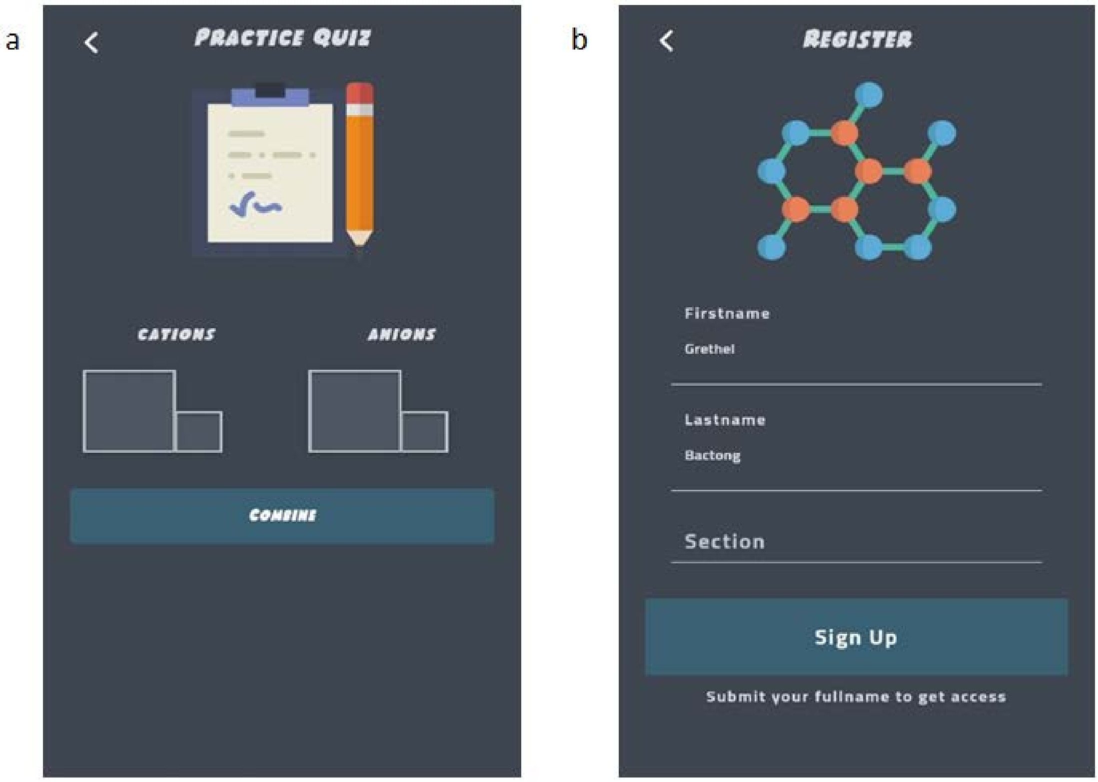

Figure 3. CHEMBOND Application for Practice and Assessment

2.4. Application Evaluation

The CHEMBOND app was evaluated using the researcher-made evaluation rubric and the Intrinsic Motivation Inventory (IMI). The researcher-made application evaluation rubric was utilized by five chemistry teachers to evaluate the CHEMBOND while students answered the a revised IMI (Activity Perception) [20]. The researcher-made application evaluation rubric is composed of the accuracy of concept, attractiveness, function, accessibility, and interactivity and is shown in Table 1. It was subjected to thorough content and face validation by chemistry and science teachers. The instrument was then pilot-tested for reliability and validity. Krippendorff's alpha was utilized as the interrater reliability measure [19]. The instrument was found to be $\alpha = 0.82$ which is considerably reliable.

Table 1. Application Evaluation Rubric

Criteria	Very Good (4)	Good (3)	Fair (2)	Poor (1)
Accuracy of concept	Contents are scientifically accurate concepts. Graphics promote understanding of science concepts.	Contents are scientifically accurate although the scope is limited. Graphics promote somewhat complete understanding of science concepts.	Some of the contents are scientifically inaccurate. Graphics somehow promote understanding of science concepts.	Contents are scientifically inaccurate concepts. Graphics do not promote understanding of science concepts.
Attractiveness	The mobile application is attractive, readable, has illustrations that complement the text and has appropriate media type.	The mobile application is readable, has illustrations that complement the text and has appropriate media type.	The mobile application has illustrations that complement the text and has appropriate media type.	The mobile application has appropriate media type.
Function	Student can launch and operate the application independently	Student can launch and operate the application with minimal supervision.	Student needs to have a teacher to show or model how to operate the app.	App is difficult to operate and students need to be cued each time the app is used.
Accessibility	The mobile application exceptionally is downloadable and does not require an internet connection.	The mobile application is downloadable and needs an internet connection.	The mobile application needs an internet connection when used.	The mobile application is not downloadable and needs an internet connection.
Interactivity	The mobile application allows user to interact effectively with the application's features, content, and functions.	The mobile application allows user to interact with the application's features, content, and functions.	The mobile application allows user to interact a little with the application's features, content, and functions.	The mobile application does not allow the user to interact with the application's features, content, and functions.

3. Results and Discussion

3.1. Application Evaluation

The CHEMBOND app was evaluated in terms of five criteria set based from the literature review. The results are summarized in Table 2. As shown, the app has been rated to be very good in all criteria. It is noteworthy to mention that Interactivity has been scored the highest. This is important since effective integration of technology in the instruction is not limited only in giving instructions and information but also when students are encouraged to engaged in the learning process through interactive features. It has been established that the learning in the traditional classroom can be enhanced when interactive technologies are employed in the instruction [10]. More so, mobile technologies are not supposed to complicate learning process but rather facilitate learner's learning process [21]. More so, in terms of mobile learning context, students have greater acceptance when apps are easy to use and easy to navigate [22].

The evaluators scored the app least compared to other criteria although it is still considered to be very good. The least score given could be due to the fact that application may vary its function based on the mobile phone used. To test the functionality, the evaluation was not made using a mobile phone with pre-installed app but instead the evaluators were asked to download it by themselves and install it. This would allow a more authentic scoring of the app. And with this, it was found that the application really vary its functionality based the model and brand of phone used.

Accessibility was also scored very good which is very important since as posited by Odabasi et al. [11], that mobile apps should be easily accessible and ubiquitous to be valuable in science education. In addition, current mobile applications available highlight the importance of ubiquity, mobility, and portability which supports learning process [21]. This good rating could be due to the fact that the CHEMBOND app does not require internet access for it to be operational which allows users to use it even without mobile data or Wi-Fi connection.

Table 2. Mean Scores of CHEMBOND Application Evaluation

Criteria	Mean ± SD	Description
Accuracy of the concept	3.83 ± 0.38	Very Good
Attractiveness	3.93 ± 0.25	Very Good
Function	3.70 ± 0.54	Very Good
Accessibility	3.85 ± 0.38	Very Good
Interactivity	3.98 ±0.02	Very Good

Several verbatim comments and suggestions (Figure 4) were also noted from students who used the app which supports the evaluation of teachers as shown previously (Table 2). As shown in Figure 4c, "*I like the apps it can help me to more understand the topic about chemistry keep up the good work*", this highlights the quality of the application being interactive and at the same time attractive. Figure 4b, "*It is good. I can easily share it to my classmate using Bluetooth or ShareIt*", which notes the accessibility characteristic of the application while Figure 4c, "*The app is not log* [lag] *and easy to manipulate*" which supports the functionality of the application.

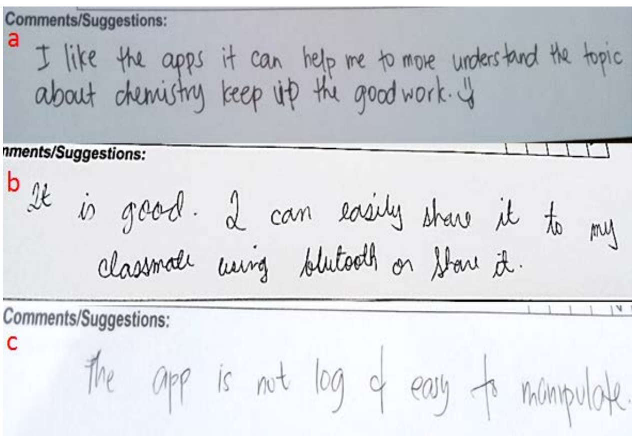

Figure 4. Selected verbatim comments and suggestions of students

Table 3. Student's Intrinsic Motivation in using the CHEMBOND.

Statements	Mean ± SD	Description
1. I believe that manipulating the app could be of some value for me.	4.43±0.82	Very True
2. I believe I had some choice about doing this activity	3.80±0.25	True
3. While I was manipulating the app, I was thinking about how much I enjoyed it.	4.53±0.78	Very True
4. I believe that doing manipulation on the app is useful for improved concentration.	4.73±0.52	Very True
5. This activity was fun to do	4.40±0.93	Very True
6. I think this activity is important for my improvement.	4.63±0.56	Very True
7. I enjoyed doing this activity very much.	4.27±1.05	Very True
8. I really did not have a choice about doing this activity.	2.60±1.30	Somewhat true
9. I did this activity because I wanted to.	4.10±0.88	Very True
10. I think this is an important activity	4.47±0.73	Very True
11. I felt like I was enjoying the activity while I was doing it.	4.50±1.06	Very True
12. I thought this was a very boring activity	1.70±0.99	False
13. It is possible that this activity could improve my studying habits	4.60±0.77	Very True
14. I felt like I had no choice but to do this activity.	1.60±1.13	False
15. I thought this was a very interesting activity	4.43±0.82	Very True
16. I am willing to use again the app because I think it is somewhat useful.	4.53±0.73	Very True
17. I would describe this activity as very enjoyable.	4.33±0.80	Very True
18. I felt like I had to do this activity	3.90±1.10	True
19. I believe doing manipulating the app could be somewhat beneficial for me.	4.57±0.32	Very True
20. I did this activity because I had to.	3.46±1.22	True
21. I believe doing this activity could help me do better in school.	4.47±0.68	Very True
22. While doing this activity, I felt like I had a choice.	3.43±1.12	True
23. I would describe this activity as very fun.	4.30±0.98	Very True
24. I felt like it was not my own choice to do this activity	2.03±1.27	Somewhat true
25. I would be willing to use again the app because it has some value for me.	4.77±0.50	Very True

3.2. Intrinsic Motivation

The mobile application evaluation questionnaire used the description of very true (5), somewhat true (3) and not at all (1). As shown in Table 3, respondents reported to agree most that the mobile application the has value in it and that they will use it again (Statement #25). This could imply that the students find the application to be useful in their mastery of the topic. This is also consistent with the findings that the application allows user to effectively interact with the different features, contents, and functions (Table 3). This is essential since motivation has been identified as one of the fundamental aspects of learning [23]. More so, students with intrinsic motivation tend to persist at difficult problems and learn from their mistakes [24]. In addition, when students see the purpose of a certain theory in their lives in a practical setting, they are more likely to see the value of that theory [25].

Students also find the application to be useful in improving their concentration (Statement #4). Concentration is significantly related to the learning process and is considered to be the fuel of mental operations involved in the acquisition of knowledge [26]. This highlights the importance of attention and concentration in learning. In addition, mobile applications with richer content is positively correlated with higher concentration levels [27]. This is important since students concentrate on a particular activity when they are interested on it [28]. When students possess interest and concentration, they perform well with their mobile learning tasks.

Students also did not agree that they were forced to the activity (Statement #14) and that the use of mobile application was boring (Statement #12). Most of the contents of science lessons are abstract and teachers find it difficult for students to comprehend, thus the use of constructivist-based and student-based instructional materials is a must [29]. This implies that better designed materials provide students opportunities to express their cognitive styles. More so, learning can be increased by allowing students to express their real reactions easily [30]. All of these suggest that the mobile application elicit motivation of students to learn through the different features and functionalities.

4. Conclusion

This study aimed to design, develop, and evaluate a mobile application that can be used to develop mastery in binary ionic bonding concepts. A mobile application called CHEMBOND was designed based from recommendations taken from the literature. It was then developed, validated, and alpha- and beta-tested by both IT experts and chemistry educators. Necessary improvements were then taken into consideration after the validation. The final application was then floated to high school students in a nearby high school. It was found that the mobile application is interactive and attractive as rated by the respondents. This interactivity and attractiveness could be due to the unique features and functions of the application where students can explore and do trial-and-error. There are assessment tasks which allows respondents to interact and learn from their mistakes. More so, the use of mobile application also developed the intrinsic motivation of the respondents particularly in terms of their concentration and their willingness to use it again. This suggests that the mobile application can be used to teach and master binary ionic bonding topic in chemistry.

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