Journal of Innovations in Teaching and Learning, 2022, Vol. 2, No. 1, 18-23
Available online at http://pubs.sciepub.com/jitl/2/1/3
Published by Science and Education Publishing
DOI:10.12691/jitl-2-1-3

Virtual Chemistry Laboratory for Methods of Separating Mixtures: A Design, Development, and Evaluation of a Mobile Application

Kristine Joy Q. Garcia[1], Monica B. Guibar[1], Nova Mae Llamera[2], Jennie Rose Sacay[1], Angelo Mark P. Walag[1,*]

[1]Department of Science Education, University of Science and Technology of Southern Philippines, Philippines
[2]Philippine Statistics Authority, Cagayan de Oro City, Philippines
*Corresponding author: walag.angelo@gmail.com

Received July 09, 2022; Revised August 15, 2022; Accepted August 25, 2022

Abstract The laboratory component of the general chemistry course has long been regarded as a crucial component of the curriculum. Due to disruptions brought about by the pandemic, access to laboratory instruction has been reduced. This poses a problem in science education as learners will have difficulty grounding their chemistry lectures in hands-on exercises. As such, this study aims to design, develop, and evaluate a virtual chemistry laboratory application for methods of separating mixtures as a remote alternative to face-to-face laboratory activities. A design and development research design was utilized to develop the mobile application. An adopted application evaluation rubric and intrinsic motivation inventory were used to evaluate the app. Based on the results of the evaluation, the application was found to be accurate in terms of concept, and it is accessible due to its offline feature. Similarly, students found the application to be fun and important during their use. This suggests that mobile applications can be potentially used as part of remote strategies to address face-to-face class disruptions brought about by the pandemic. It is recommended that an experimental study be conducted to compare the use of virtual laboratory activities and face-to-face laboratory activities.

Keywords: *chemistry education, mobile learning, digital technologies, virtual laboratory*

Cite This Article: Kristine Joy Q. Garcia, Monica B. Guibar, Nova Mae Llamera, Jennie Rose Sacay, and Angelo Mark P. Walag, "Virtual Chemistry Laboratory for Methods of Separating Mixtures: A Design, Development, and Evaluation of a Mobile Application." *Journal of Innovations in Teaching and Learning*, vol. 2, no. 1 (2022): 18-23. doi: 10.12691/jitl-2-1-3.

1. Introduction

The main goal of science education is to develop a scientifically literate citizenry [1,2,3,4]. The COVID-19 pandemic has disrupted this goal as teachers have difficulty learning new pedagogies and other teaching modalities [5]. This can be addressed by integrating information and communications technology (ICT) tools available to make teaching and learning of science exciting and engaging [6,7]. Despite the advancement of using ICT in the classroom, teachers continually report that they face many challenges in using them in the science classroom. One problem highlighted was that the use of ICT tools is only limited to routine tasks like sporadic and mechanical retrieval of information from the internet [6]. This suggests that ICT in science education classrooms does not automatically translate into better science teaching. In addition, much of the responsibility is laid on teachers, particularly in selecting and evaluating appropriate ICT tools to integrate into their science classes.

Mobile applications are one of the most common ICT tools used widely in education [8,9]. Mobile gadgets are handheld devices that support individual and collaborative learning [10]. More smartphones have made it possible to use and expand mobile-based educational initiatives [11]. Currently, the usage of mobile technology is changing and altering traditional and conventional classrooms into one that is more participatory through applications that boost students' learning [12]. Additionally, mobile learning gives students the chance to participate in problem-based learning activities. The benefits of mobile applications in scientific teaching are their portability, ubiquity, and ease of accessing [13]. Moreover, when utilized as a component of blended learning, mobile applications may be used in the classroom effectively [14].

Students frequently view Chemistry as a challenging rite of passage on their path to reaching numerous careers in science, technology, and mathematics [15]. The same writers also asserted that learners struggle because they only remember data and formulae rather than comprehending the ideas and honing their basic problem-solving abilities. As such, chemistry courses in both the basic education and higher education curricula have laboratory components. The laboratory component of the general chemistry course has long been regarded as a crucial component of the curriculum [16,17]. The theory discussed in the lecture should be grounded in laboratory exercises, which should also foster the hands-on technical skills required of STEM workers.

One challenge with laboratory instruction during the COVID-19 pandemic is access to school laboratories while ensuring health and safety regulations are observed. Modern and advanced education institutions addressed this challenge by employing a hybrid setup [18], kitchen-chemistry laboratory setups [19], online laboratory classes [20], and virtual laboratory setup [21], to name a few. Lab courses tailored for online delivery include class materials and activities that have been carefully planned to provide students with an experience comparable to using the lab in person—as such, designing remote laboratory activities requires tailor-fitting them to students' needs instead of a one-size-fits-all approach. As such, this study aims to design, develop, and evaluate a virtual chemistry laboratory mobile application to teach methods of separating mixtures for high school students in the Philippines.

2. Methods

2.1. Research Design

This study utilized a design and development research design [22]. The process is summarized based on the design framework developed by Bactong et al. [7], as shown in Figure 1. The virtual chemistry laboratory mobile application (VCLMA) for methods of separating mixtures was designed based on the different recommendations found in the literature. Based on the interface and features of the app design, the application was developed by application developers from the university. The application was then subjected to alpha- and beta-testing by experts in IT, chemistry, and chemistry education to identify glitches and inaccurate concepts found in the app. After the validation, the app was then evaluated by one in-tact class in a nearby public secondary high school in the city.

2.2. Application Interface Design and Mechanics

The interface design of the application is shown in Figure 2. Once students open the application on their mobile phones, they will be welcomed by the home page shown in Figure 2A. On this homepage, students can choose which methods of separating mixtures they will be learning and operating in the app. Each method is composed of a description including safety hazards, procedures, list of equipment and apparatus, and quiz. This will help students master the concept and the skill at the same time. The application mechanics are summarized in the following steps:

1. The students will be prompted to choose which methods of separating mixture activity they will perform. They will be able to tap the icon of the respective method.
2. They will then be redirected to the respective page of their chosen method, as shown in Figure 2B-2H.
3. The students can also tap the label icon encircled in Figure 2B. This label icon, once tapped, will provide labels to the different lab apparatus and equipment necessary for the laboratory activity.
4. Students can also opt to tap the "flask" icon encircled in Figure 2C, which will then provide the necessary procedures for students to follow when performing the activity.
5. To operate the procedure, students will only need to drag and drop the different lab apparatus in their right places and set up for it to run automatically.
6. Once students are done performing the activity, they can tap the quiz icon encircled in Figure 2E to be redirected to the practice quiz for the respective laboratory activity.

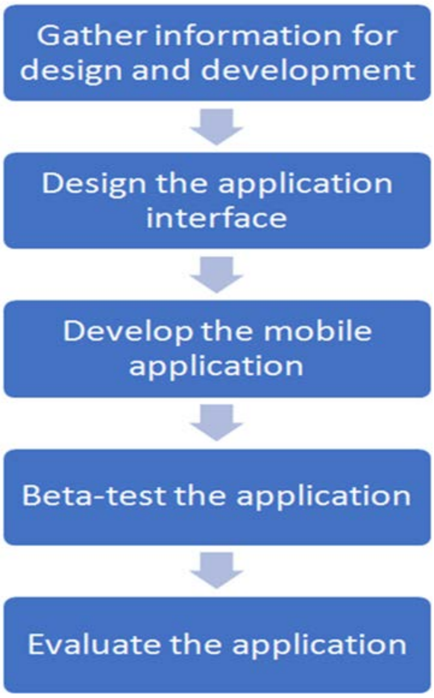

Figure 1. Schematic representation of the research design, development, and evaluation of the Virtual Chemistry Laboratory Mobile Application (VCLMA) [7]

2.3. Application Evaluation

The VCLMA was evaluated using an adopted application evaluation rubric and intrinsic motivation inventory (IMI) utilized by Bactong et al. [7]. The respondents were given sufficient time to independently use the app while the researchers were on standby for clarifications or difficulties encountered. Five chemistry teachers utilized the application evaluation rubric to evaluate the VCLMA while students answered the IMI on activity perception. The application evaluation rubric was composed of the following criteria: accuracy of concept, attractiveness, function, accessibility, and interactivity, as shown in Table 1.

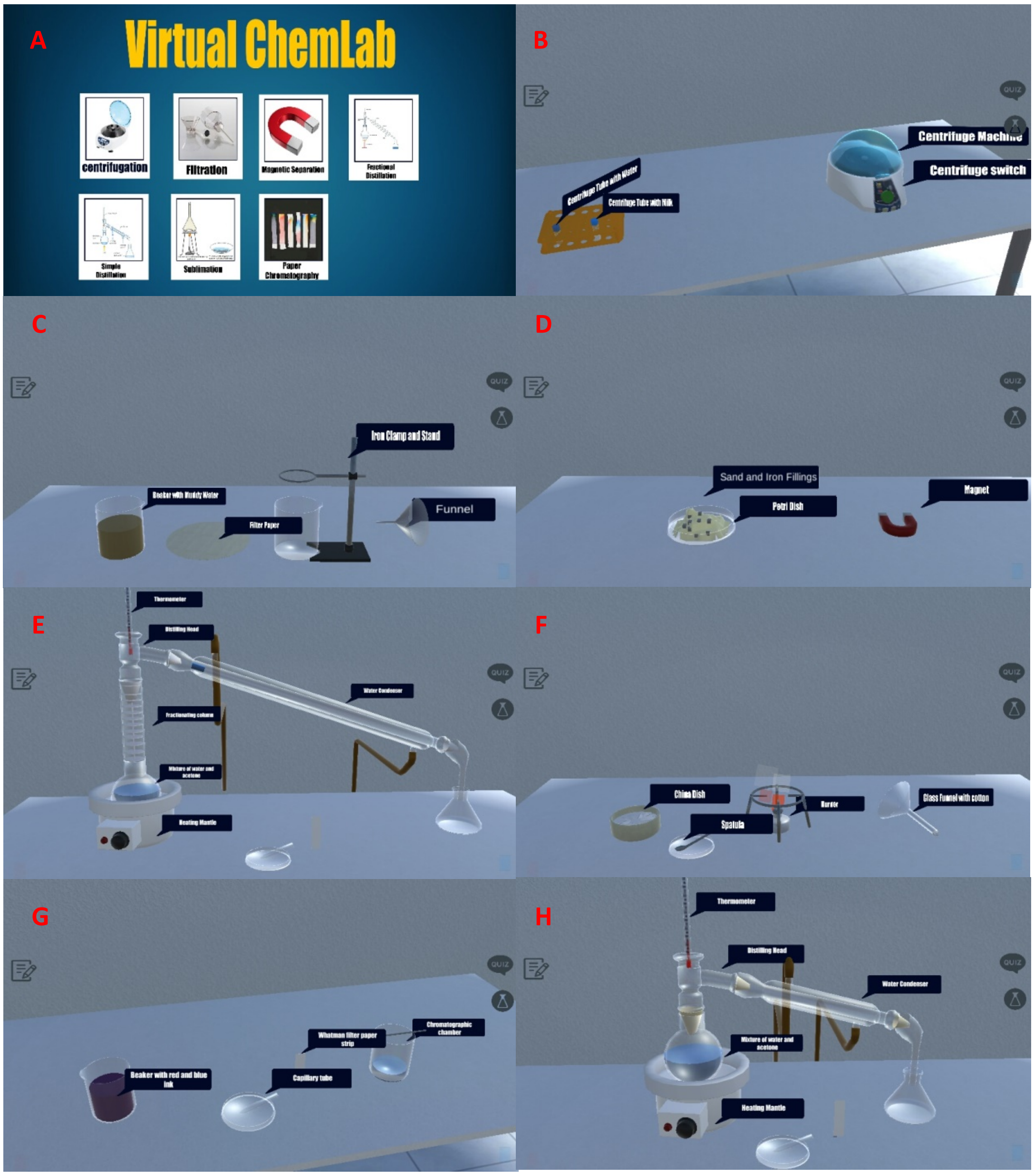

Figure 2. VCLMA Interface and Sample Laboratory Activities

Table 1. Application Evaluation Rubric adopted from Bactong et al. [7]

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 a 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 an appropriate media type.	The mobile application has illustrations that complement the text and has an appropriate media type.	The mobile application has the appropriate media type.
Function	Students can launch and operate the application independently	Students can launch and operate the application with minimal supervision.	Student needs to have a teacher show or model how to operate the app.	The app is difficult to operate, and students need to be cued each time the app is used.
Accessibility	The mobile application is exceptionally 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 users to interact effectively with the application's features, content, and functions.	The mobile application allows users to interact with the application's features, content, and functions.	The mobile application allows users 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 VCLMA was evaluated in terms of five criteria set based on the work of Bactong et al. [7]. The results are summarized in Table 2. As shown, the VCLMA has been rated Very Good in the accuracy of the concept, accessibility, and interactivity, during Good in attractiveness and function. It is noteworthy that the application has been rated highest in both accessibility and accuracy of the concept. This is significant because encouraging student participation in the learning process through interactive features is another way technology may be effectively integrated into the classroom. It has been demonstrated that integrating interactive technology into education can improve learning in traditional classroom settings [12]. Furthermore, mobile devices should help learners learn rather than complicate their learning processes [23]. In addition, Students embrace applications more readily when they are simple to use and navigate in the context of mobile learning.

Accessibility was also given a very high rating, which is crucial since mobile applications should be widely available and simple to use to be effective in scientific teaching [13]. Current mobile apps also emphasize the value of ubiquity, mobility, and portability as they help the learning process. This very good rating for accessibility can be because VCLMA does not require internet connectivity for it to be operational.

The teacher-evaluators scored the app least at the function criteria. The application's function may differ depending on the mobile phone type, which may account for the lower score given. Instead of utilizing a mobile device with an app pre-installed to verify functionality, the evaluators were requested to download and install it independently. Consequently, the app was scored more accurately. In light of this, it was discovered that the application's functioning varies significantly depending on the phone's make and model. These results are similar to the work of Bactong et al. [7] and Limbaco et al. [9].

Table 2. Mean Scores of CHEMBOND Application Evaluation

Criteria	Mean ± SD	Description
Accuracy of the concept	3.60 ± 0.55	Very Good
Attractiveness	3.30 ± 0.66	Good
Function	3.20 ± 0.81	Good
Accessibility	3.80 ± 0.41	Very Good
Interactivity	3.50 ±0.73	Very Good

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, students reported agreeing most that the activity was fun to do (Statement #5) and that it was important (Statement #10). This is crucial since motivation has been recognized as one of the core components of learning [24]. Intrinsically motivated students are more likely to stick with challenging assignments and make amends for their faults [25]. Students are also more likely to recognize the importance of a theory when they can apply it to their daily lives [26]. Furthermore, when students have fun while making sense of the learned content, it enhances their conceptual understanding and motivation [27,28].

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

Statements	Mean ± SD	Description
1. I believe that manipulating the app could be of some value for me.	4.00±0.81	Very True
2. I believe I had some choice about doing this activity	3.80±0.96	True
3. While I was manipulating the app, I was thinking about how much I enjoyed it.	3.90±0.97	True
4. I believe that doing manipulation on the app is useful for improved concentration.	4.20±0.99	Very True
5. This activity was fun to do	4.30±0.80	Very True
6. I think this activity is important for my improvement.	4.20±0.85	Very True
7. I enjoyed doing this activity very much.	4.00±0.89	Very True
8. I really did not have a choice about doing this activity.	2.20±0.30	Somewhat true
9. I did this activity because I wanted to.	3.90±0.88	True
10. I think this is an important activity	4.30±0.79	Very True
11. I felt like I was enjoying the activity while I was doing it.	4.20±0.77	Very True
12. I thought this was a very boring activity	1.90±0.79	False
13. It is possible that this activity could improve my studying habits	3.90±0.94	True
14. I felt like I had no choice but to do this activity.	1.99±0.93	False
15. I thought this was a very interesting activity	3.80±0.82	True
16. I am willing to use again the app because I think it is somewhat useful.	4.20±0.99	Very True
17. I would describe this activity as very enjoyable.	3.80±0.80	True
18. I felt like I had to do this activity	3.50±0.98	True
19. I believe manipulating the app could be somewhat beneficial for me.	4.20±0.82	Very True
20. I did this activity because I had to.	3.10±0.22	True
21. I believe doing this activity could help me do better in school.	4.10±1.08	Very True
22. While doing this activity, I felt like I had a choice.	3.40±1.12	True
23. I would describe this activity as very fun.	4.10±1.05	Very True
24. I felt like it was not my own choice to do this activity	2.20±0.27	Somewhat true
25. I would be willing to use the app again because it has some value for me.	4.10±0.94	Very True

Consistently, students reported least agreeing that the application was boring (Statement # 12) and that they had no choice but to do this activity (Statement #14). It is essential to employ constructivist-based and student-based instructional materials since most scientific lesson content is abstract, and teachers find it challenging for children to understand [29]. This means that more thoughtfully created materials provide pupils a chance to express their cognitive preferences. Allowing pupils to express their genuine feelings readily can also improve learning. All of these point to the possibility that the many features and functions of the mobile application inspire pupils to be motivated learners [30].

4. Conclusion

This study aimed to design, create, and evaluate a mobile application that could be used as virtual laboratory activity on methods of separating mixtures for high school students. Based on the results, respondents reported that the VCLMA is engaging and attractive. Students reported that the activities in the VCLMA is fun and important. These positive evaluations are essential as these are prerequisites to meaningful and engaging learning. Furthermore, these results provide an important generalization that mobile applications, when designed with learners in mind, are beneficial both to educators and to the learning process.

References

[1] Walag AMP, Fajardo MTM, Bacarrisas PG, Guimary FM. Are our Science Teachers Scientifically Literate? An Investigation of Science Teachers' Scientific Literacy in Cagayan de Oro City, Philippines. Science International 2020; 32: 179-82.

[2] Altun-Yalçn S, Açşli S, Turgut Ü. Determining the levels of pre-service science teachers' scientific literacy and investigating effectuality of the education faculties about developing scientific literacy. Procedia - Social and Behavioral Sciences, vol. 15, 2011, p. 783-7.

[3] Demirel M, Caymaz B. Prospective Science and Primary School Teachers' Self-efficacy Beliefs in Scientific Literacy. Procedia - Social and Behavioral Sciences 2015; 191: 1903-8.

[4] Walag AMP, Fajardo MTM, Bacarrisas PG, Guimary FM. A Canonical Correlation Analysis of Filipino Science Teachers' Scientific Literacy and Science Teaching Efficacy. International Journal of Instruction 2022; 15: 249-66.

[5] Gavia MM, Cabingas JP, Rodriguez NP, Pallo JE. Hands-on School-based Gardening: An Intervention for Teachers' Well-being amidst Pandemic. Journal of Innovations in Teaching and Learning 2021; 1: 41-6.

[6] Salihi AM. The use of ICT in science education. Global Educational Research Journal 2015; 3: 258-64.

[7] Bactong GG, Sabas ADH, Salva KMM, Lituañas AJB, Walag AMP. Design, Development, and Evaluation of CHEMBOND: An Educational Mobile Application for the Mastery of Binary Ionic Bonding Topic in Chemistry. Journal of Innovations in Teaching and Learning 2021; 1: 4-9.

[8] Alqahtani M, Mohammad H. Mobile applications' impact on student performance and satisfaction. Turkish Online Journal of Educational Technology 2015; 14: 102-12.

[9] Limbaco JB, Romerde KEN, Estilo JP, Mondelo BC, Walag AMP. Use and Perceptions of Students of a Mobile Application as a Classroom Response System. Journal of Innovations in Teaching and Learning 2021; 1: 29-35.

[10] Pilar R-A, Jorge A, Cristina C. The Use of Current Mobile Learning Applications in EFL. Procedia - Social and Behavioral Sciences 2013; 103: 1189-96.

[11] Behboudi F, Pouralizadeh M, Yeganeh MR, Roushan ZA. The effect of education using a mobile application on knowledge and decision of Iranian mothers about prevention of foreign body aspiration and to relieve choking in children: A quasi-experimental study. Journal of Pediatric Nursing 2022; 62.

[12] Scornavacca E, Huff S, Marshall S. Mobile phones in the classroom: If you can't beat them, join them. Commun ACM 2009.

[13] Odabasi MB, Uzunboylu H, Popova O v., Kosarenko NN, Ishmuradova II. Science Education and Mobile Learning: A Content Analysis Review of the Web of Science Database. International Journal of Emerging Technologies in Learning (IJET) 2019; 14: 4.

[14] Ping GLY, Lok C, Wei Yeat T, Cherynn TJY, Tan ESQ. "Are chemistry educational apps useful?" -a quantitative study with three in-house apps. Chemistry Education Research and Practice 2018.

[15] Cook E, Kennedy E, McGuire SY. Effect of teaching metacognitive learning strategies on performance in general chemistry courses. Journal of Chemical Education 2013.

[16] Hofstein A, Mamlok-Naaman R. The laboratory in science education: The state of the art. Chemistry Education Research and Practice 2007; 8.

[17] Serafin JM, Chabra J. Using a cooperative hands-on general chemistry laboratory framework for a virtual general chemistry laboratory. Journal of Chemical Education 2020; 97.

[18] Szoke M, Katz A, Borgoltz A, Devenport W. Development of Hybrid Laboratory Sessions During the COVID-19 Pandemic. Advances in Engineering Education 2022; 10.

[19] Schultz M, Callahan DL, Miltiadous A. Development and Use of Kitchen Chemistry Home Practical Activities during Unanticipated Campus Closures. Journal of Chemical Education 2020; 97.

[20] Ashkanani A, Ashkanani G, Bayraktar N, Subhash E, Chaari A. Converting a formerly in-person biochemistry course based undergraduate research experience to online teaching during the COVID-19 pandemic. Biochemistry and Molecular Biology Education 2022; 50.

[21] Candace G-C, E. G-OM. An Upper-Division, Remote Microbiology Laboratory That Blends Virtual and Hands-on Components to Promote Student Success during the COVID-19 Pandemic. Journal of Microbiology & Biology Education 2022; 0: e00328-21.

[22] Casino J, Walag AMP. Design and Development of a Science Literacy Material on Vaccination as an Intervention Campaign for Parents of High School Students in the Philippines. American Journal of Educational Research 2020; 8: 762-6.

[23] Jeng YL, Wu TT, Huang YM, Tan Q, Yang SJH. The add-on impact of mobile applications in learning strategies: A review study. Educational Technology and Society 2010; 13: 3-11.

[24] Brewer EW, Burgess DN. Professor's Role in Motivating Students to Attend Class. Journal of Industrial Teacher Education 2005; 42: 24.

[25] Walker CO, Greene BA, Mansell RA. Identification with academics, intrinsic/extrinsic motivation, and self-efficacy as predictors of cognitive engagement. Learn Individ Differ 2006; 16: 1-12.

[26] Nilsen H. Influence on Student Academic Behaviour through Motivation, Self-Efficacy and Value-Expectation: An Action Research Project to Improve Learning. Issues in Informing Science and Information Technology 2009; 6: 545-56.

[27] Byusa E, Kampire E, Mwesigye AR. Game-based learning approach on students' motivation and understanding of chemistry concepts: A systematic review of literature. Heliyon 2022; 8: e09541.

[28] Ziden AA, Ziden AAA, Ifedayo AE. Effectiveness of Augmented Reality (AR) on Students' Achievement and Motivation in Learning Science. Eurasia Journal of Mathematics, Science and Technology Education 2022; 18.

[29] Tüysüz C. The effect of the virtual laboratory on students' achievement and attitude in chemistry. International Online Journal of Educational Sciences 2010; 2: 37-53.

[30] Karamustafaoğlu O, Aydin M, Özmen H. Bilgisayar destekli fizik etkinliklerinin ogrenci kazanimlarina etkisi: basit harmonik hareket ornegi. The Turkish Online Journal of Educational Technology – TOJET 2005; 4: 67-81.