

Creating a Virtual Science Lab (VSL): Towards the Adoption of Virtual Labs in Federal Polytechnic Auchi

Anyaorah, I. E.*, Akhetuamen, S. O. and Obeten, O. M.

Department of Computer Science, School of Information and Communication Technology, Auchipolytechnic, Nigeria.

Corresponding Author: anyaorah.ifeanyichukwu@auchipoly.edu.ng
michealobeten@auchipoly.edu.ng

Abstract:

Experiential learning has been shown to help students significantly. Science and engineering education faces huge challenges in providing important and substantial practical experience to all undergraduate students. The limitation in facilities, equipment, and laboratory space has been a critical constraint of academic institutions in the country. This problem is evident in Auchipolytechnic, Nigeria, which houses over 3000 students in the School of Applied Science and Engineering alone. Maintenance and management of laboratory equipment have also been problematic due to the vast number of technologists and students that use these facilities. In this paper, a proposed Virtual Laboratory named AP-VLab was built and implemented using the Easy JavaScript Simulations (EJSS) toolkit for the Chemistry/Biochemistry Option of the School of Applied Science. Five experiments were created on the AP-VLab environment. Furthermore, we studied students' and technologists' impressions of the new learning experience using questionnaires disseminated. Nevertheless, our findings imply that the AP-VLab is well-suited to be utilized as a supplement or as a primary tool for laboratory experiments.

Keywords: Virtual Laboratory, Students' Perception, Education, Performance impact, Computer-Based learning

1. Introduction

Higher education within science and technology offers considerable practical knowledge for learners to enhance technical skills [1], connecting practical knowledge to new conceptions about the processes and procedures involved. Moreover, due to cost effective and logistical difficulties [2], laboratories are often regarded to have constraint of equipment, limited time allowed for the topic or poor laboratory settings, causes technologists to undertake laboratory activities in packed groups, or sometimes a demonstrational activity can be performed [3]. Consequently, the COVID-19 epidemic has resulted in educational establishments nationwide being geographically closed, impacting 2.8 percent of total enrolled learners globally [4], leading in increased need to educate online. An innovative technique is needed to integrate information and learning process which aids in solving difficulties, increasing teamwork and developing new experiments, the above problem can be resolved via the aid of the Virtual Laboratory (VL). A computer-assisted activity which helps the students conduct the experiments on real or VL environment, utilizing proper computer-based interface is called Virtual Laboratory [5]. The VLS can be utilized as supplement to the conventional laboratory, increasing the learning of students remotely via the internet [6], helping students to be autonomous learner as it can be implemented in a flexible manner [7], and also enabling students and technologists to minimize the gap between conducting experiments using actual resources and collaborating in a virtual setting [8]. This research proposed a web-based

virtual laboratory platform called AP-VLab, implemented for the Chemistry/Biochemistry option of the School of Applied Science, Auchi Polytechnic, Nigeria.

The remaining sections of the paper focused on the technologies and implementation of existing VL environments. In Section 2, the relevant literatures reviewed. Section 3, the methodology and survey and analysis of the proposed system. Section 4, details of the results collected from the distributed questionnaires with regards to the usability of the proposed VL. Lastly, the conclusion and future scope of the work.

2. Literature Review

This section covers a general overview of virtual laboratories, their significance, and a review of studies that have used VL.

2.1 Virtual Laboratories and Hands-On Laboratories

As stated by Keller and Keller, virtual laboratory practical is defined as “a computerized laboratory experiment, using the computer for replicating the processes in the real laboratory, which helps students to link readily between the theoretical and practical aspects” [9]. It has also been characterized as “application; that allow users to design recurring trials to investigate the impact of various parameters” [10]. In the VSL, students can collect real data from remotely controlled instruments and explore them using simulated ones, such as the virtual microscope that uses high-resolution images instead of actual specimens [11]. The activities in both virtual laboratories (VLs) and hands-on laboratories (HOLs) can enhance the learning environment and make it more constructive. However, there are differences between them related to the nature of students’ learning situations, for example, the students in HOLs focus on how to use the physical equipment and the outcomes, while VLs direct students’ attention to variables and the interaction of the variables that produce the outcomes [10], [12].

2.2 Implemented Virtual Laboratory Applications

Researchers from the College of Engineering, Bulacan State University, Philippine constructed a 3D virtual reality environment for their pneumatic courses, employing Blender and Unity software at the system creation stage [13]. Upon review and testing of the system, the researchers found that the system provides an alternate solution to lack of sufficient laboratory equipment. The 3D-DCLab and blending learning approach were implemented for the same reason as Cruz et. al. [13] to supplement the constraints of existing physical laboratories [14]. The 3D-DCLab offers the following functionalities: a three dimensional student client with a simulated environment, a web-based educator interface with an integrated evaluation tool, and a database server with an embedded calculation engine. The implementation of the 3D-DCLab provides students and instructors with a broader choice of virtual instruments, a critical level methodology, a more user-friendly user interface, and more robust operational effectiveness. A group in Australia [15] provided a blueprint for the design and implementation of a cloud-based Genomics Virtual Laboratory environment, this assisted researchers to arbitrarily sized compute clusters on demand, pre-populated with fully configure bioinformatics tools, reference datasets and workflow, and visualization option.

Students’ conceptual knowledge is the basic outcome of all education in the globe, whereby student learn through reading, viewing, experiencing, or thoughtful, reflective mental activities [16]. Students must be able to understand the topic well in order to use their

knowledge in daily life. One of the approaches to improve the conceptual comprehension is through computer-based learning [17]. The study conducted by Gunawan et. al. [18] aims to increase the students' conceptual knowledge of physics by using the virtual laboratory, and further results via experimental group survey reveals the good effect it has on student conceptual understanding.

Furthermore, works by Liu et. al. [19] presents a web-based virtual laboratory to support teaching of Sensitive High Resolution Ion Micro-probe (SHRIMP) implementation, termed SHRIMP VL. This virtual laboratory is primarily developed to facilitate learning of the instrument operation technique. Upon evaluation of SHRIMP VL, Two questionnaires were distributed to students, who claimed that SHRIMP VL is helpful in assisting them in understanding and mastering the instrument and experimental techniques, enhancing their learning efficiency and providing the groundwork for personal operation of on-site instruments. The development and implementation of Virtual Science Laboratory in Nigeria can be seen in Oluwole et al. [17] work, where their research created a cross-platform Mobile Virtual Laboratory (MVL) architectural framework for higher education institutions in Nigeria. The MVL framework was evaluated using Science students from Ambrose Alli University in Ekpoma, Edo State. A detailed analysis revealed that, while there is significant evidence in Nigeria that there is an increase in the use of mobile devices, more research on how it can be used positively to impact educational outcomes is required. Gambari [20] carried out a survey on the impact of Virtual Laboratory on high school students' performance in Minna, Niger State, Nigeria, primary focus was on homogeneous and heterogeneous collaborative nature was these students interact with the platform. It was concluded that grouping students according to ability levels (high, medium, low) and gender (male, female) can determine the success or failure of the teaching and learning process. Gambari identified that there was a significant difference between high, medium, and low scoring students in the heterogeneous and homogenous groups. Respondents in homogeneous groups performed better than those in heterogeneous groups. However, gender-based likelihood clustering favours female homogeneity over their homogeneity in male-dominated, male-dominated and female-dominant homogenous groups, respectively. Similarly, high achievers in a homogenous group outperformed their peers in the Medium, Low, Predominant Medium, Predominant Low, High, Medium, and Low groups. This implies that homogenous grouping of students, by gender or ability level, has the potential to promote effective cooperative learning.

3. Methodology

This section addresses the establishment of the AP-VLab, its system architectural design, and the pre-questionnaires delivered to users of the proposed VL environment to gain users' impression to the technology.

3.1 Easy JavaScript Simulations (EJSS)

After a systematic assessment of literature, the learning environment for the AP-VLab system was created utilizing the Easy JavaScript Simulations (EJSS), saving significant work required to develop virtual laboratories from the beginning [21]. Designed for non-experts' programmer [22], the EJSS is an open-source software tool that was created in Java and principally designed for the building of research discrete computational methods in JavaScript programming language for digitally online laboratory [23]. Subsequently, AP-VL system was installed on a cross-platform, Apache, MySQL, PHP and Perl local server generally known as XAMPP.

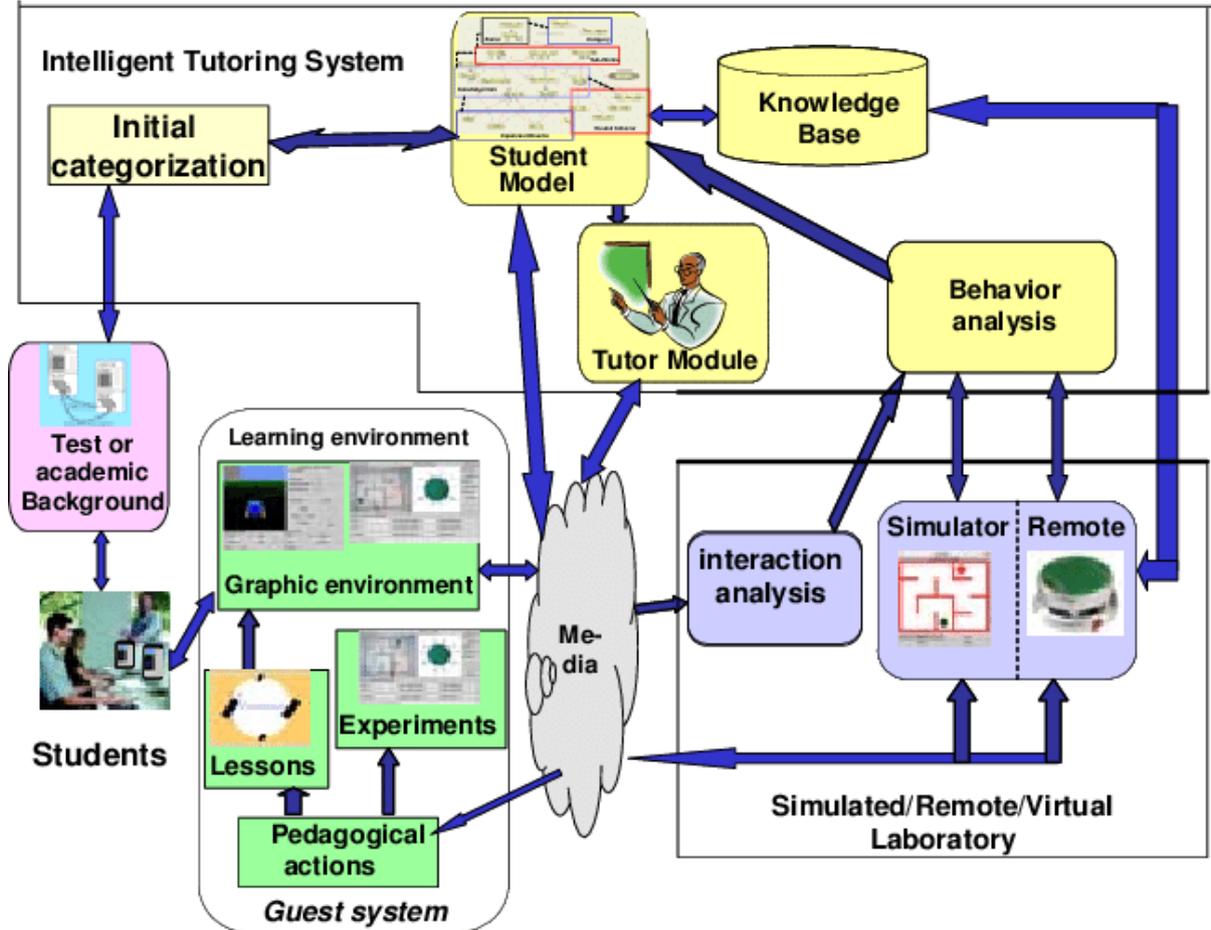


Figure 1: General Architectural Design for a virtual lab[24]

3.1.1 Structure of EJSS

There are two options to develop simulation applications, loudly. Native app and hybrid app. Although native apps are designed and encoded for specific types of devices, Hybrid Apps is created with Cross platform web technology such as HTML5, CSS, JavaScript [22]. In our case, we would like to create desktop applications and maintain EJSS Model-View-Controller (MVC) patterns and simulation flows and EJSS libraries. Therefore, we decided to generate a hybrid app based on simple templates that can be easily changed in the HTML editor. The structure of the EJSS simulation app is based on the ion-side menu template. Once the project is created, you will find index.html at the root of your www folder. This file contains the side menu code. Figure 2 shows the interface of EJSS.

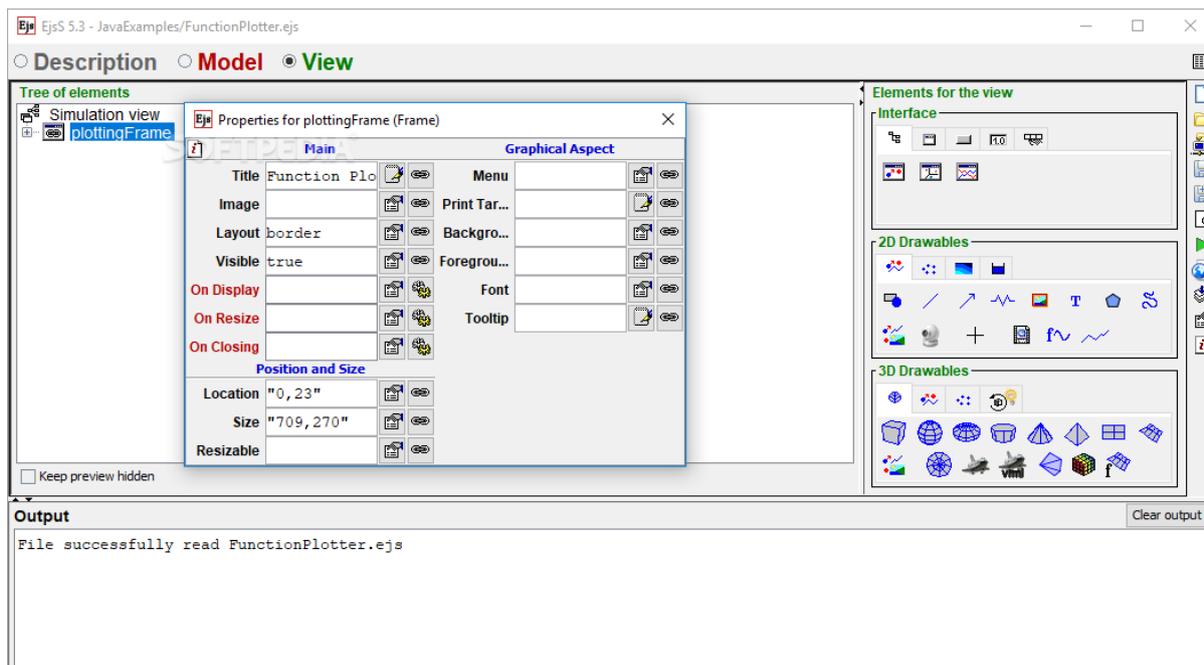


Figure 2: EJSS Interface

Once the EJSS-generated program is complete, the user can launch it using the EJSS interface. The application will then launch in a new window and be ready to use. Another alternative is to package the application to be launched offline (for Java applications) and inside web pages (for Java and JavaScript apps) [25].

3.2 Evaluation

Teachers and students experimented with and assessed the constructed simulation and activities' functioning to validate the created virtual learning environment (AP-VLab). The final version incorporated all of the comments, criticism, and ideas. The work team was then sent the final adjusted version of the platform resources. Table 1 shows the total number of experiments carried out.

Table 1: Experiments implemented

S/N	EXPERIMENTS
1.	Apparatus and Experimental Technologies
2.	Units of Measurements
3.	Acid-Base Standardization
4.	Energy Effects in Chemical Reactions
5.	Redox Titration: Use of Potassium Permanganate

3.3 Research Participants

The evaluation to check teacher/students' perception of the AP-VLab was carried out using the Applied Science Students of Auchu Polytechnic, Nigeria. This group of teachers or technologists and students were selected because of their participation in testing the AP-VLab, and can give a wider view about usefulness and effectiveness of the system. A total of one hundred (100) questionnaires was issued, ninety (90) of the questionnaires was returned back, while seventy (70) was valid or tagged properly filled. The questionnaire template

contains two sections: Demographic and Technologist/Student’s perception factors; these factors was adopted from Hao et. al. [14] where the authors gathered constructs from related journals reviewed. The instrument used 4-point Likert scale rating: Strongly Disagree = 1, Disagree = 2, Agree = 3 and Strongly Agree = 4. Table 2 and Table 3 gives an overview of the questionnaire format.

Table 2: Demographic of the questionnaire

Gender	Age	Participant
Male	16 – 20	Student
Female	21 – 30	Technologist
	31 – 40	
	41 - above	

Table 3: Student/Technologist Perception Evaluation [14]

S/N	FACTORS	INTERPRETATION
1.	Experimental design	Students can learn about experimental design by using the virtual laboratory.
2.	Loop process	Students can run experiments as many times as they choose because they are not limited by a laboratory area or laboratory guidelines.
3.	C1	The virtual equipment must be identical to the physical gear.
4.	C2	Theory and operation must be identical to those found in a real physical laboratory.
5.	C3	Laboratory scenes must be rendered as realistically as practicable.
6.	C4	Students and teachers should be able to communicate and collaborate.
7.	Immediate control	The virtual environment should be capable of responding to user queries in a timely manner.
8.	Appealing visually	The visualization of laboratory situations should be visually pleasing.
9.	Usability	The UI should be straightforward to use
10.	Game-like	The virtual laboratory should be developed in a game-like manner
11.	Immersion	Students should be engrossed in the virtual platform
12.	Enjoyment	The virtual experiment should make students feel happy
13.	Reflective thinking	Through the virtual laboratory, students can think more on the relationship between the new experience and early theoretical knowledge, not just the operation.
14.	Easy to evaluate	Practical, thorough, and intelligent assessment systems should be supplied.

4. Result and Discussion

The Statistical Package for the Social Sciences was used to present the data collected for this study (SPSS Statistics 20.0). SPSS has altered the data analysis method in research in this period. This procedure encourages academics and scholars all over the world to use this software in their research projects.

4.1 Data Analysis

Table 4: Gender of Respondents

GENDER	COUNT	PERCENTAGES
Male	30	42.9
Female	40	57.1
Total	70	100

Source: Field Survey, 2022

The table 4 shows responses according to gender, we could see from the figures and percentage that the females are more the males.

Table 5: Age of Respondents

AGES	COUNT	PERCENTAGES
15-20	10	14.3
21-30	25	35.7
31-40	32	45.7
41 & above	3	4.3
Total	70	100

Source: Field Survey, 2022

According to table 5 above, 10 respondents which constitute 14.3% had age range of less than 20, 25 respondents which represent 35.7% are of the age range 21-30, 32 respondents which represent 45.7% are of the age range 31-40 while 3 respondents which represent 4.3% are of the age range 41 and above.

4.1.1 Users’ Perception

In this section, the AGREE and STRONGLY AGREE were collapsed as AGREE while the DISAGREE and STRONGLY DISAGREE were collapsed as DISAGREE. Percentage analysis was employed to get the count and percentage of AGREE and DISAGREE. The percentage values are enclosed in a bracket. Table 6 gives an overview of users’ interaction with the system.

Table 6: Users’ Perception

SN	QUESTION	AGREE	DISAGREE
1.	Experimental design	Students can learn about experimental design by using the virtual laboratory.	52 (74.3) 18 (25.7)
2.	Loop process	Students can run experiments as many times as they choose because they are not limited by a laboratory area or laboratory guidelines.	44 (62.9) 26 (37.1)
3.	C1	The virtual equipment must be identical to the physical gear.	56 (80) 14 (20)
4.	C2	Theory and operation must be identical to those found in a real physical laboratory.	39 (55.7) 31 (44.3)
5.	C3	Laboratory scenes must be rendered as realistically as practicable.	40 (57.1) 30 (42.9)
6.	C4	Students and teachers should be able to communicate and collaborate.	47 (67.1) 23 (32.9)
7.	Immediate control	The virtual environment should be capable of responding to user queries in a timely manner.	53 (75.7) 17 (24.3)
8.	Appealing visually	The visualization of laboratory situations should be visually pleasing.	48 (68.3) 22 (31.7)
9.	Usability	The UI should be straightforward to use	40 (57.1) 30 (42.9)
10.	Game-like	The virtual laboratory should be developed in a game-like manner	55 (78.6) 15 (21.4)
11.	Immersion	Students should be engrossed in the virtual platform	45 (64.3) 25 (35.7)
12.	Enjoyment	The virtual experiment should make students feel happy	59 (84.3) 11 (15.7)
13.	Reflective Thinking	Through the virtual laboratory, students can think more on the relationship between the new experience and early theoretical knowledge, not just the operation.	51 (72.9) 19 (27.1)
14.	Easy to evaluate	Practical, complete and intelligent assessment systems should be offered	37 (52.9) 33 (47.1)

5. Conclusion

The development of the AP-VLab system for the School of Applied Science at Auchi Polytechnic in Nigeria is described in this study. The AP-VLab provides students and technical professionals (technologists and lecturers) with open and affordable virtual experimental resources, making analytical learning methodologies and experimental operation processes available via virtual instruments. Furthermore, this virtual laboratory provides an immersive experimental setting, which alleviates the issue of students' difficulty in gaining access to important and uncommon large-scale analytical equipment. The results of an evaluation of the questionnaire issued revealed that the VL is a favourable teaching tool for the students' experiments, decreasing the on-site instrument training time and promoting greater experimental time for scientific analysis. AP-VLab increases student passion for learning and strengthens their understanding of various analysis methodologies; nonetheless, one of the general limitations of the VL system is the learners' inability to feel, smell, or touch the experiment being conducted. [26].

Future Works

Future work includes introducing new experiment modules to the AP-VLab with reference to the ones offered by the School of Applied Science, Auchi Polytechnic. More effort is required to make the virtual framework more applicable to a variety of test [14]. Machine Learning-based methodology could be considered as well [8]. Furthermore, the future of education in Nigeria is shifting into Mobile Learning [17], as the usage of smart devices among students is expanding dramatically; future work on the AP-VLab will include building and deploying a mobile version.

Acknowledgement

This work has been supported by the Tertiary Education Trust Fund, Nigeria (TETFUND), under the Institution Based Research grant (IBR). A special appreciation goes to my colleagues in developing the project.

References

- [1] L. D. Feisel and A. J. Rosa, "The Role of the Laboratory in Undergraduate Engineering Education," *Journal of Engineering Education*, vol. 94, no. 1, pp. 121–130, Jan. 2005, doi: 10.1002/J.2168-9830.2005.TB00833.X.
- [2] U. E. Nwachukwu, "The State of Science and Technology Infrastructure in Secondary Schools in Nigeria," *Academic Journal of Interdisciplinary Studies*, 2013. <https://www.mcser.org/journal/index.php/ajis/article/view/1679> (accessed Feb. 28, 2022).
- [3] "Tüysüz, C. (2010). The Effect of the Virtual Laboratory on Students' Achievement and Attitude in Chemistry. *International Online Journal of Educational Sciences*, 2, 37-53. - References - Scientific Research Publishing." [https://www.scirp.org/\(S\(351jmbntvnsjt1aadkozje\)\)/reference/referencespapers.aspx?referenceid=2327634](https://www.scirp.org/(S(351jmbntvnsjt1aadkozje))/reference/referencespapers.aspx?referenceid=2327634) (accessed Feb. 28, 2022).
- [4] "Education: From disruption to recovery." <https://en.unesco.org/covid19/educationresponse> (accessed Feb. 28, 2022).
- [5] N. Kapilan, P. Vidhya, and X. Z. Gao, "Virtual Laboratory: A Boon to the Mechanical Engineering Education During Covid-19 Pandemic:," <https://doi.org/10.1177/2347631120970757>, vol. 8, no. 1, pp. 31–46, Dec. 2020, doi: 10.1177/2347631120970757.

- [6] G. Carnevali and G. Buttazzo, “A virtual laboratory environment for real-time experiments,” *IFAC Proceedings Volumes*, vol. 36, no. 12, pp. 31–36, Jul. 2003, doi: 10.1016/S1474-6670(17)32509-0.
- [7] W. D. Sasongko and I. Widiastuti, “Virtual lab for vocational education in Indonesia: A review of the literature,” *AIP Conference Proceedings*, vol. 2194, no. 1, p. 020113, Dec. 2019, doi: 10.1063/1.5139845.
- [8] N. M. Deepika, M. M. Bala, and R. Kumar, “Design and implementation of intelligent virtual laboratory using RASA framework,” *Materials Today: Proceedings*, Feb. 2021, doi: 10.1016/J.MATPR.2021.01.226.
- [9] H. E. Keller and E. E. Keller, “Making Real Virtual Labs,” *The Science Education Review*, vol. 4, no. 1, 2005.
- [10] E. E. Toth, “Analyzing ‘real-world’ anomalous data after experimentation with a virtual laboratory,” *Educational Technology Research and Development 2015 64:1*, vol. 64, no. 1, pp. 157–173, Nov. 2015, doi: 10.1007/S11423-015-9408-3.
- [11] M. M. Waldrop, “The virtual lab: confronted with the explosive popularity of online learning, researchers are seeking new ways to teach the practical skills of science,” *Gale OneFile: Health and Medicine*, vol. 499, no. 7458, p. 268, 2013, Accessed: Mar. 01, 2022. [Online]. Available: <https://go.gale.com/ps/i.do?id=GALE%7CA337370661&sid=googleScholar&v=2.1&it=r&linkaccess=abs&issn=00280836&p=HRCA&sw=w&userGroupName=anon%7E29506950>
- [12] A. Widodo, R. A. Maria, and A. Fitriani, “Constructivist Learning Environment During Virtual and Real Laboratory Activities,” *Biosaintifika: Journal of Biology & Biology Education*, vol. 9, no. 1, pp. 1–8, 2017, doi: 10.15294/biosaintifika.v9i1.7959.
- [13] D. R. dela Cruz and D. M. M. Mendoza, “Design and Development of Virtual Laboratory: A Solution to the Problem of Laboratory Setup and Management of Pneumatic Courses in Bulacan State University College of Engineering,” *2018 IEEE Games, Entertainment, Media Conference, GEM 2018*, pp. 20–23, Oct. 2018, doi: 10.1109/GEM.2018.8516467.
- [14] C. Hao, A. Zheng, Y. Wang, and B. Jiang, “Experiment Information System Based on an Online Virtual Laboratory,” *Future Internet 2021, Vol. 13, Page 27*, vol. 13, no. 2, p. 27, Jan. 2021, doi: 10.3390/FI13020027.
- [15] E. Afgan *et al.*, “Genomics Virtual Laboratory: A Practical Bioinformatics Workbench for the Cloud,” *PLOS ONE*, vol. 10, no. 10, p. e0140829, Oct. 2015, doi: 10.1371/JOURNAL.PONE.0140829.
- [16] “Conceptual Knowledge in the Workplace - Training Industry.” <https://trainingindustry.com/glossary/conceptual-knowledge/> (accessed Mar. 01, 2022).
- [17] O. Oluwale, G. Nicolae, O. Olawale, and A. Oludele, “Mobile Virtual Laboratory in Nigeria,” *International Journal Of Engineering And Computer Science*, vol. 4, pp. 11417–11421, 2015, Accessed: Mar. 01, 2022. [Online]. Available: www.ijecs.in
- [18] G. Gunawan, N. Nisrina, N. M. Y. Suranti, L. Herayanti, and R. Rahmatiah, “Virtual Laboratory to Improve Students’ Conceptual Understanding in Physics Learning,” *Journal of Physics: Conference Series*, vol. 1108, no. 1, Dec. 2018, doi: 10.1088/1742-6596/1108/1/012049.
- [19] Y. H. Liu, Y. T. He, D. Tian, R. L. Fan, and L. Yao, “A web-based virtual laboratory for SHRIMP,” *Computer Applications in Engineering Education*, vol. 26, no. 5, pp. 1493–1506, Sep. 2018, doi: 10.1002/CAE.22053.
- [20] A. I. Gambari, H. Kawu, and O. C. Falode, “Impact of Virtual Laboratory on the Achievement of Secondary School Chemistry Students in Homogeneous and Heterogeneous Collaborative Environments,” *Contemporary Educational Technology*, vol. 9, no. 3, pp. 246–263, Jul. 2018, doi: 10.30935/CET.444108.

- [21] F. Esquembre, “Easy Java Simulations: a software tool to create scientific simulations in Java,” *Computer Physics Communications*, vol. 156, no. 2, pp. 199–204, Jan. 2004, doi: 10.1016/S0010-4655(03)00440-5.
- [22] F. J. G. Clemente, F. Esquembre, and D. Matemáticas, “Deployment of physics simulation apps using Easy JavaScript Simulations”.
- [23] K. el Kharki, K. Berrada, and D. Burgos, “Design and Implementation of a Virtual Laboratory for Physics Subjects in Moroccan Universities,” *Sustainability 2021, Vol. 13, Page 3711*, vol. 13, no. 7, p. 3711, Mar. 2021, doi: 10.3390/SU13073711.
- [24] L. E. Sucar, J. Noguez, L. E. Sucar, G. Huesca, and E. Rodríguez, “A Semi-Open Learning Environment for Mobile Robotics.,” *researchgate.net*, 2007, Accessed: Mar. 02, 2022. [Online]. Available: https://www.researchgate.net/profile/Julietta-Noguez/publication/26463726_A_Semi-Open_Learning_Environment_for_Mobile_Robotics/links/00b49529f978f2dcbd000000/A-Semi-Open-Learning-Environment-for-Mobile-Robotics.pdf
- [25] J. Saenz, F. Esquembre, F. J. Garcia, L. D. la Torre, and S. Dormido, “An Architecture to use Easy Java-Javascript Simulations in New Devices,” *IFAC-PapersOnLine*, vol. 48, no. 29, pp. 129–133, 2015, doi: 10.1016/J.IFACOL.2015.11.225.
- [26] Z. Tatli and A. Ayas, “Virtual laboratory applications in chemistry education,” *Procedia - Social and Behavioral Sciences*, vol. 9, pp. 938–942, Jan. 2010, doi: 10.1016/J.SBSPRO.2010.12.263.