chimica didactica acta

CDA, Vol. 11 No. 1 June 2023 read the article online

Article History
Received:23/09/2022
Accepted: 14/05/2023
Published: 25/06/2023

*Corresponding author
dheaulhaq12@gmail.com

THE EFFECT OF USING PhET SIMULATION VIRTUAL LAB ON THE UNDERSTANDING OF THE ACID-BASE CONCEPT (A Case Study at Chemistry Education Department, Syiah Kuala University)

Dhea Ulhaq[a]*, Latifah Hanum[a], Habibati[a]
[a]*Department of Chemistry Education, Universitas Syiah Kuala, Kopelma Darussalam-Banda Aceh, Indonesia, 23111*

Abstract
The Covid-19 pandemic has introduced numerous limitations to face-to-face learning, prompting a transition to online platforms. Consequently, this study aims to investigate the impact of using the PhET virtual lab on chemistry education students' understanding of the acid-base concept. Employing a quasi-experimental approach with a one-shot case study design, the research selected two classes (an experimental class and a control class) from the 2021 chemistry education cohort using purposive sampling. Data collection involved the use of tests, as multiple-choice questions, and non-test instruments, including questionnaires. The results of the study indicate that the calculated t-value t_{count} of 14.905 surpassed the critical t-value t_{table} of 2.262 at a significance level of 5% (0.05), leading to the rejection of the null hypothesis (Ho) and the acceptance of the alternative hypothesis (Ha). This finding signifies a significant effect of utilizing the PhET virtual lab on chemistry education students' understanding of the acid-base concept. Moreover, students responded positively to the use of the PhET virtual lab, with 41% rating it as good and 40% rating it as very good.

Keywords: *PhET simulation; Virtual lab; Distance learning; e-learning; Acid and base*

doi:10.24815/jcd.v11i1.28257

INTRODUCTION

The Covid-19 pandemic represents a serious health emergency, and globally, several countries have closed their schools, colleges, and universities. While the economic impact of the spread of the coronavirus was initially felt, the education sector is now also experiencing its consequences [1]. Indonesia has implemented policies to halt all educational activities, urging the government and other relevant institutions to adopt alternative education processes for students who cannot participate in conventional education. Many campuses and schools in Indonesia have now implemented rules for online classes and distance learning activities[2], [3]. Online learning refers to the use of computer networks for educational purposes. Students now have the option of more flexible learning, as it enables them to study anytime and anywhere they prefer. Through various available technologies such as online courses, Zoom, or WhatsApp groups, students can communicate with their teachers. This innovative approach to education addresses the issue of diverse learning resources.

Utilizing computer media is one way to expand understanding of chemistry subjects. Without the need for physical objects, situations, or instruments, computer media allows students to learn, comprehend, and acquire specific skills that are the objectives of teaching [4]–[6]. Computers can be used to present completed experiments in a virtual format known as Virtual Laboratories, as well as experiments involving changes. The use of virtual laboratories in education can help students develop conceptual knowledge, critical thinking, scientific methods, communication skills, ICT (Information and Communication Technology) skills, and interpretive abilities. The Interactive Virtual Laboratory Simulation PhET, created by the University of Colorado in the United States, is one of the rapidly evolving Virtual Laboratories [7].

To ensure students fully understand the concepts of acids and bases, educational innovations in the form of media usage should be implemented. Conceptual understanding is the capacity to acquire experiences, facts, and events that lead to principles or theories, without the need for in-depth difficulties. Virtual practicals can assist students in compensating for the limited practical activities they can participate in a physical lab [8], [9]. Computers or smartphones can be used to access virtual practicals, which present simulated experiments to aid in learning. If a student understands the taught concept, they will be able to reiterate it in their own words and overcome difficulties unrelated to the subject matter.

METHOD

The research design only involves one treatment considered to have an impact, namely a one-shot case study followed by a post-test. The population consists of 72 participants from the 2021 cohort. The research sample consists of 28 individuals. The process of collecting samples for a specific purpose is known as sampling. Purposive sampling is a technique of sample collection based on specific considerations that make them suitable as samples.

The study was conducted at the Faculty of Education, Department of Chemistry Education, Syiah Kuala University. The location was chosen based on observations of chemistry education students. The research duration was from February to June 2022. The data collection technique utilized a questionnaire. The questionnaire method is a way for researchers to obtain, manage, interpret, and collect data or information. A questionnaire can be used as a data collection technique and as a research instrument [4]. The distribution of the questionnaire for data collection was done through a Google Form link via the WhatsApp application.

Validity Test

Before the questions were delivered to students, the the validity was determined. Validity refers to the accuracy (validity) of the instrument compared to its legality. The quantity of validity for each question determines the validity requirements for that question. If the calculated r-value is greater than the tabled r-value, it is considered "valid." However, if the calculated r-value is less than the tabled r-value, it is considered "invalid" at a significance level of 5%.

Conducting a pilot test with respondents similar to those who will participate in the actual test is how empirical validity is achieved which is considered as crucial part in the velopment of a product in industry and education. The criteria as depicted in table 1 are used to measure the degree of validity.

Table 1. Coefficient Validity Interpretation

Correlation coefficient	Interpretation
0.8-1.0	Highest Validity
0.6-0.8	High Validity
0.4-0.6	Medium Validity
0.2-0.4	Low Validity
<0.2	Not Valid

Reliability Test

Reliability refers to the ability of an instrument to produce reliable data that can be used as a data collection tool. When an instrument is used to measure the same or similar aspects multiple times, the results are considered to have a sufficient level of dependency [6]. The Kuder Richardson formula (KR-20) is used to calculate the reliability coefficient as follows:

$$r_i = \frac{k}{(k-1)}\left\{\frac{s_t^2 - \sum p_i q_i}{s_t^2}\right\}$$

Where r_i represents reliability, k is the number of test items, s_t^2 is the total variance, p_i is the proportion of subjects who answer each test item, and q_i is 1 – p_i. The correlation criteria as given by table 2 can be applied once the reliability coefficient value is determined.

Table 2. Classification and Interpretation of reliability coefficient

Correlation coefficient	Reliability interpretation
0.8 ≤ 1.0	Very high
0.6 ≤ 0.8	High
0.4 ≤ 0.6	Medium
0.2 ≤ 0.4	Low
r < 0.2	Very Low

RESULTS AND DISCUSSION

Problem and Potential Analysis

A questionnaire was administered to 28 students to gather their feedback, and the average percentage of correct responses was as follows: 40% for "very good," 41% for "good," 19% for "fair," and 0% for "poor" and "very poor." Based on the collected data, the students' responses fall into the "good" category.

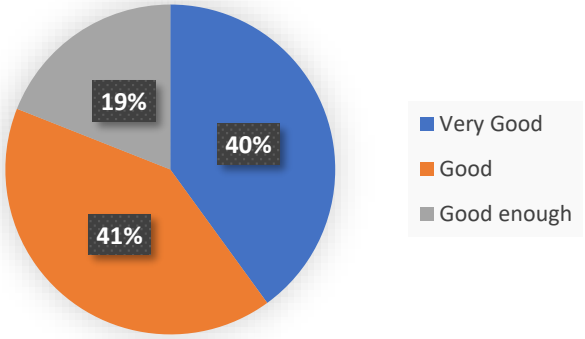


Figure 1. Student Responses to the use of PhET in comprehending the acid and base concept

The PhET virtual lab received positive feedback from users regarding the use of PhET simulations on acid-base materials. After the conclusion of the learning process, a student feedback survey was conducted. To ascertain the impact and perspectives of students regarding the use of PhET simulations, a survey on student responses is currently being conducted. It is evident that the PhET simulations generate student interest and assist them in understanding the acid-base material.

The PhET Interactive Simulations, developed by the University of Colorado Boulder, offer numerous benefits as a virtual laboratory for learning and teaching. PhET simulations provide an interactive and engaging learning experience. They offer dynamic visualizations and interactive controls that allow students to manipulate variables, observe outcomes, and explore concepts in a hands-on manner. This interactivity helps to capture students' attention and enhance their understanding and retention of complex scientific phenomena.

In addition, PhET simulations also promote conceptual understanding by providing a platform for students to visualize and interact with abstract

concepts. Through the simulations, students can observe cause-and-effect relationships, explore different scenarios, and make connections between theory and real-world phenomena. This visual and interactive approach aids in developing a deeper understanding of scientific principles. PhET simulations provide a safe and controlled environment for students to experiment and explore without the limitations or potential hazards of traditional laboratory settings. Students can engage in virtual experiments that may be difficult, expensive, or dangerous to conduct in a physical lab. This allows for greater experimentation, exploration, and learning opportunities [10], [11].

Furthermore, one of the significant advantages of PhET simulations is their accessibility. They can be accessed online from any device with an internet connection, making them available to students and educators anytime and anywhere. This flexibility allows for self-paced learning, independent exploration, and integration into various educational settings. The simulations ultimately offer flexibility in adapting to different learning needs and styles. Educators can modify simulations to align with specific learning objectives, create customized activities, or tailor the experience to cater to individual student needs. This adaptability enables personalized and differentiated learning, enhancing student engagement and understanding [12].

Moreover, PhET simulations bridge the gap between theoretical concepts and real-world application. By simulating real-world scenarios, students can explore how scientific principles are applied in various contexts and gain a better understanding of their relevance and practical implications. This promotes a deeper connection between classroom learning and real-world situations. The system is ultimately useful for students and teachers because PhET simulations are developed based on research and pedagogical best practices. The simulations undergo rigorous testing, iteractive design, and validation processes to ensure their effectiveness in promoting learning outcomes. This research-based approach enhances the quality and educational value of the simulations.

Validity test result

Masuwai et al [13] determain the validity assessment as a process used in research and measurement to evaluate the extent to which a particular study or instrument measures what it intends to measure. It is concerned with determining whether the conclusions or inferences drawn from the data collected are accurate and meaningful. Validity is a fundamental concept in research, and it refers to the degree to which a study or measurement accurately captures the concept or construct it claims to measure. In other words, it assesses whether the study or instrument measures what it is supposed to measure[14].

Table 3. Validity of questions used in evaluating students competence

No	Validity Score	Criteria
1	0.59	Valid
2	0.61	Valid
3	0.89	Valid
4	0.65	Valid
5	0.51	Valid
6	0.27	Not Valid
7	0.88	Valid
8	0.52	Valid
9	0.64	Valid
10	0.52	Valid
MEAN	0.608	
SD	±0.181	

Table 2 depicts the validity score of each question used to evaluate the students' ability to comprehent the concept of acid and base after using the PhET simulation (Experiment Class) and for control class. 9 question out of 10 are cathegorized as valid while question number 6 is invalid due to low validity score. The question was then eleminated from the test instrument, 9 other questions was employed in the test.

There are several types of validity that can be assessed, depending on the nature of the research or measurement. Here are some common types of validity assessment: 1) Content Validity: Content validity examines the extent to which the items or questions in a measurement instrument represent the entire range of the construct being measured. It involves evaluating whether the items adequately cover the content domain of interest. 2) Criterion Validity: Criterion validity assesses the extent to which a measure or test correlates with an external criterion or standard. It determines whether the results of the measure or test are consistent with other measures or outcomes that are known to be valid. 3)Construct Validity: Construct validity examines the degree to which a measure accurately assesses an underlying theoretical construct or concept. It involves evaluating the relationships between the measure and other measures or concepts in a way that is consistent with the theoretical expectations. 4) Internal Validity: Internal validity focuses on establishing a cause-and-effect relationship between variables within a study. It addresses whether the observed effects can be attributed to the manipulation of the independent variable and not to confounding factors, and 5) External Validity: External validity refers to the generalizability of research findings to the broader population or real-world settings. It assesses whether the results of a study can be applied

or generalized to other populations, contexts, or situations [14].

Validity assessment typically involves a combination of quantitative and qualitative methods, including statistical analyses, expert judgment, and theoretical reasoning. It is an ongoing process that begins during the design phase of a study and continues through data collection, analysis, and interpretation [13]. By conducting validity assessment, researchers can ensure that their studies produce reliable and accurate results, which enhances the credibility and usefulness of their findings. Therefore, the reliable product is important to achieve several goals in learning. The reliability concept also important to ensure that the product would give a proper results when implemented.

Reliability test of instrument

The instrument of the test (in this case is a set of question, 2 tier multiple choice equiped with CRI) was tested for the reliability and the result is given in table 4.

Table 4. Reliability test result of questions

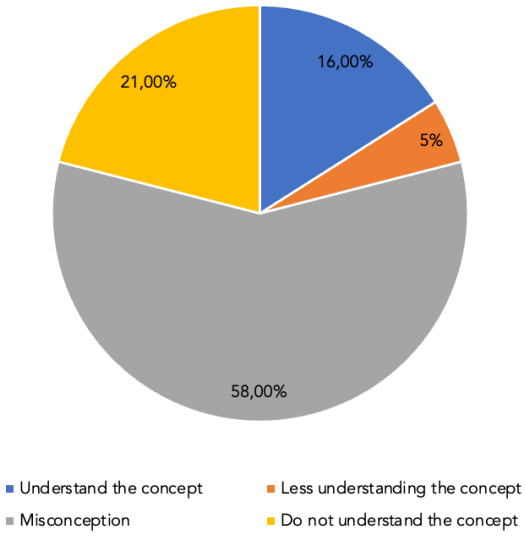
Number of question	Reliability Coefficient	Criteria
10	0.86	High reliability

Table 4 suggests that the whole instrument is reliable and can be use simultaneously to ealuate the students' competence. Reliability testing is crucial in evaluation for several reasons:1) *Consistency:* Reliability refers to the consistency or stability of measurement. It assesses whether the evaluation instrument or assessment tool produces consistent results across different occasions or raters. If a measurement is reliable, it should yield similar results when administered under similar conditions. Reliability testing helps ensure that the evaluation is not influenced by random error or inconsistencies, providing more accurate and trustworthy results. 2) Precision: Reliability testing helps determine the precision or accuracy of the measurement instrument. It identifies the extent to which the instrument measures the true score of the construct being evaluated, as opposed to measurement error. By reducing measurement error, reliability testing increases the precision of the evaluation, allowing for more reliable and precise conclusions to be drawn. 3) Comparability: Reliability testing enables comparisons across different groups, settings, or time points. If an evaluation instrument lacks reliability, the results may not be comparable across different contexts. By establishing the reliability of the measurement instrument, evaluators can confidently compare results and make valid conclusions about the effectiveness of interventions or programs in different situations. 4) Decision-making: Reliability testing provides evaluators with confidence in the results when making important decisions based on evaluation outcomes. When evaluating the impact of interventions or policies, reliability helps ensure that decisions are based on solid evidence. Reliability testing helps prevent erroneous conclusions that may lead to ineffective or inappropriate actions. 5) Evaluation Integrity: Reliability testing enhances the integrity of the evaluation process. It demonstrates the rigor and scientific validity of the evaluation design and methods. By demonstrating the reliability of the evaluation instruments and procedures, stakeholders and decision-makers can have greater confidence in the evaluation process and the findings it produces [14].

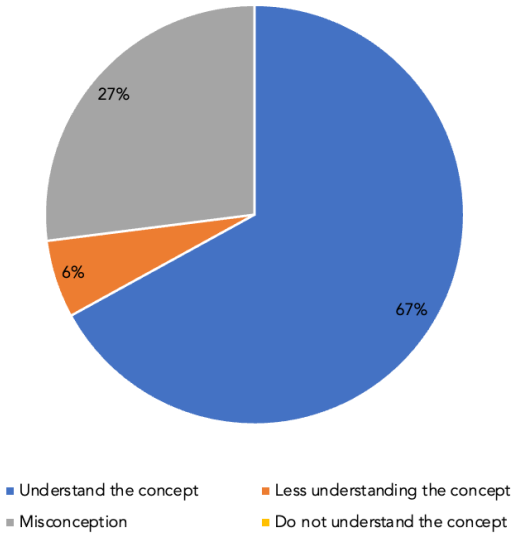
Furthermore, Reliability testing enhances the overall trustworthiness and credibility of the evaluation. Stakeholders and other interested parties are more likely to accept and value the evaluation findings if they are based on reliable measures. Reliability testing ensures that the evaluation is conducted with rigor and that the results are dependable and meaningful.

Students' Level of Understanding of Acid-Base Concepts

Based on the results of the acid-base concept knowledge test administered to students, it can be observed that the experimental class obtained a score of 67.14%, while the control class scored 15.71% in the category of concept understanding. The test results indicate that the class utilizing the PhET virtual lab achieved significantly higher scores compared to the class that did not use the PhET virtual lab. This suggests that the positive outcomes of using the PhET virtual lab effectively enhance students' conceptual understanding.



(a)



(b)

Figure 2. Student Conceptual Understanding for (a) the class of control, and (b) the class of experiment

Based on the test results, it is evident that the experimental class consistently answered questions better than the control class. The post-test responses indicate positive outcomes, and there is a significant improvement in learning outcomes in the experimental class. This highlights the benefits of using PhET simulations as a teaching tool.

The provided result suggests that the experimental class performed better than the control class in answering questions, indicating a positive outcome. The post-test responses indicate that the experimental class experienced significant improvement in learning outcomes compared to the control class. These findings emphasize the advantages of utilizing PhET simulations as a teaching tool.

This result suggests that the use of PhET simulations had a positive impact on the experimental class's learning outcomes. The experimental class consistently outperformed the control class, implying that the implementation of PhET simulations helped students grasp the subject matter more effectively. This finding is noteworthy because it indicates that the use of interactive and visual simulations can enhance learning outcomes. The results also indicates that the post-test responses indicate positive outcomes. This suggests that the benefits of using PhET simulations were not limited to immediate performance during the experimental phase but had a lasting effect. It implies that the students in the experimental class retained the knowledge gained from the simulations and were able to apply it successfully in the post-test.

Furthermore, a significant improvement in learning outcomes highlights the statistical significance of the results. This indicates that the observed difference between the experimental and control classes' performance is unlikely to have occurred by chance. It strengthens the validity of the conclusion that the use of PhET simulations played a crucial role in enhancing learning outcomes. Therefore, incorporating interactive simulations into the classroom can be advantageous for both students and teachers. PhET simulations provide an engaging and interactive learning experience, allowing students to explore concepts in a hands-on manner. They can help students develop a deeper understanding of complex topics by visualizing abstract concepts and facilitating active learning [15]–[17].

Overall, based on the research findings, it can be concluded that the experimental class exhibited better performance, with significant improvement in learning outcomes, when compared to the control class. These findings support the effectiveness of PhET simulations as a teaching tool and highlight their potential to enhance student learning in educational settings.

Hypothesis Testing

The paired t-test, commonly known as the test for the difference between two means with dependent samples, is used to test the research hypothesis. The paired comparison of the same subjects evaluated twice is examined using the paired t-test. To draw conclusions from this t-test, a significance value (2-tailed) ≥ 0.05 is required, indicating a difference between the class that used the PhET Virtual Lab and the class that did not use it.

Based on the output table "Paired Sample Test," 0.000 ≤ 0.05, indicating that the difference between the class that used the PhET Virtual Lab and the class that did not use it affects how the PhET virtual lab is utilized. Furthermore, the significance test is conducted by comparing the calculated t-value (t_{uit}) and the critical t-value (t_{tabel}). The criterion for this research using a significance level is t-table = 0.05/2 = 0.025 (two-tailed test). The degrees of freedom, or Df, are expressed as n-1 or 10-1. This results in a table value of 2.262.

Conclusion making criteria:
- If the calculated t-value (t_{uit}) > the critical t-value (t_{tabel}), then Ho is rejected, and Ha is accepted.
- If the calculated t-value (t_{uit}) < the critical t-value (t_{tabel}), then Ho is accepted, and Ha is rejected.

Based on the "Paired Samples Test" output, the calculated t-value is negative, or -14.905. The negative t-value may be beneficial in the context of this example. The calculated t-value is now 14.905. The criterion for rejecting Ho and accepting Ha is $t_{uit} > t_{tabel}$, or 14.905 > 2.262 at a significance level of 5% (0.05). This criterion indicates that the use of the PhET Virtual Lab has a significant impact on students' understanding of acid-base concepts in chemistry class. This results also suggest that there are significantly different in the

concept understanding between the group of experiment and the group of control.

CONCLUSION

Based on the research findings, the following conclusions can be drawn:

1) The results of the data analysis indicate that Ho is rejected and Ha is accepted, as $t_{uit} > t_{tabel}$ (14.905 > 2.262). Thus, this criterion demonstrates that the utilization of the PhET Virtual Lab has a significant impact on students' understanding of acid-base concepts in chemistry. This implies that using the PhET Virtual Lab is an effective approach to enhance students' comprehension of acid-base concepts.
2) The use of PhET Simulation in teaching acid-base materials receives a positive response from students, as indicated by the average percentage of 41% in the "good" category. This suggests that the implementation of PhET Simulation can facilitate students in understanding the concepts of acid-base materials. The positive feedback from students further supports the effectiveness of incorporating PhET Simulation as a teaching tool for acid-base topics.

REFERENCES

[1] C. Eka and M. Munzil, "Development of Virtual Laboratory Based on Augmented Reality on Electrolysis Material for Class XII High School Students in the Covid-19 Pandemic Era," vol. 209, no. Ijcse, pp. 198–201, 2021.

[2] L. T. Prawanti and W. Sumarni, "Obstacles of Online Learning During the Pandemic of Covid-19," *National National Proceeding, Pascasarjana UNNES*, pp. 286–291, 2020.

[3] D. S. Sitorus and T. N. B. Santoso, " Utilizing Quizizz as Game Based Learning Media During Covid-19 Pandemic Attack" *Scholaria: Jurnal Pendidikan dan Kebudayaan*, vol. 12, no. 2, pp. 81–88, 2022, doi: 10.24246/j.js.2022.v12.i2.p81-88.

[4] K. A. Nihuka and F. Peter, "Challenges Facing Implementation of Ict Curriculum in Primary Challenges Facing Implementation of Ict Curriculum," in *Inaugural International conference on Open and Flexible Education*, Hongkong, 2014, pp. 1–20.

[5] K. A. Nihuka and F. Peter, "Challenges Facing Implementation of Ict Curriculum in Primary Challenges Facing Implementation of Ict Curriculum," in *Inaugural International Conference on Open and Flexible Education*, Hongkong, 2014, pp. 1–20.

[6] Meenakshi and (Research, "Importance of ICT in Education," *Journal of Research & Method in Education*, vol. 1, no. 4, pp. 3–8, 2013.

[7] A. Gani, M. Syukri, K. Khairunnisak, M. Nazar, and R. P. Sari, "Improving concept understanding and motivation of learners through Phet simulation word," in *Journal of Physics: Conference Series*, Institute of Physics Publishing, Jul. 2020. doi: 10.1088/1742-6596/1567/4/042013.

[8] N. D. Williams, M. T. Gallardo-Williams, E. H. Griffith, and S. Lowery Bretz, "Investigating Meaningful Learning in Virtual Reality Organic Chemistry Laboratories," *J Chem Educ*, vol. 99, no. 2, pp. 1100–1105, Dec. 2021, doi: 10.1021/acs.jchemed.1c00476.

[9] M. Nazar, S. Uliah, K. Puspita, and W. Artika, "Developing and Implementing Android Based-Augmented Reality Virtual Lab in the Practicum of Corrosion," in *12 th Annual International Conference*, 2022, pp. 1–7.

[10] A. A. Juan, B. Loch, T. Daradoumis, and S. Ventura, "Games and simulation in higher education," *International Journal of Educational Technology in Higher Education*, vol. 14, no. 1, pp. 0–2, 2017, doi: 10.1186/s41239-017-0075-9.

[11] K. Pansuwan, S. Klankhajhon, J. Keperawatan Padjadjaran, and K. Pansuwan Assistant Professor, "The Effect of Using Simulation-Based Learning on Nursing Performances of Early Postpartum Hemorrhage in Nursing Students OPEN ACCESS," *Original Article Jurnal Keperawatan Padjadjaran*, vol. 9, no. 3, pp. 175–180, 2021, doi: 10.24198/jkp.

[12] B. E. Wiggins, "An Overview and Study on the Use of Games , Simulations , and Gamification in Higher Education," *International Journal of Game-Based Learning*, vol. 6, no. 1, pp. 18–29, 2016, doi: 10.4018/IJGBL.2016010102.

[13] A. Masuwai, N. M. Tajudin, and N. S. Saad, "Evaluating the face and content validity of a Teaching and Learning Guiding Principles Instrument (TLGPI): A perspective study of Malaysian teacher educators," *Geografia - Malaysian Journal of Society and Space*, vol. 12, no. 3, 2016.

[14] B. Bujeng, A. Kamis, M. A. M. Hussain, M. B. Rahim, and S. Soenarto, "Validity and reliability of multimedia interactive making clothes (MIMP) module for home science subjects," *International Journal of Innovative Technology and Exploring Engineering*, vol. 8, no. 8 S, pp. 593–596, 2019.

[15] F. M. Ippoliti, J. V. Chari, and N. K. Garg, "Advancing global chemical education through interactive teaching tools," *Chem Sci*, vol. 13, no.

20, pp. 5790–5796, 2022, doi: 10.1039/d2sc01881k.

[16] S. Sannikov, F. Zhdanov, P. Chebotarev, and P. Rabinovich, "Interactive Educational Content Based on Augmented Reality and 3D Visualization," in *Procedia - Procedia Computer Science*, Elsevier Masson SAS, 2015, pp. 720–729. doi: 10.1016/j.procs.2015.11.082.

[17] R. E. Evans and P. Kortum, "The impact of voice characteristics on user response in an interactive voice response system," *Interact Comput*, vol. 22, no. 6, pp. 606–614, 2010, doi: 10.1016/j.intcom.2010.07.001.