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Development of Virtual Laboratory in Acid-Base Titration for Grade 11 Learners

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Abstract

The increasing use of virtual laboratories in educational institutions necessitates developing a new laboratory activity that would substantially assist teachers in the classroom without web programming obstacles. Hence, the primary aspiration of this study is to create a virtual laboratory in acid-base titration for Grade 11 Learners as an alternative instructional material for conducting experimentation in Chemistry, specifically acid-base titration. The study employed a quantitative research design that involved a research and development approach (R&D) utilizing the ADDIE (Analysis, Design, Develop, Implement, and Evaluate) method. Development of the virtual laboratory was started by crafting a worksheet to guide the creation of the platform. Considering experts' comments and suggestions, the final revision of the developed worksheet was prepared and ready for making a virtual laboratory. The adviser scrutinized the virtual laboratory platform to check for any errors for further revisions. Through comments/suggestions, virtual simulation was then worked out and validated by the three (3) experts in the field of chemistry education, with rubrics having three (3) categories: pedagogy, content, and ICT. Incorporating comments and suggestions, a final version was crafted with an overall rating of 0.85 in the validity index, which indicates a good and valid tool. To identify errors and discrepancies in the Worksheet and Virtual Laboratory, pilot testing was employed through Grade 11 STEM students. Garnering a 0.91 reliability coefficient using Cronbach's alpha indicates an excellent instructional material in terms of its internal consistency. The developed student worksheet and virtual laboratory are recommended after going through these processes. They are ready to be used as teaching and learning material for long-distance and face-to-face learning experiments.

Keywords: worksheet, e-learning, chemistry, activity

1. Introduction

The COVID-19 lockout situation affects people all over the world. The lockdown enforced to slow down the economy significantly impacted education. The COVID-19 pandemic has spread to teachers at all levels of school. We're suddenly confronted with the need to adapt their classes, which have been converted to online ones.

This created several issues, ranging from the pedagogical and psychological aspects of teaching and learning online. Since the teaching mode has been switched to online learning, it has been a big problem for teachers and students to teach and learn quickly in their lessons, especially in chemistry.

Chemistry is a science that cannot be separated from chemical experimentation, and chemists cannot be separated from their mastery of concepts and skills in conducting experiments [1]. As a result, students must take chemistry coursesto participate in experiments. Chemistry must be taught properly, as this will lead to further misconceptions if not treated [2]. However, in this situation, experimentation, particularly in acid-base titration, cannot be performed by students, as it needs to be done at school laboratories due to its hazardous chemicals and proper usage of apparatus. However, acid-base titrations are standard experiments carried out by students in introductory chemistry classes. This one is considered quite complex, as students must also

do experiments or trials in the laboratory to fully grasp particular concepts or fundamental theories that have been covered. Of this, there is a need to develop an intervention that could serve as an alternative that is more useful for students and teachersto perform laboratories while staying at home continuously. This leads to the adaptation of a virtual laboratory.

2. Objectives

This initiative aims to address the need for an intervention that enhances the continuity of laboratory-based learning experiences for both students and teachers in remote learning environments. Recognizing the limitations of traditional in-person laboratories, particularly in the context of students and teachers staying at home, there is a compelling need to develop and implement a virtual laboratory as a viable alternative. This objective aims to explore and implement a digital platform that replicates the essential elements of hands-on experiments and provides an accessible and effective means for students and teachers to engage in laboratory activities remotely. The goal is to establish a virtual laboratory that contributes to sustained and meaningful learning experiences, ensuring that practical components of education remain robust even in a remote or hybrid learning setting.

3. Methods

The study employed a quantitative research design involving the Research and Development approach (R&D), representing the processes used to develop educational productsby adaptingthe ADDIE Model (Analysis, Design, Development, Implementation, and Evaluation) [3]. The Students employed cluster sampling to test the reliability of the developed Virtual Laboratory and Worksheet. For the experts, purposive sampling was also used to assess the validity of the formed Virtual Laboratory and Worksheet. The study was conducted in one of the secondary public schools in Zamboanga del Sur. The researchers chose this school to determine the result of the developed Virtual Worksheet in Acid-Base Titration.

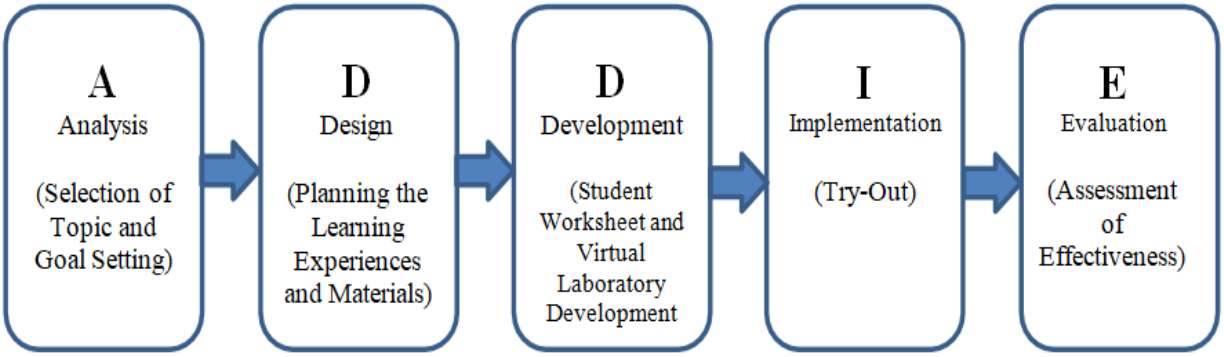


Figure 1. ADDIE Model

Analysis Stage: *Selection of Topic and Goal Setting.*

The research procedure applied in the Development of the Virtual Laboratory is the ADDIE MODEL. The ADDIE model consists of 5 stages: Analysis, design, Development, implementation, and evaluation. Figure 1 shows the structure of ADDIE MODEL.

Researchers chose (1) one least learned topic in chemistry and acid-base titration topic had chosen. Researchers consider acid-base titration as one (1) of the least learned in which students are less able to connect the acid-base concept accurately, lack understanding of the underlying chemistry, and need help understanding the microscopic form of the material. To resolve this issue and provide literature-based variations in teaching strategies for learning acid-base titration, a virtual laboratory can be devised as an alternative to actual experimentation; thereby necessitating the need for the researchers to develop a virtual laboratory for the given topic.

Design Stage: *Planning the Learning Experiences and Materials.*

The activity on Acid-base titration was designed for Grade 11 learners enrolled in Senior High School – STEM (Science, Technology, Engineering and Mathematics) Specialized Subjects Track, with the content based on the DepEd existing curriculum,namely; pH- a measure of acidity,

strength of acids and bases and weak acids/weak bases and ionization constants.

The learning experiences that the students performed in the developed virtual laboratory were aligned with the Key Stage Standards for Science Learning Areas for Senior High School of DepEd (Department of Education) K+12 curriculum.

At the end of Grade 11, the learners should have gained skills in obtaining scientific and technological information from varied sources about global issues that have impact on the country. They should have acquired scientific attitudes that will allow them to innovate and/or create products useful to the community or country. They should be able to process information to get relevant data for a problem at hand. In addition, learners should have made plans related to their interests and expertise, with consideration for the needs of their community and the country — to pursue employment, entrepreneurship, or higher education.

Figure 2. Standards in Science Learning Areas for Grades 11 STEM

The topic was integrated with the competency criteria to ensure the students would be presented with high-quality acid-base titration teaching through a virtual laboratory. As part of the present K–12 curriculum, these standards functioned as directives for supporting students' learning at all stages of the teaching-learning process.

Develop Stage*:Student Worksheet and Virtual Laboratory Development*

The development stage, in other words, includes selecting and determining appropriate methods, media, and learning strategies used in delivering personal material [4]. In this stage, the framework that had been designed will be realized to produce a product that can be implemented. Student Worksheet and Virtual Laboratory using Interactive PowerPoint Presentation was created in the Development Stage.*The figure* below shows the process ofdeveloping the Worksheet and Virtual Laboratory.

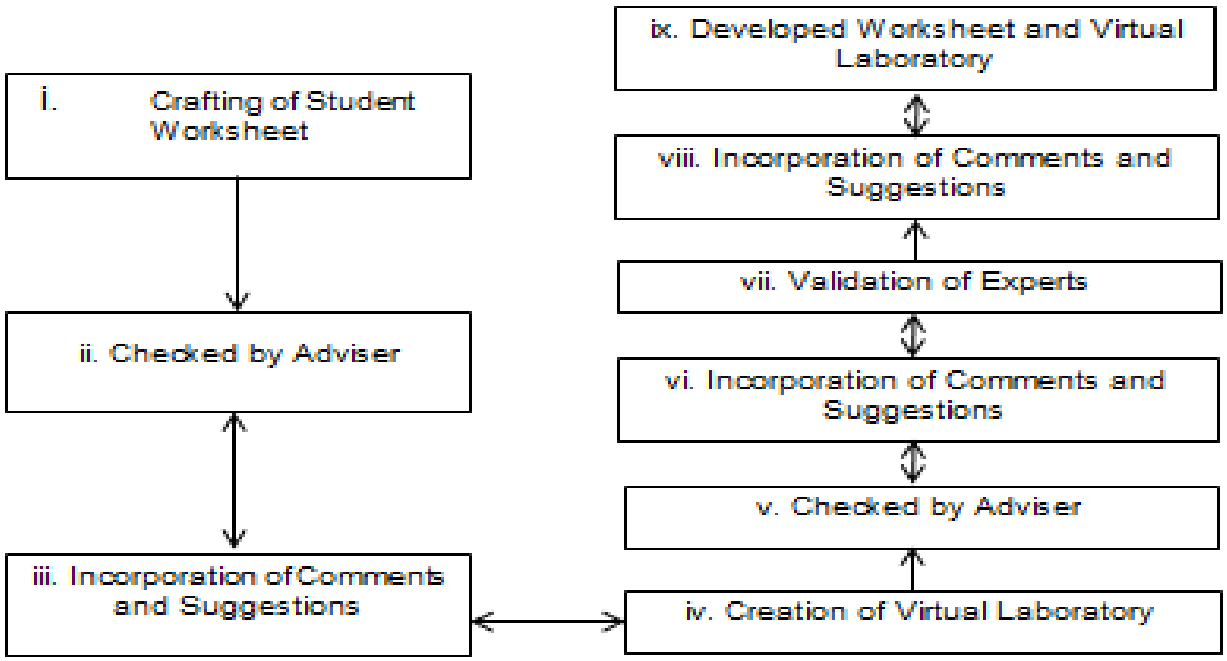


Figure 3. The process of developing worksheetsand virtual laboratory

Crafting of Student Worksheet

The topic selection was aligned with the K to 12 DepEd Curriculum, which was proven to be the least learned topic in Chemistry. From the topic itself, students'worksheetswere being crafted (See Figure 4). Student worksheets undergo checking with the adviser to correct grammatical errors and sequence if there are.

Acid-Base Titration Worksheet

Name:_____ Course:

Lab. Course:_____ Lab No.:

Date:_____ Score:

Learning Competency:

- Determine the pH of a solution of a weak acid or weak base. **(STEM_GC11AB-IVf-g-158)**

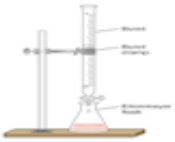
OBJECTIVES:

- Use available materials and substances at home in acid-base titration.
- Conduct titration to determine the concentration of a strong and weak acid and base.

Acid-Base Titration Worksheet

- Draw the pH curve of a strong and weak acid and base.

Introduction



Titration is a simple technique that involves finding an unknown concentration of a solution by reacting it with another solution of a known concentration. Conducting titration experiments is a routine undertaken as part of the high school and undergraduate Chemistry laboratory curriculum (Bandyopadhyay and Rathod, 2017). One of the common types of titration is acid-base titration. "An acid-base titration is a quantitative analysis of acids and bases; through this process, an acid or base of known concentration neutralizes an acid or base of unknown concentration. ("Course hero," n.d.)" In an acid-base titration, a solution containing a known concentration of a base is slowly added to an acid. The endpoint is indicated by means of a pH indicator (Nollet, 2004). The two solutions in titration are the analyte and titrant. An analyte is an unknown substance whose quantity or concentration must be reacted with a carefully controlled volume of accurately known concentration called a standard solution. It can be identified as either a strong acid or a strong base. At the same time, the titrant, is the solution involved or used in titration to determine the concentration of an unknown solution, the analyte. The titrant is usually the solution of known concentration delivered by the burette into the analyte. It can also be identified as a strong base or a strong acid. When enough titrant has been added to react to the analyte with no leftover, it will reach the equivalence point. In this experiment, you will be determining the volume of sodium carbonate (Na_2Co_3) solution and *acetic acid solution* (*CH3COOH*). The 2 substances are, vinegar and

4. Add 5 drops of natural indicator to the Erlenmeyer flask with 15ml acetic acid. Put it on the magnetic stirrer.
5. Turn on the magnetic stirrer up to medium speed.
6. Turn on the burette valve. Then observe.
7. Record your observation in Table 2.

Acid-base Titration of Acetic Acid (Vinegar) and Sodium Carbonate (Detergent Powder)

Table 1. Data and observation in preparing the analyte and titrant.

	Color of the titrant/analyte after adding natural indicator	Inference (Acidic/Basic)
Analyte		
Titrant		

Table 2. Data and observation in titration process

Volume of Sodium Bicarbonate (**Na2CO3**)	
Volume of Acetic Acid (**CH3COOH**)	
Concentration of Sodium Bicarbonate	
Concentration of Acetic Acid	

Questions:

1. Write the balanced chemical reaction equation of the detergent solution and vinegar.

_____

_____

_____

2. Identify the endpoint and the equivalence point on the titration process.

_____

_____

_____

3. Draw the pH curve of titration of strong acid-strong base and weak acid-base home.

_____

_____

_____

Conclusion: (*Write your observations during the titration process and make an inference.*

_____

_____

_____

Figure 4. Acid-Base Titration Worksheet

Virtual Laboratory Development

Researchers took steps to improve the established platform as they created the final edition of the developed virtual laboratory, responding to comments, recommendations, and additional adjustments made by this study's adviser and subject-matter experts. The outcome of the virtual laboratory was successfully created (see Figure 5).

Three (3) chemistry experts participated in this study. The Developed Virtual Laboratory and

Worksheet were validated by experts using a rating sheet. Experts were eligible for the study because they have firsthand expertise in developmental research studies. One (1) section of Grade 11 STEM students was charged with taking part in the pilot testing of the developed virtual laboratory after validating the developed platform, which the experts assessed. Pilot testing was done to demonstrate how dependable the virtual laboratory is.

Figure 5. Virtual Laboratory in Acid-Base Titration

Researchers adapted rating sheets for validators and students for the Developed Virtual Laboratory in Acid-Base Titration. For validators, the rating sheets are to measure the validity of theDeveloped Virtual Laboratory, while for students, rating sheets are to measure the reliability of whether the Developed Virtual Laboratory is ready to implement or needs a revision for better performance. The descriptive statistics applied were Mean and Standard Deviation, Aiken's content validity, and Cronbach's alpha for the validity and reliability of the developed virtual laboratory.

4. Results and Discussion

Validity of the Developed Virtual Laboratory

As evaluated by three (3) experts, the validity test of the developed virtual laboratory got an average validity index of 0.93 in the pedagogy aspect, 0.82 in the content aspect, and 0.73 in the ICT aspect. The overall validity index of the developed virtual laboratory was 0.85. This means that the instructional material developed was valid and effective for the aid of students and teachers, specifically for Grade 11 STEM students.

Table 1. Aiken's Content Validity Overall Ratings

Category	Aikens Validity Index (AVI)	Interpretation
Pedagogy	0.93	GOOD
Content Aspect	0.82	
ICT	0.73	
Overall	0.85	

Reliability of the Developed Virtual Laboratory

Fifteen (15) respondents evaluated the reliability test of the virtual laboratory. Fifteen students from Grade 11 STEM were tasked to rate the developed material. The respondents assessed the virtual laboratory through a rating sheet usingfive rubrics. (5) Categories: content, accuracy, sequence of information, use of graphics, and mechanics. The developed virtual laboratory got 0.91 reliability using Cronbach's alpha, indicating excellent internal consistency. This means that the developed virtual laboratory has passed the reliability test and has proven useful and practical.

Table 2. Student Ratings and Overall Reliability Ratings of the Virtual Laboratory

Respondents	Content	Accuracy	Sequence of Information	Use of Graphics	Mechanics	Total
RES 1	90	90	96	98	95	469
RES 2	96	95	97	99	98	485
RES 3	95	96	97	98	96	482
RES 4	95	96	97	98	99	485
RES 5	96	94	98	97	98	483
RES 6	90	90	90	90	90	450
RES 7	98	97	96	96	95	482
RES 8	97	98	98	95	97	485
RES 9	96	94	97	97	95	479
RES 10	95	95	96	96	95	477
RES 11	96	98	99	99	99	491
RES 12	97	99	90	98	98	482
RES 13	99	98	99	94	94	484
RES 14	95	97	97	99	98	486
RES 15	96	95	96	95	95	477
Mean					95.96	
SD					0.148938	

Note: M= mean, SD= standard deviation, QD=qualitative description, level1=50-59, level2= 60-69, level 3=70-79, level 4= 80-100

Tabulation of Reliability of the Developed Virtual Laboratory

VARIANCE	DESCRIPTION	VALUES	INTERNAL CONSISTENCY
K	# of item	5	
$\sum s^2 y$	sum of the item variance	30.07	EXCELLENT
$S^2 x$	variance of total score	112.01	
a	Cronbach's alpha	0.91	

Note: 0.90 and above=Excellent, 0.80-0.89=Good, 0.70-0.79=Acceptable, 0.60-0.69=Questionable, 0.50-0.59=Poor, below 0.50=Unacceptable

5. Conclusion

Based on the findings of this study, the following conclusions were made:a virtual laboratory for acid-base titration was created so that teachers and students could conduct effective experiments. The educational content goes through validation and review to ensure its accuracy and dependability for usability. Through this, the Developed Virtual Laboratory produced great results. It was now prepared to be used as instructional material to teach Chemistry, specifically Acid-Base Titration, for Grade 11 learners. Worksheets and Virtual Laboratory can be completed digitally and in person during

classes. Sutarno et al. [5] claimed that using Virtual Labs can enhance one's ability to think critically. Moreover, theinteractive nature of such teaching methods offers a clear and enjoyable learning environment, thus providing solutions to the lack of facilities and premises and introducing students to recent trends in technology and innovation.

6. Recommendation

This study focuses on developinga Virtual Laboratory in Acid Base Titration for Grade 11 Learners. Thus, the following recommendations are presented now: For future researchers to apply programming manipulation for a better virtual laboratory. Teachers may utilize the virtual laboratory with students, affectingtheir interests, attitudes, conceptual understanding, critical thinking, etc.

From the results above, it is proven that the students understand and are interested in the new instructional material developed. It is also expected that if they use the virtual laboratory, students can get a good score in science, specifically in chemistry. The study of Permadi& Ahmad proved this [6], which showed thatstudents using a virtual laboratory with augmented reality can get good scores in science learning.

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