Terakreditasi S4 sinta Science and Technology Index

pISSN 2685-0761
eISSN 2685-0850

JURNAL INOVASI PEMBELAJARAN KIMIA
(Journal of Innovation in Chemistry Education)
https://jurnal.unimed.ac.id/2012/index.php/jipk
email: Jinovpkim@unimed.ac.id

**Recieved** : 9 April 2024
**Revised** : 19 April 2024
**Accepted** : 29 April 2024
**Publish** : 30 April 2024
**Page** : 111 – 119

# Implementation PhET Virtual Laboratory-Based Learning Media to Increase Learning Outcomes on Teaching of Acid-Base

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***Abstract***: *Chemistry learning contains abstract concepts that require understanding through three levels of representation. So that innovative learning media is needed that supports the achievement of concepts learned in chemistry, especially in acid-base material. This research aims to develop and implement PhET virtual laboratory-based learning media to build student activeness in learning and improve student learning outcomes in learning the topic of Acid-Base. The use of this innovative learning media is supported by a project-based learning model. This research was conducted by research and development (RnD) with the procedures of define, design, development, and implementation. The research includes the development of PhET laboratory-based learning media, standardization of learning media, and implementation to students in class XI MIPA SMA Negeri 5 Medan, SMA Negeri 1 Habinsaran and SMA Negeri 1 Borbor in sample classes, namely Control class and Experiment Class. The feasibility of the learning media measured 87.06% with a very feasible category. The results of the media implementation can be seen in the N-gain value in the experimental class higher than the control class with a value at SMA Negeri 5 Medan 60.9%, SMA Negeri 1 Habinsaran 68.69%, and SMA Negeri 1 Borbor 67.03% with each in the effective category.*

***Keywords***: *Development and Implementation; PhET Virtual Laboratory-Based Learning Media; Student Learning Outcomes*

## INTRODUCTION

Education includes all learning experiences carried out throughout life in all environments and situations that play a role and provide positive meaning in the growth of each individual (Pristiwanti et al., 2022). Learning chemistry at the high school level is one of the subjects that plays a role in developing students' scientific understanding. The scope of chemical studies is divided into concepts that are visible to the eye and some that are abstract. In an effort to help students understand quite complex chemical concepts, students are expected to be able to master three interrelated levels of chemical representation, namely at the macroscopic level which shows real and visible phenomena such as chemical reactions, submicroscopic levels such as atoms or structures that are not visible, as well as symbolic levels such as representation symbols, formulas or equations (Hu et al., 2022).

One of the materials in learning chemistry that requires a deep understanding of the three levels of chemical representation is the concept of Acid-Base (Ivanoska & Stojanovska, 2021). The topic of acids and bases is conceptual, calculating and abstract, so effective learning strategies are needed so that they can provide experience and practice that can develop the development of students' competencies (Lestari et al., 2021). Several previous studies have shown that there are still many students who experience difficulties and misconceptions about several basic concepts of acid-base material. When learning acids and bases, students cannot deepen the material because most students have difficulty understanding the concept and calculation of pH (Supatmi et al., 2019). Students are still limited in understanding at the microscopic level which also hinders students' ability to solve problems on macroscopic and symbolic representations (Susilaningsih et al., 2020). So that the use of appropriate learning media and learning models can support the achievement of learning objectives and provide a very necessary representation of chemistry (Amry et al., 2022).

Based on observations it shows that the learning media used in the Acid-Base learning process is still focused on teaching materials that are less interesting, less innovative, and are only limited to textbooks provided by the school. One method used to build an active learning atmosphere in learning is the application of innovative learning (Nainggolan et al., 2020). The application of innovation in chemistry learning is expected to improve learning outcomes and student competence (Pakpahan et al., 2022).The teaching method using PhET virtual laboratory-based learning media is one innovation that provides interactive simulations in understanding chemical concepts. Learning with the help of virtual laboratories can make learning more interesting which can increase students' motivation in participating in learning (Yakob et al., 2023). The choice of using PhET simulation media is based on the interaction simulation capabilities of PhET which supports the involvement of three levels of chemical representation through animation and connects the integration of the three levels in the chemistry learning process (Salame & Makki, 2021). The application of this learning media helps students build a solid conceptual understanding, reducing the possibility of misconceptions between concepts (Rahmawati et al., 2022).

## LITERATURE REVIEW

Learning media is a tool or media that contains learning material as a messenger in learning activities. Where this learning media will develop in accordance with developments in learning technology. Learning media can make the learning process more fun, challenging, motivate learning, and make learning more interactive and inspiring by containing important material or points. This allows students to participate actively with other students, this also becomes an incentive for students to express opinions to each other, show their creativity, according to their respective interests and talents. Not only that, the education process also involves various parties, which must be balanced with technological developments to make it easier to achieve a certain atmosphere. In this way, the learning atmosphere will feel comfortable, interesting and easier to understand. The essence of learning is a process of direction to achieve the goal of gaining knowledge by carrying out an activity through the experience that has been created. In learning, teaching materials or media are needed. The aim of using teaching materials or media is to really help students understand the material in learning. With this media or teaching materials, educators can direct the activities that will be taught in the learning process (Zahwa et al., 2022). Virtual learning can run effectively if the teacher is able to utilize learning resources and media. Teachers are required to be able to utilize technological advances to support learning, while students are expected to be actively involved in solving the problems they face (Supriadi & Hignasari, 2019). According to Dzikro & Dwiningsih, (2021) said that the use of virtual laboratories

as a learning medium when applied in teaching and learning activities is considered very practical. Virtual laboratories are also effective in making students familiar with the laboratory environment, especially for students who have not had the opportunity to explore the laboratory before. PhET (Physics Education Technology) virtual laboratory is an online platform that provides virtual laboratory-based teaching and learning simulations. PhET simulations provide experiments in several fields such as physics, chemistry, biology, and mathematics. The use of this PhET virtual laboratory helps explain material concepts macroscopically and microscopically with experiments on web features. The use of this PhET virtual laboratory is one of the applications of technology in the field of education (Warsiki, 2023).

The implementation of PhET's virtual laboratory supports the running of limited chemistry experiments in a real laboratory (Firmayanto et al., 2021). Students can construct their own understanding and knowledge by providing authentic problems provided in the learning through the problem centered learning (Putri Apriliana et al., 2019). To enhance student motivation and improve learning results, it's essential to implement a learning approach that aligns with continuous learning (Damanik & Maulidza, 2024). Educational media serves as a conduit for conveying information on learning materials, aiming to engage students' attention, interest, thoughts, and emotions to fulfill learning goals (Nursalsabillah Nasution & Jahro, 2023). Various elements impacting student success encompass external and internal factors. External factors originate externally to the individual, whereas internal factors stem from the students themselves, encompassing activities, interests, knowledge base, intelligence, and learning approaches (Ramadhana & Sutiani, 2023).

## METHODS

### Population and Sample

This research was conducted in the even semester of the 2023/2024 academic year at three schools, namely SMA Negeri 5 Medan, SMA Negeri 1 Habinsaran, and SMA Negeri 1 Borbor. This research was conducted on class XI students in the Mathematics and Natural Sciences department. The sample was selected purposively by taking two classes from each school which would be divided into two groups, namely the experimental class and the control class. The research sample used was 216 students which are shown in table 1.

**Table 1.** Sample distribution from three implementation test schools.

| No | | Class | Sample | | Total |
|---|---|---|---|---|---|
| | | | Exp | Control | |
| 1. | SMA Negeri 5 Medan | 2 | 36 | 36 | 72 |
| 2. | SMA Negeri 1 Habinsaran | 2 | 36 | 36 | 72 |
| 3. | SMA Negeri 1 Borbor | 2 | 36 | 36 | 72 |
| | Total | | 108 | 108 | 216 |

### Research Prosedures

The procedure in this research contains several stages, namely the development of virtual laboratory-based learning media, validation and standardization of learning media and implementation of learning media on student learning outcomes in acid-base material. The research procedure scheme is shown in Figure 1.

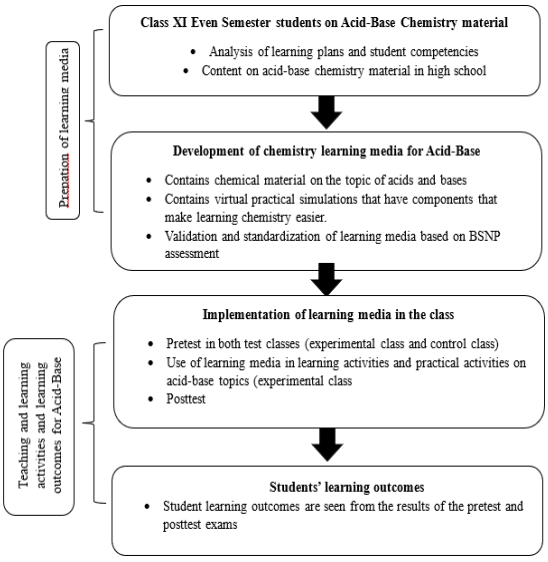


**Figure 1.** General description of research procedures

### Development of Learning Media

The learning media development stage begins with analyzing the acid-based learning topic based on the learning plan, analysis of textbooks applied in schools to obtain chemical material studied in the Acid-base subtopic that is in accordance with the curriculum applicable in each school. The learning media developed is then evaluated by expert lecturers to see the suitability of the learning media based on the criteria set by the Indonesian National Education Standards Agency (BSNP). Assessment of the feasibility of learning media uses a Likert scale survey with the criteria: (4) very good, (3) good, (2) not good, and (1) very bad (Situmorang et al., 2020).

### Implementation of Learning Media

Virtual laboratory-based learning media is applied to class XI MIPA students in Acid-Base learning. Before implementation, students are first given an initial test to see the extent of students' abilities in acid-base material. Learning in the experimental class uses developed learning media, while in the control class it is taught using existing chemistry books where the allocation of learning time is the same (Purba et al., 2019). The data that will be obtained to calculate the increase in student learning outcomes in the experimental class and control class are the results of the pretest and posttest scores. The pretest and posttest results will be processed to see the effectiveness of the implementation of learning media with several statistical tests, namely normality test, homogeneity test, hypothesis test and N-Gain test using IBM SPSS 25. The main purpose of the N-gain test in the two-group test is to assess the effectiveness of certain treatments by observing changes from the initial understanding test (Pre-Test) to the final understanding test after the treatment is applied (Post-test) in both treatment groups.

## RESULT AND DISCUSSION

### Description of PhET Virtual laboratory-Based Learning Media

Learning media analysis shows that the use of learning media is necessary to support teaching and learning activities. Virtual laboratory-based learning media was developed for the topic of acids and bases. This learning media contains discussion of material, virtual simulations linked to PhET virtual laboratory simulations, as well as practice questions. The PhET virtual laboratory is a very appropriate choice for Acid-Base material in learning for various reasons. First, the interactivity and visualization offered by the PhET Lab helps students better understand abstract concepts such as pH, titration, and acid-base reactions through dynamic simulations. In addition, its online accessibility allows students to access it from anywhere and at any time without having to be in a physical laboratory, supporting distance learning and minimizing the risk of accidents. Furthermore, PhET Lab also provides in-depth explanations and realistic simulations, allowing students to explore complex concepts better than static material. Finally, the ability to conduct repeated experiments in the PhET Lab strengthens students' understanding of the impact of parameter changes on acid-base reactions, making learning more engaging, safe, and effective.

### Validation and Standardization of Learning Media

The learning media that has been developed is validated by media and materials expert lecturers, showing that the PhET laboratory-based learning media that has been developed meets the eligibility requirements as learning media for class XI students in accordance with BSNP criteria. The validation results are shown in table 2. Learning media is assessed based on an assessment that determines the quality of the teaching materials such as appropriateness of the material, appropriateness of the language, appropriateness of the presentation and

appropriateness of the graphics. The validation results of the PhET virtual laboratory-based learning media which were validated by three validator lecturers overall obtained an average score of 87.06% which is in the "very good" feasibility category so that the learning media developed is suitable for use and implementation.

**Table 2.** Results of validator opinions regarding PhET-based learning media

| Aspect | Validator (%) | | | Ave-rage (%) | Cate gory |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | | |
| Material Eligibility | 86.12 | 94.44 | 80.56 | 87.03 | Very Good |
| Language Eligibility | 80.77 | 100 | 61.54 | 80.77 | Good |
| Presentation Eligibility | 90.63 | 96.88 | 81.25 | 89.59 | Very Good |
| Graphic Eligibility | 87.5 | 100 | 85 | 90.84 | Very Good |
| Average | | | | 87.06 | Very Good |

## Implementation of Learning Media

PhET laboratory-based learning media is used to help students learn acids and bases. The learning media developed has been implemented as learning media in the experimental class, while in the control class the textbooks provided by the school are used. At the initial stage of learning, a pretest was carried out in the experimental class and control class, then the learning process was carried out and practical activities were carried out. In the experimental class, practical activities are carried out by accessing the PhET virtual laboratory website which has been linked to the acid-based learning media. Student learning activities in the experimental class can be seen in table 3.

**Table 3.** Student activities in implementing PhET virtual laboratory based learning media for acid-base learning

| No | Students activities | Description of teaching and learning activities |
|---|---|---|
| 1 | Preparation and initial ability | In this activity students will work on 20 questions. This activity aims to determine the initial ability of students. |
| 2 | Readiness to understand the material | Students learn the material with the help of learning media. Students can access the application by downloading through the link provided. At this stage students already know what is needed in conducting experiments. |
| 3 | Virtual practicum with PhET | Students can run practicum using PhET simulation in groups. Students can run interactive PhET simulations related to acid-base concepts, namely on acid-base solutions and the pH scale. |
| 4 | Data analysis and interpretation | Students analyze data generated from simulations, such as graphs of changes in pH over time or substance concentration and understand the meaning and relationship of the data to the concept of acid-base. |
| 5 | Evaluation and reflection | Students discuss the results of data analysis in groups and formulate conclusions from the virtual practicum conducted. The results of data analysis and conclusions are included in the practicum report. |

After all learning activities have taken place in both the experimental and control classes, a posttest is carried out to measure students' understanding of the acid-base material. Student learning outcomes through pretest and posttest are shown in the table 4.

**Table 4.** Data on student learning outcomes

| | Learning outcomes | | | | | |
|---|---|---|---|---|---|---|
| | Experimental class | | | Control classs | | |
| | A | B | C | A | B | C |
| Pre test | 41.8 | 22.6 | 23.9 | 37.5 | 26.3 | 27.5 |
| Post test | 75.9 | 76.39 | 55.97 | 62.08 | 45.56 | 41.11 |

Note:
A = SMA Negeri 5 Medan
B = SMA Negeri 1 Habinsaran
C = SMA Negeri 1 Borbor

The research results show that the average pretest scores in the experimental class and control class in each school are not too different, which shows that both the experimental class and the control class have a similar understanding of the acid-base topic with an average of 29.90. However, after the learning activities took place there was an increase in learning outcomes as shown in the posttest scores. The experimental class achieved an average of 69.45 in the posttest,

higher than the control class with a posttest average of 49.58. This can be seen from the level of student participation in learning activities, where students in the experimental class show high enthusiasm in working on projects, are active in group discussions, and tend to use new learning material as the main source for solving problems in the subjects they study.

Learning outcome data in the form of pretest and posttest are then used to see the effectiveness of using learning media on learning outcomes through the N-gain test. The N-Gain test in these two groups is used to compare the increase in learning understanding between two groups with different treatments or interventions. The N-gain test results are shown in table 5.

**Table 5.** Data from the N-gain test on learning outcomes

| Class | | N-gain Score | % N-gain | Criteria |
|---|---|---|---|---|
| Experimental | A | 0.609 | 60.90% | Effective |
| | B | 0.68 | 68.69% | Effective |
| | C | 0.67 | 67.03% | Effective |
| Control | A | 0.336 | 33.60% | Ineffective |
| | B | 0.28 | 28.75% | Ineffective |
| | C | 0.22 | 22.16% | Ineffective |

Based on the results of the N-gain test in the experimental group and control group in the three implementation schools, it can be seen that there is an increase in student learning outcomes, namely at SMA Negeri 5 Medan with an N-gain percentage of 60.9%, SMA Negeri 1 Habinsaran with an N-gain of 68.69%, and SMA Negeri 1 Borbor 67.03% with each in the effective category so that it can be concluded that the implementation of PhET laboratory-based learning media is effective in improving learning outcomes.

The implementation of this learning media supports student activities in learning and also practicum activities using the PhET (Physics Education Technology) website. Before starting the practicum, students are given the opportunity to learn and understand about the project that will be carried out by searching for available literature and in experimental classes supported by learning media. The initial abilities that have been learned can help carry out the practicum smoothly, the students' ability to carry out this practicum will support students' knowledge in cognitive areas and also skills. The practicum results that have been obtained will then be displayed in a report, this can support students in presenting the results of the thoughts they have learned. Through learning and practicum activities, students can train in gaining knowledge and also train students to be responsible both in carrying out learning, practicums and in completing the homework that has been given. However, there are also some students who are still behind in understanding the material and following the learning. So, to overcome this, in carrying out learning activities, especially in practicum, students are combined into groups so that they can help each other and share knowledge together. Through this grouping, it can improve students' affective.

## CONCLUSION

The conclusions obtained from the results of the study are that there is an increase in student learning outcomes with the implementation of PhET virtual laboratory-based learning media where the learning outcomes in classes that use learning media are higher than the learning outcomes of classes that do not use learning media.

Based on hypothesis testing with the independent sample t-test on "Equal variances assumed" the Sig (2-tailed) value was obtained, namely 0.00 < 0.005, so that H0 was rejected and H1 was accepted so it can be concluded that there is a significant difference in learning outcomes in the experimental class and the control. The level of effectiveness of media implementation was obtained from the N-gain test with a percent score at SMA Negeri 5 Medan 60.9%, SMA Negeri 1 Habinsaran 68.9%, and SMA Negeri 1 Borbor 67.03% with each in the effective category. Based on the results of this study, it can be seen that the use of PhET virtual laboratory-based learning media is effective in improving student learning outcomes in acid-base topics. It also encourages the development of learning media that are more adaptive and

responsive to the individual needs of students, which in turn can improve future scientific and technological achievements.

## ACKNOWLEDGEMENT

The author would like to thank SMAN 5 Medan, SMAN 1 Habinsaran, and SMAN 1 Borbor for providing the opportunity to conduct research.

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