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Development of Acid-Base Multimedia (ABM) in Chemistry Learning to Empower Students' Scientific Literacy

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Abstract: This research is motivated by the importance of the process of empowering scientific literacy in constructing students' understanding of learning chemistry. This study aimed to determine the effectiveness of developing Acid Base Multimedia (ABM) in chemistry learning to empower students' scientific literacy. This research uses research and development methods. It is used 4D models, with definition, design, develop, and deploy stages. The study involved participants consisting of teachers and students in class XI MIPA at SMA Santo Paulus Pontianak. Development of Acid-Base Multimedia design through expert appraisal from media, design, and material experts obtained a score of 4.86; 4.72; 4.51; with a very valid category. The stages of development testing, obtained an average response rate of 4.71, 4.54, and 4.24, respectively, with a very good category. The N-gain score is 0.6028, which means that the interpretation of the level of influence of increasing test results from learning to use Acid Base Multimedia is moderate. Testing the effectiveness of Acid-Base Multimedia with effect size obtained a value of 2.2 in the strong effect category. Based on the results of the study, it can be concluded that Acid Base Multimedia can empower scientific literacy effectively in constructing students' understanding of acid-base material.

Keywords: Acid-base multimedia; Chemistry learning; Science literacy; 4D model

Introduction

Chemistry has the characteristic of simplifying abstract materials through theory, concepts, procedures, and rules (Nazalin et al., 2016). Chemical materials are often microscopic and vary between things, that are, abstract and concrete (Puji et al., 2014). In addition, according to Jhonston in Iswara (2020), there are three representative levels of chemical concepts, macroscopic, submicroscopic, and symbolic. Those often cause students to experience difficulties with learning chemistry.

According to Permendikbud No. 37 of 2018, chemistry education aims to develop students' cognitive competencies in analyzing factual, conceptual, and procedural knowledge. To fulfill this requirement, students need to receive suitable instructional approaches that effectively convey the study material. One approach involves utilizing appropriate models, methods, and learning media to enhance the learning experience.

During the 2 years of distance learning amidst the pandemic at SMA Santo Paulus Pontianak, the acid-base material presented a considerable level of incompleteness. Specifically, 28.3% (30 out of 106 students in XI MIPA for 2019-2020) and 24.7% (25 out of 101 students in XI MIPA for 2020-2021) struggled with understanding acid-base material. It is important to note that acid-base material is a fundamental component of basic competencies in the second semester of class XI MIPA and serves as a prerequisite for the subsequent three competencies. Insufficient comprehension of acid-base material can lead to difficulties for students when learning topics such as buffer solutions, salt hydrolysis, and neutralization titrations. This aligns with the findings of Nazalin's research (2016), which emphasized the presence of prerequisite competencies in various chemistry topics that greatly influence and determine the success of subsequent learning. It is crucial to

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address the incomplete understanding of acid-base material among students, as it directly impacts their ability to grasp subsequent concepts and successfully navigate the curriculum.

Contextual-based learning and involving students in maximizing their knowledge in solving daily problems can help educators improve students' scientific literacy and provide more meaningful learning (Hatimah et al., 2021). According to Harliana et al. (2019), a learning model that is suitable for learning chemistry is an inquiry model that emphasizes providing direct learning experiences, empowering science process skills, and habituating scientific attitudes. With these models and methods, students are expected to be able to build their understanding. In addition, variations in the using media according to technological developments are expected to be able to visualize abstract concepts so that they can be understood better.

According to Padmanaba et al. (2018), learning media based on information and communication technology is very good for developing chemistry learning because it can package video, sound, text, graphics, and others into one. Learning to use information, communication, and technology (ICT) based media can train the ability to find and select information, think critically and evaluate, collaborate, communicate, and be creative (Indahsari et al., 2023). It can make chemical materials at the macroscopic, microscopic, and symbolic levels better. This opinion is in line with Iswara (2020) that using technology such as computers can integrate chemical concepts at these three representative levels. Media like this are also known as multimedia because there are several media combined into one (Ibrahim et al., 2020).

To present fun learning, learning multimedia must be interactive (Kharolinasari et al., 2020). With interactive multimedia, users can control and choose the desired process to provide opportunities to develop user creativity in learning (Istiqomah et al., 2022). The development of multimedia is also based on preliminary research related to general scientific knowledge and attitudes toward science, which can be used as a reference for the initial scientific literacy skills of SMA Santo Paulus Pontianak students. The findings reveal the fact that in learning science, St. Paulus High School students like challenges, and have a real desire to learn science through practicum and other scientific processes (Suliono et al., 2022).

Method

This research uses the research and development (RnD) method. In this study, the development model used is the 4D model. Reigeluth et al. (2021) briefly explain the stages in the 4D model, namely define, design, develop, and deploy. In this study, the define stage consists of needs analysis steps. The needs analysis will then obtain instructional needs according to the characteristics of students and the need for learning. After obtaining the instructional needs, the research will enter the design stage. At the design stage, all instructional needs will be taken into consideration to be compiled and developed to produce an initial product design contained in the storyboard. The resulting storyboard will be a reference for the multimedia development process in the develop stage. At the develop stage, the initial product developed based on the storyboard will be validated by experts regarding the feasibility of multimedia in design, media, and material aspects. Furthermore, the developed multimedia will go through development trials to get the initial user response. The result is referred to as the final development product. This final product will go through the next stage, namely deploy in the form of implementing the use of multimedia in learning and its dissemination. The study involved participants consisting of one teacher and 102 students in class XI MIPA at SMA Santo Paulus Pontianak.

Data analysis techniques in this study are qualitative data analysis and quantitative analysis. At the qualitative data analysis stage, descriptive analysis was used to explain the results of expert validation and student responses to the development of Acid-Base Multimedia. The scores obtained from each aspect of the assessment are averaged and interpreted with the validity criteria as shown in the following validity criteria table.

Table 1. Validity Criteria

Validity Criteria	Score Range
Very Valid	4.1 – 5.0
Valid	3.1 – 4.0
Less Valid	2.1 – 3.0
Invalid	1.0 – 2.0

Student responses to the use of Acid-Base Multimedia are interpreted following the response criteria table as follows.

Table 2. Classification of Student Responses

The questionnaire's average score	Response classification
4.1 – 5.0	Very Good
3.1 – 4.0	Good
2.1 – 3.0	Good Enough
1.0 – 2.0	Not Good

Quantitative analysis techniques were carried out to assess the effectiveness of Acid-Base Multimedia as the final product used in chemistry class XI MIPA on acid-base materials. Researchers utilized a quasi-experimental non-equivalent control group design to determine the effectiveness of multimedia. This was achieved by administering the treatment to the experimental group while providing a control group for comparison (Sugiyono, 2019). The quantitative analysis technique used was for pretest and posttest data analysis in the control and experimental classes. The quantitative data analysis techniques used in this study involved prerequisite tests and statistical tests with the help of SPSS 25, namely The Shapiro-Wilk normality test, Levene homogeneity test, and T-test. The effectiveness was evaluated through the N-gain test and the effect size test. The interpretation of the effectiveness was based on the N-gain score calculation results, which were evaluated according to the criteria table for N-gain.

Table 3. N-gain Score Criteria (Hake, 1999)

Criteria	Score Range
Failed	≤ 0.00
Low	0.00 < N-gain < 0.30
Moderate	0.30 < N-gain ≤ 0.70
High	N-gain > 0.70

The Effect Size test results are interpreted with the following classification table:

Table 4. Classification of Effect Size (Cohen et al., 2018)

Effect Size	Interpretation
0 – 0.20	Weak effect
0.21 – 0.50	Modest effect
0.51 – 1.00	Moderate effect
>1.00	Strong effect

Result and Discussion

Acid-Base Multimedia Design

The design of Acid-Base Multimedia is obtained in the define and design stages. The define stage is the step of determining what instructions are needed and how to plan an instructional design project. Therefore, this stage includes analysis processes in the form of front analysis, learner analysis, task analysis, concept analysis, and specifying instructional objectives.

The results of front analysis and learner analysis indicate that chemistry education in class XI MIPA at SMA Santo Paulus Pontianak still refers to the 2013 curriculum. The majority of students at SMA Santo Paulus use Android smartphones. It is worth noting that the students at SMA Santo Paulus Pontianak exhibit a strong inclination towards challenges and a genuine enthusiasm for learning science through practical experimentation and other scientific methods. If effectively harnessed, this aspect has the potential to enhance their self-reliance in learning and foster their scientific literacy skills.

The outcomes of the task analysis, concept analysis, and specification of instructional objectives serve as the foundation for formulating tasks, materials, and learning objectives that align with the nature of chemistry education. The assignments, materials, and learning objectives are arranged more flexibly according to the results of the previous analysis. This approach is implemented to maximize students' competence development. This approach is consistent with Yunus' perspective (2016) that educators should exhibit flexibility and attentiveness in designing learning components that cater to the student's needs, thereby facilitating their growth. Furthermore, the assignments, materials, and learning objectives are devised while considering the cognitive load that students experience. This approach aligns with the viewpoint of Turan et al. (2016).

The findings and outcomes of the analysis conducted during the define stage have led to the development of an Acid-Base Multimedia design, serving as an innovative learning tool. The purpose of this innovation is to enhance students' scientific literacy while studying acid-base chemistry. This approach aligns with the viewpoint of Maharani et al. (2022), who argue that fostering thinking skills and problem-solving abilities necessitates the implementation of innovative learning strategies.

The application also provides students worksheets to control learning activities for skill aspects directly during learning. This approach ensures continuous feedback from educators to students, aligning with the perspective of Amsari (2018). Their viewpoint highlights the positive impact of direct reinforcement through praise, warm treatment, and additional points on learning responses. Moreover, manually crafted students' worksheets are employed to facilitate group work activities, fostering elaborate knowledge construction. This practice draws inspiration from the research conducted by Winatha et al. (2020), emphasizing that collaborative learning activities cultivate a cooperative mindset among students, encouraging them to embrace group opinions and collaboratively tackle learning challenges.

Development of Acid-Base Multimedia

The Acid-Base Multimedia design is currently in the development stage, which involves expert appraisal and development testing. This stage aims to create a validated final product through input from both experts and users. The expert appraisal process involves a total of six experts, with four experts specializing in each category: media, design, and materials. The outcomes of the validation conducted by the media, design, and materials experts are currently being compiled in the expert validation data recapitulation chart, as outlined below:

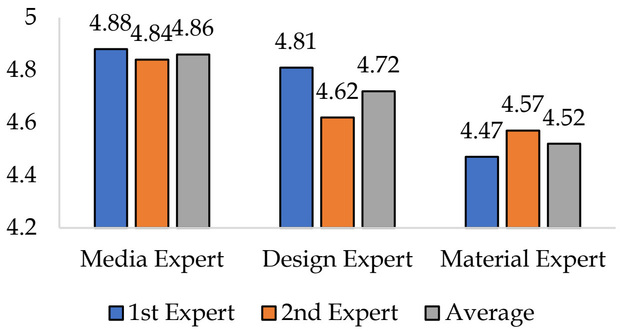

Figure 1. Expert's validation chart

The results of expert validation in the expert appraisal stage indicate that the average quantitative validation scores for media, design, and material experts are 4.86, 4.72, and 4.52, respectively. These scores fall within the "very valid" category. The quantitative assessment findings were further supported by all six experts, who justified that the product is "fit for testing."

Recapitulation of response questionnaire results in stages of development testing can be presented on the graph as follows:

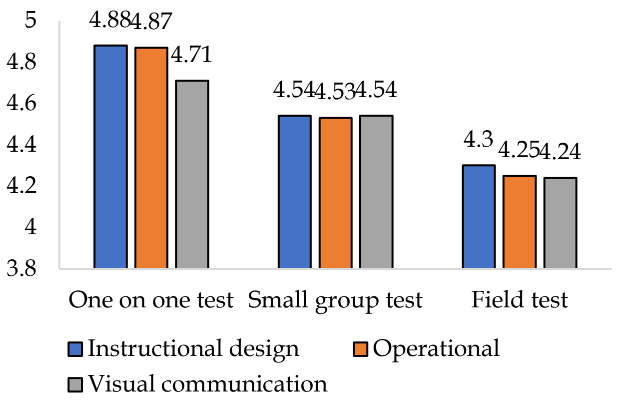

Figure 2. Response result chart

The average scores obtained from the questionnaires for individual trials, small groups, and field trials were 4.71, 4.54, and 4.24, respectively. These results fall within the "very good" category, indicating that the learning design and operational and visual communication of Acid-Base Multimedia are highly rated. However, from the quantitative data obtained, it can be seen that there was a decrease in the average value of the response questionnaire results as the number of trial participants increased. This can be attributed to individual preferences, as a larger number of participants leads to greater diversity in assessing Acid-Base Multimedia.

The visual representation of Acid-Base Multimedia, following its progression through the development stages, can be depicted in the figure below:

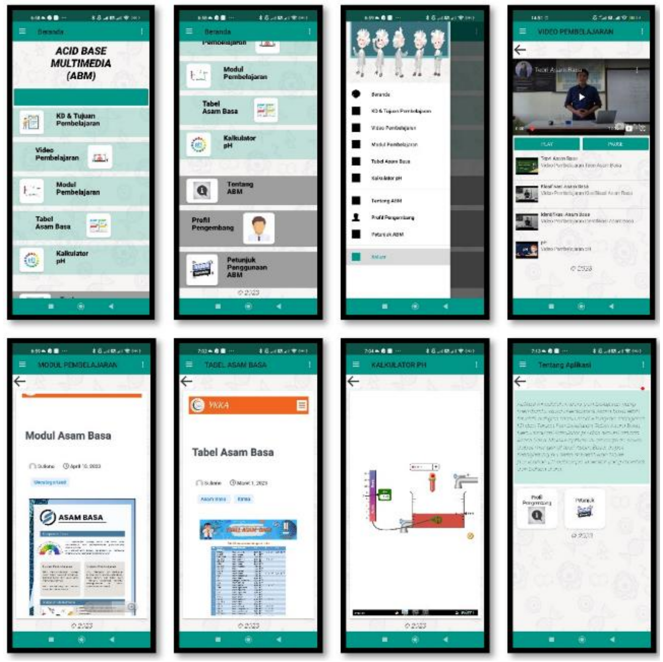

Figure 3. Visual representation of acid-base multimedia

The Acid-Base Multimedia menu comprises Basic Competencies and Learning Objectives, Learning Videos, Learning Modules, Acid-Base Tables, pH Calculator, About ABM, Developer Profile, and ABM Instructions. The first five menus are dedicated to acid-base chemistry learning content, while the last three menus offer general application information. Overall, the Acid-Base Multimedia menu aligns with multimedia components according to Munir (2020), incorporating text, images, audio, video, and simulations of learning materials.

Learning content is available in both the video menu and learning modules. The content is meticulously curated, considering the five referenced scientific literacy indicators. Additionally, the arrangement of the content is purposeful, aligning with specific learning objectives. This ensures a focused rather than a broad scope, facilitating the attainment of expected competencies more effectively. This approach resonates with the perspective of Lutfi et al. (2021), indicating that mobile learning, structured with a clear learning goal orientation, outperforms other forms of assignments in accomplishing learning objectives.

The pH calculator menu transforms into a simulator, empowering students to independently enhance their scientific literacy skills and deepen their comprehension of acid-base materials. This approach aligns with Istiqlal (2017) perspective, emphasizing that multimedia interactivity enhances students' engagement with the learning material. To effectively utilize this menu, students are encouraged to actively explore various simulations, enabling the construction of a more comprehensive understanding of both knowledge and skills. Enhanced competency in science learning is achievable when the educational approach emphasizes meaningful learning through a series of inquiry processes, facilitating students in acquiring a deeper understanding (Listiani, 2016; Sugrah, 2020).

Effectiveness of Acid-Base Multimedia

The effectiveness of Acid-Base Multimedia is obtained by looking at the influence that multimedia has on empowering students' scientific literacy. This effect can be measured from the results of the pretest and posttest of students on the Test of Scientific Literacy Skills (TOSLS) adaptation test instrument with acid-base material. Testing the effectiveness of Acid-Base Multimedia in this study was carried out using a quasi-experimental non-equivalent control group design. Before testing the effectiveness, prerequisite tests and different tests were carried out on the pretest and posttest data of the control class and the experimental class which are presented as follows.

Table 5. Prerequisite Test and Statistical Tests Results

Data Type	Significance
Control Class Pretest Normality	0.054
Control Class Posttest Normality	0.282
Experimental Pretest Normality	0.283
Experimental Posttest Normality	0.054
Homogeneity of Control-Experiment Data	0.219
Control Class T-test	0.000
Experimental Class T-test	0.000

The test results indicate that all data follow a normal distribution, and the control class and experimental class data exhibit homogeneous variance. The T-test results reveal significant differences between the pretest and post-test data for both the control class and the experimental class. Moreover, the effectiveness testing was conducted using the N-gain test and the Effect Size Test, the findings of which are presented below.

Table 6. N-gain Test and Effect Size Test Results

Data Type	Score
N-gain Pre - Post Control Class	0.4355
N-gain Pre - Post Experimental Class	0.6028
Effect Size	2.20

The N-gain score for the control class is 0.4355, falling within the medium category, while the experimental class achieves an N-gain score of 0.6028, also classified as medium. However, the experimental class has a higher N-gain value compared to the control class. These findings suggest that the use of Acid-Base Multimedia in learning is more effective than traditional classroom methods. This outcome is further supported by the effect size test result of 2.2, which indicates a strong effect size for the effectiveness of Acid-Base Multimedia.

Overall, the strong effect category in which Acid-Base Multimedia falls implies that it significantly enhances scientific literacy and aids in developing students' comprehension of acid-base concepts. Acid-Base Multimedia provides a platform for independent learning and encourages exploration based on students' curiosity and inquiry needs. This aligns with Caesariani's research (2018), which demonstrates that interactive multimedia-based learning improves student outcomes by fostering an independent and enjoyable learning process. Similarly, Ardiansyah et al. (2020) shows that Android-based multimedia effectively increases student motivation and learning outcomes.

Furthermore, the increase in the achievement of each indicator of scientific literacy is tested using the N-gain method. The table below presents a summary of students' pretest-posttest results for each scientific literacy indicator.

Table 7. Recapitulation of Pretest-Posttest Results for Each Scientific Literacy Indicator

Indicator	% correct answer		N-gain score
	Pretest	Posttest	
indicator 1	28.3	83.3	0.767
indicator 2	31.6	71.6	0.584
indicator 3	50	80	0.6
indicator 4	40	70	0.5
indicator 5	51.6	70	0.38

Information: Indicator 1= Identify a valid scientific argument; Indicator 2= Evaluate the use and misuse of scientific information; Indicator 3= Understand elements of research design and how they impact scientific findings/conclusions; Indicator 4= Read and interpret representations of data; Indicator 5= Solve problems using quantitative skills.

Based on the test results, it is evident that all indicators of scientific literacy investigated in the research have shown improvement. The indicator that exhibited the highest increase was the ability to identify a valid scientific argument, scoring 0.767 and falling within the high category. Student interviews revealed that before using Acid Base Multimedia, they faced challenges in identifying valid scientific arguments, particularly when analyzing arguments involving concepts and their contextual application. This difficulty arose from limited exposure to questions framed in the context of scientific investigation, as most questions encountered were focused on content-specific learning.

The significant improvement in this indicator was attributed to the emphasis placed on factual, conceptual, procedural, and metacognitive knowledge of acid-base material in the learning videos available through Acid-Base Multimedia. This emphasis enabled students to better understand scientific premises within different conceptual and contextual frameworks. Consequently, this factor contributed to the overall increase in scientific literacy indicators. This finding aligns with the research conducted by Ihsan et al. (2021), which demonstrated that improved scientific literacy resulted from facilitating students' comprehension of chemical material across competency, attitude, knowledge, and contextual aspects, particularly in procedural and metacognitive aspects related to acid-base material.

Conversely, the indicator with the lowest increase was problem-solving using quantitative skills. This is likely because quantitative skills are closely linked to an individual's mathematical abilities, which do not typically undergo rapid or substantial changes within a short timeframe. Hence, the increase in this indicator was modest, measuring 0.38 and falling within the low category. This finding aligns with the research conducted by Hafriani (2021), which indicated that fundamental mathematical abilities do not significantly improve under time constraints or without exposure to non-routine problem-solving exercises. Nonetheless, when considering the overall results of the pretest and posttest scores, it is evident that all indicators of scientific literacy in this study experienced improvement. Therefore, it can be concluded that Acid Base Multimedia has proven to be effective in enhancing students' scientific literacy in the context of learning acid-base chemistry.

Conclusion

Acid-Base Multimedia was developed with a 4D model (define, design, develop, deploy) which was validated in a very good category through an assessment process at the expert appraisal stage by media, design, and material experts. The product obtained an average response from students in the very good category at the development testing stage, which included individual trials, small group trials, and field tests. The effect of Acid-Base Multimedia on increasing learning outcomes based on the N-gain score of the experimental class is 0.6028, which is included in the moderate category. Testing the effectiveness of Acid-Base Multimedia with effect size obtained a value of 2.2 in the strong effect category.

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Author Contributions

The first author, Suliono, contributed to the entire research from planning, implementation, article writing, and dissemination. The second author, Eny Enawaty, contributed as the first supervisor in research and article writing. The third author Indri Astuti contributed as the second supervisor in research and article writing. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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