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EFFECTIVENESS OF THE pH MASTER APPLICATION ON ACID-BASE CONCEPTS AS A DIGITAL ALTERNATIVE TO CONVENTIONAL LABORATORY PRACTICES FOR ENHANCING STUDENT LEARNING OUTCOMES

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ABSTRACT

Traditional Chemistry Laboratories, such as acid-base reactions, are hard to demonstrate for present-day students in their lab classes when they need to have the knowledge exchange we had, graduating (and teaching) with mortar boards lined up and ready for weddings. The Evaluation Of The Digital Platform "pH Master" For Enhancing Chemistry Student Performance Through A Virtual Imitation of Traditional Lab Practices The study used Akker's research and development model, including initial studies, product design, testing products, and trials. Validation was done using the Aiken formula by two expert validators and three practitioners for all items with a V value greater than 0.87. Surveys for needs analysis involved 45 students, and the learning effects were assessed with 90 students across three schools. Results Students responded favourably to the pH Master app and perceived ineffable pedagogical value. Most students agreed on the necessity of doing practical activities about what was being learned, and almost all also had trouble understanding study materials specifically related to acids and bases. The results showed a statistically higher mean n-gain value in the experimental group than in control one (0.6622 versus 0.5691) by independent t-test across three schools at $p < 0,001$ significance level between the two groups. This then confirms that the media created did support student learning. This study highlights the potential of the pH Master app to enhance student learning experience and active involvement in chemical education, which suggests a promising approach towards digitalising conventional practical work.

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INTRODUCTION

Chemistry is a field of science that serves as the core of science and, hence, is fundamental in studies like distinctive branches in science, technology, industry, etc [1]. Chemistry describes the composition, structure, properties and change of matter (as well as those of an atom). Chemistry is a two-fold subject: it exists in opposite terms if we see according to supplies of chemical accumulations consisting information Facts, Concepts, Principles Laws and Theories which are coming from on has been moved chemistry a long extent way possible by its application containing illustration orally both exemplarily or pictorial demonstrative lessons and symbolically.

Digital chemistry labs refer to applying digital technology in standard chemical practice and executing experimentation through traditional approaches. One example of this digitisation is the virtual laboratory, where computer simulations replace or complement physical lab work [2]. Within this context, chemistry learning in the 21st century has been more concerned with renewable technology as one of these breakthroughs at a time when concepts are increasingly being digitised rather than carried out through traditional learning activities. There are many ways to use smartphones as a learning medium [3]. Smartphones are especially suitable as experimental tools for increasing student performance due to their mounting sensors [4]. It can also make your chemistry lesson more fun and inspiring if you use smartphones to learn. Both of these target areas are enabled by mobile device-based learning, which makes personalised and student-specific experiences easy to deliver [5].

Educational media are described by [6] as all means and devices that help transmit the learning messages or information from a teacher to students to achieve pre-established goals. As facilitators, teachers have had to provide a friendly learning atmosphere so that students can gain maximum benefit in each lesson [7] other than educational media. In other words, if educational media manages to present material properly, the learning process can also occur well, and later, it will improve student achievement [8]. Dale's Cone of Experience is also applied in Educational media [9]. Figure 1 Edgar Dale Cone of Experience

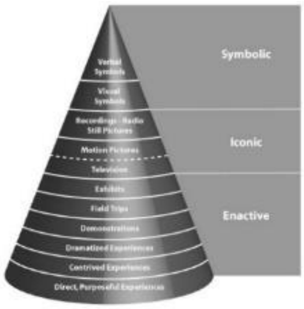

Figure 1. Edgar Dale's Cone of Experience

Chemistry is an abstract concept, to begin with, and understanding the basic concepts in Chemistry may prove necessary because any misunderstanding of these elementary principles will eventually lead to difficulty in comprehension regarding other more advanced theories, which could cause disadvantages in the learning process [10]. These abstract concepts must be made more concrete to tackle this challenge, thus aiding students to recall better and increase their overall learning outcomes.

Add this to a virtual laboratory that simulates the same environment as an authentic lab (using artificial objects representing real-world items and manipulated for creating realistic experimental scenarios [11]). An indirect comparison of virtual laboratories indicates a positive impact on practical performance [12] and may assist in dealing with difficulties in traditional experiments. Virtual labs have advantages such as cost savings (there is no need for expensive equipment and materials), ease of replicating experimental setups to suit specific needs, more students can access the same virtual apparatus & material simultaneously, and greater durability to lab appliances [13]. Virtual laboratories, in addition to saving time and energy on demand for infinite resources that are too dirty or impossible savings [1]. Some other existing systematic reviews have studied the use of technology and VR arrangement in virtual laboratories across specific domains like biological or chemical sciences; others observed multiple disciplines but within a single technological solution—virtual reality; yet some provided general insights on theoretical aspects concerning practical application for an array of subjects where VL has been described as necessary [5][11][12].

METHODS

1. Type of Research

The answer to this question was found through four steps in the Akker research and development model: preliminary studies up faze, product development-test phase, validation test phase-finally pilot finalisation. This paper adheres to the guidelines of distinctly separate themes for this analysis, signalling an early stage, predominantly qualitative descriptive. The research subjects are thoroughly investigated using quality, in-depth analysis. Intended as a comprehensive description of sectors for which little information is normally available, often restricted to only one individual or handful of groups—or incident. This approach is especially valuable for bringing unique perspectives to insufficiently studied issues [14].

2. Research Subjects

The research subjects were three chemistry teachers chosen from all grade eleven students in each of the High State Schools, as many as 3 schools in Sragen. There is a total of 45 students in each participating class. These students were self-selected through a questionnaire to measure self-regulated learning readiness. Given the vast heterogeneity of nontraditional students, it was important for this examination to pinpoint particular groups and provide valuable insight on how research could be modified/adapted depending on what group (or sub-group) a specific study may involve.

3. Location of Research

The research was conducted in Sragen Regency, Central Java Province, with data collection at three state senior high schools. The centre is in this location to access students from different schools that may come from the region and thus understand some of their local educational experiences.

4. Books on Data Collection Methods

Materials and Methods: Data Collection Various tools and methods were used in data collection for this paper. This met different forms like interviews, questionnaires and cognitive tests. The chemistry teachers were asked in interviews to determine their requirements and desires for teaching with virtual laboratory tools. Students also completed a survey regarding tools used in their courses and readiness for self-directed learning. Cognitive assessments were employed to assess the association of a new product with student learning outcomes. Overall, this strategy was rigorous in terms of data collection and provided a detailed account based on the perceptions of both teachers and students.

5. Data Analysis Techniques

Statistical analysis of data in this study was performed through different phases. Aiken's formula, a statistical method to measure the validity of an item, was initially applied to validate a developed product. An N-Gain formula was used to measure the effect of virtual laboratory (mainly pH Master) on student learning outcomes. This formula calculates the difference in learning outcomes from two test essays before and after. A two-tailed t-test (independent samples) was further employed to investigate the effect of using a virtual laboratory on student learning outcomes. Its rigorous data analysis helped us ensure that we had tested hypotheses well, so the findings have given good insights into whether a virtual laboratory tool such as Virtual Lab Journal can improve chemistry learning.

RESULTS AND DISCUSSION

1. Problem Analysis

This preliminary study is related to the need for Acid-Base laboratory practices in digitalising form by investigating student and teacher perceptions regarding virtual laboratory learning media. With that knowledge of the inputs as to what the students needed, they could take action on design and development. A questionnaire asked students about their willingness to participate in this study before conducting the research. After reaching an agreement, the questionnaires were distributed based on preliminary study questions related to the research. Figure 2 shows the survey results of the questionnaire distributed.

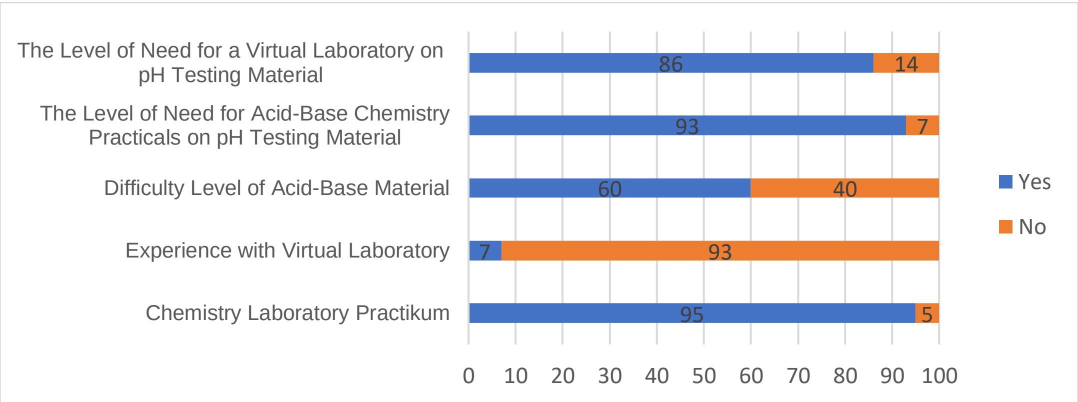

Figure 2. Diagram the percentage of the results from the perception survey and the need for practical-based learning media.

About 95% opined on implementing practical activities in chemistry learning among the 45 students [Table 4]. Student views on the learning of chemistry and practicals: Many students reported positive experiences regarding teaching chemistry, followed by oral-practical sessions, but some felt that there should be more practical sessions.

Many students also stated they had never participated in practicals, only 1–2 times/semester. This means practicals are still not well-aligned with how chemistry is learnt in schools. One student said, 'We get used to practical situations, and our understanding will increase with frequent PBL classes about laboratories; when we have better knowledge of chemistry, it is possible to apply principles in a more realistic way in everyday life'. Thus, there is a demand for an extensive use of practicals to improve understanding and functionality in chemistry teaching at the school level. Other works have been studied and researched, such as virtual laboratories as a substitute for physical ones to assist learning, which can enhance students' motivation [5][15]. Research conducted by Potkonjak on the use of virtual and remote labs in STEM education illustrates that integrated data visualisation provides a toolset for understanding both teaching complexities and the learning process within an online environment [16]

Of the 45 students, only a few (7%) had already used a virtual laboratory, and most needed to be more experienced in using such technologies (93%). The opinions about the achievement of Android-based virtual laboratories in mobile learning on various aspects like skills, interactions or automation and feedback that affects accuracy (no individual pre-test score available) raised questions towards continuing autonomy. Most students approved of this change, citing wide availability and novel concepts as important for understanding the material. Some respondents said the app could also advance digital literacy among students. However, many students disagreed, arguing that hands-on experience with traditional labs is necessary to prevent misunderstanding and misinterpretation. Other arguments stressed the necessity of precision and laboratory work for a complete knowledge of chemistry. For students, it was seen as a novel experiment. However, some preferred the conventional method with actual practice in the laboratory. However, it is important to note that technology has made practical chemistry learning better and more efficient, reflecting the need for time in this modern era. Virtual laboratories are considered ‘technological’ tools to supplement and enhance traditional practical laboratory settings; a user-friendly, cost-effective, flexible and easily accessible platform with no time constraints promoting self-directed learning can benefit from providing free spaces for practical workshops [17]. Reeves and Crippen studied how previous experience using digital learning tools affected student outcomes. They found that students with greater digital experience have outperformed others regarding technology-oriented tasks; they had grown accustomed to changes and innovation in teaching styles and installed problem-solving skills thanks to their use of digital outlets. On the other hand, students having less digital experience needed more time and directions to adapt to these new tools; they went through much technical anxiety, which would act as a barrier to their learning process [17] and required extra sessions of orientation to get used with how those tools work.

More than 60% of the students reported having problems with acid-base material, whereas some (40%) thought they could understand contextual and theoretical parts. Feedback related to the interpretative aspects of chemical concepts like pH, titration, and equilibrium demonstrated that acid–based content elaboration was a compelling enlist in scores by a majority. The understanding of abstract concepts to the identification based on the properties and strengths of acids and bases can generally be viewed as follows: These materials are hard, and last but not least, they are difficult to find. A few students said they had not covered this material sufficiently or properly understood what their teachers were explaining. Several students said they did not understand acidity, pH, or how to test for acid-base properties. Several commented that they had never been taught this material before, so their understanding of pH was limited. This is consistent with previous research on the need for supporting learning media in teaching chemistry chemicals that are not familiar [3]. Rahman et al. explored the problems students had in understanding more difficult aspects of chemistry and whether virtual labs could help with these difficulties. A virtual laboratory has been discovered to be a huge aid in learning difficult chemistry topics as it allows for much more interactive visualisation, resulting in clearer understanding among students. These virtual labs let them carry out experiments which are practically impossible to conduct in some cases or are too hazardous. On the other hand, it has also been pointed out that students with less experience in this kind of technology can find them more difficult to operate and use (e.g. watering down learning), decreasing their effectiveness [12].

Students who express disinterest or dislike for a subject, as negative views towards learning chemistry, also create barriers to understanding acid-base materials. Consequently, these answers reflect that most students consider the acid-base material the most difficult-to-understand chemical concept.

As per the outcome, 93% of students agreed with that (or somewhat) and said practical activities allow them to experiment or explore the teacher's ideas better by personalising them. Verals are one of the best ways to know what happens when a substance is acidic or basic. They are seen as being able to take ideas you have read about in theory and prove them true directly. Factual assessment and experimental work are important for table-based scientific subjects [18].

Students' views on measuring acidity/pH levels through a virtual laboratory using smartphone applications are in agreement and considered an advancement in chemistry learning technology by most. 86% of students thought this would be a very simple, efficient method for measuring pH and that it would be student-friendly.

Some students mentioned that virtual laboratories could serve as an effective alternative to being unable to test the substances during experiments or practicals for testing whether a substance is acidic in nature or basic in character. Several students think this is a huge leap ahead in learning chemistry by opening it up to allow them to learn anywhere and at any time. Moreover, virtual labs work out economically and more convenient, saving time with the environmental benefits of having no chemicals [1]. They are accessible on the internet and can be used as ice-breakers for laboratory experiments so that practical experience is had without hazards. Compared to traditional laboratories, virtual labs have advantages such as lower costs, the use of less time and are environmentally friendly since they do not require harmful chemicals [8]. Understanding acid-base concepts involves doing experiments in the lab centre, which is vital for hands-on learning. These hands-on experiences are essential for linking theoretical knowledge to practical applications where experiments can be performed, interactions observed, and changes in pH or any other chemical reactions understood [10].

Earlier studies have shown favourable responses and student involvement with VR labs (virtual labs). By providing a means for simplifying what could be viewed as highly intricate scientific practices, the motivation to learn can be improved or increased in students [21–23]. Researchers can track some types of student information by monitoring data that virtual laboratories generate. Such interaction data from students in virtual laboratories show a rise in their problem-solving abilities, critical thinking skills, laboratory process skills and knowledge acquisition [19].

2. Product Development

The design of a learning media for the pH Master is based on Virtual Laboratory using an Android application in APK format. This product's draft is built around learning signals. Developed content on Acids and Bases Text-aligned animations in the virtual laboratory [16] included as part of this media Built with Unity and Adobe Illustrator Product development design Table 1 opined in product evolution architecture

Table 1. Product Development Design

No.	Media Component	Content Description	Design Details
1.	Initial Display	Application Identity/Name	Displays the application name "pH Master" along with a laboratory icon. 
2.	Menu Page	Instructions, About the Media, and Start	Provides usage instructions for students, information about the media and its developers, and a start button.

			
3.	Classroom	Acid-Base Material and Pretest Questions	It includes content on acid-base concepts and acidity levels and a pretest button to complete the pretest before beginning the practicum. 
4.	Laboratory	Safety Information, Practicum, and Post-Test Questions	Features laboratory safety guidelines with simulations of personal protective equipment usage, a practicum button to access the practicum page, and a post-test button for completing questions after the practicum. 
5.	Practicum Page	Acid-Base Experiment	Practicum options include experiments with litmus indicators, pH meters, soap making, and using common household materials to test acids and bases. 

3. Product Validation

Table 2. Validation Results of the pH Master Media

No.	Validation	Average	Remarks
1.	Media	0.8933	Valid
2.	Content	0.9325	Valid
3.	Language	0.9047	Valid

The media was developed and then validated by six expert validators (a media expert, subject matter experts on the prevention of GBV amongst youth in India, and a language advisor) and three practitioners. Aiken's formula was used to validate the product. Aiken should be validated based on the number of validators and your criterion. Five validators in this study validated each aspect — two experts and three practitioners, using four validity criteria: 1 = Not Relevant; 2 = Less Responsible; 3 = Quite Responsible; and ≥4= Responsible according to the Aiken table is if V >0.87 (Aiken [19]). Table 2 details the validation results. This media product is suitable for use. This is indicated by scores of each aspect exceeding 0.87. Therefore, the instrument is declared suitable for trial use.

4. Implementation

The validated product was then subjected to a limited-scale trial involving six students and one teacher at each representative school used for the research. This phase aimed to test the readability aspect so the media could be effectively utilised when it moved to the next stage. Comments and suggestions from practitioners and students after the limited-scale test are presented in Table 3.

Table 3. Comments and Suggestions from Limited Scale Test Results

Participants	Comments and Suggestions
Practitioners	- The developed application is already good; next, it could be developed for other practical experiments. - The application greatly helps in learning time efficiency.
Students	- The application is attractive and easy to understand. - The application helps in learning about abstract acid-base compounds that require proof. - The application design is not boring.

After a limited-scale trial and refinement of the product, the learning application pH Master was based on virtual laboratories made by an experimental class, and the other two groups (control) conducted practical labs in vitro. The first phase comprised a cognitive test in the form of a pre-test before learning activities began, which was used to find out about the initial ability of each student. Following the delivery of the learning activities, students were asked to complete a posttest that measured progress/ improvement in outcomes from pre- to post-treatment.

5. Analysis

Pretest-posttests were employed to gather evidence of how well the media worked to achieve student learning outcomes. The students received 20 multiple-choice test items. An investigation of the effectiveness of pH Master virtual laboratory-based media on students 'understanding of teaching so that it can improve student learning outcomes.

The measure of learning outcome improvement used the N-gain formula, meaning normalised gain, which requires the data to be normally distributed and homogeneous. The research sample was tested for normality and homogeneity using SPSS Statistics 27.0 software as a prerequisite. The results of the Normality Test can be seen in Table 4.

The normality test results of the ANOVA showed a p >0.05, meaning data is normally distributed. This was followed by a homogeneity test to determine whether the variances differ significantly for data model grouping. Homogeneity test results showed the significance value (p) > 0.05, so null hypothesis Ho was acceptable, a volume of the inhomogeneous data group. Results: The prerequisite tests were met in the results of these models. After passing the pretest, data analysis was carried out using N-gain (Normalized-Gain) formula. These N-gain results can be observed from each school in Table 5.

Table 4. Results of Normality and Homogeneity Tests from Three Schools

No.	School	Test Type	Test Technique	Value of Sig.
1.	High School A	Normality (Control)	Shapiro-Wilk	0,182
		Normality (Experiment)		0,195
		Homogeneity	Levene	0,763
2.	High School B	Normality (Control)	Shapiro-Wilk	0,238
		Normality (Experiment)		0,333
		Homogeneity	Levene	0,830
3.	High School C	Normality (Control)	Shapiro-Wilk	0,205
		Normality (Experiment)		0,162
		Homogeneity	Levene	0,576

Table 5. Average N-gain Results per School

School	Class	Average N-Gain	Category
High School A	Control	0.5672	Sufficient
	Experiment	0.6915	Sufficient
High School B	Control	0.5798	Sufficient
	Experiment	0.6734	Sufficient
High School C	Control	0.5603	Sufficient
	Experiment	0.6218	Sufficient

N-Gain is an approach. To measure learning improvement after using learning media, calculate how much changed from results before and after using a media tool (pretest & posttest). The control class conducted the practicum conventionally; meanwhile, the experimental group used pH Master application instruction.

The findings revealed that the study groups tested higher performance than classes in which traditional experiments were conducted only within the classroom. These results revealed that the average N-gain score in control classes was 0.5691; in the experimental class, it was 0.6622. These results suggest that the developed media can increase student interest and understanding of what is cultivated to enhance student learning outcomes. Previous research has reported using it as a learning medium in another course. At the same time, if the virtual laboratory is well-designed, the activities will be more interesting to students [24]. Virtual labs allow students to experiment quickly and cost-effectively. Based on the results achieved in student assessments, it can be concluded that learning using pH Master through a virtual laboratory effectively improves students' learning outcomes [25].

A complete 2-tailed t-test is executed to test the alternative hypothesis, which can be followed by ANOVA involving Part 1 and also ANOVA of Groups A vs B intuitively. The independent t-test results from the three schools are shown in Table 6.

Table 6. Independent T-test Results from Three Schools

School	Test Technique	Sig. value	Class	Mean
High School A	Independent t-test 2-tailed	<0.001	Control	78.50
			Experiment	86.67
High School B	Independent t-test 2-tailed	<0.001	Control	77.00
			Experiment	82.50
High School C	Independent t-test 2-tailed	<0.001	Control	76.12
			Experiment	82.12

This is a statistic to calculate if two data sets have significant differences (for example, means of control and test groups after). This method is called T-Test. All three schools have Sig <.001. 001). Results revealed that the average student learning outcome increase is higher for experimental classes than for control. This finding is by previous research that revealed an increase in students' test scores after using virtual laboratory, proven by High Schools A & B having the highest national examination scores than any other high schools, suggesting existing potential to establish a study will document greater utility for subject mastery and analytical reasoning skills when conceptually incorporating new technology like virtual lab into e-module from PjBL based environment. The results of the present study concur with theirs; positive changes were observed in student learning outcomes because of virtual labs [14][26].

Based on the independent t-test results, the mean scores using the three schools' control classes were lower than the experimental classes. The mean scores per the independent t-test at school A were 78.50 and 86.67 for the control and experimental classes, respectively. At school B, the scores were 77 and 82.50 for the control and experimental groups, respectively. Similarly, the mean scores at school C were 76.12 and 82.12 for the control and experimental classes, respectively. From the independent t-test results on the three schools, the pH Master virtual laboratory-based media may improve student learning outcomes. Previous studies have shown that virtual laboratories could be a potential substitute for a traditional laboratory and improve students' learning outcomes. Virtual laboratories are universally acceptable as a traditional laboratory alternative in providing students with practical skills and positively affect learning. Virtual laboratory applications can help students understand more detailed concepts. For example, using the pH Master virtual laboratory media, simulations and interactive experiments have been designed, where students can observe live how the concept is put into practice. As a result, the student gets more acquainted with the learning process, increasing the efficiency of comprehending the complex courses. Stahre et al. observed a difference in the student's participation and learning outcomes in the two laboratories. According to their study, students using the virtual laboratory showed greater participation in learning and more interactive activities because of the high flexibility. Hence, there were differences in concepts, where the students using the virtual laboratory understood some areas better than their counterparts, although the practical skills used in the laboratory remained critical. Some students preferred the virtual laboratory because it was quick and easy to obtain results. Most students preferred the practical laboratory because they conducted the experiment and had the results.

This study provides practical guidance on implementing virtual laboratory learning media in teaching acid-base chemistry. A key benefit is that the pH Master smartphone & tablet APP provides a new, engaging means of interaction with complex chemistry. The design of this study demonstrated a comparison between classroom and computer interfaces, supporting the idea that digital tools can enhance student outcomes. Strengths of the study design are multiple schools, control group and statistical methods used to establish reliability. In addition, there is also a credibility factor when product assessment has been validated using Aiken's validation.

Nevertheless, there are multiple types of constraints. A further limitation is the small sample size in Phase 0 trials, which could minimise the transferability of possible results. One limitation of this study is that the duration needed to be longer to measure long-lasting retention or learning sustainability using virtual laboratory media.

CONCLUSION

Results from student questionnaires show overwhelming support for digitalising acid-base chemistry labs. Indeed, ninety-five% of college students prefer to have practicals in chemistry education. However, only 7% know virtual labs, and 60% view acid-base fabric as hard. In addition, 86% believe that pH measurement through a smartphone application as an inspection report is also the progress of learning in chemistry. Results: Compared to traditional methods, the percentage of students scoring above 90% in post-quiz was significantly higher after learning through the pH Master virtual lab, revealing an average N-Gain of Class Experimental = 0.6622 and for control class =.5691. The independent t-test results from each of the three schools show P-values < 0.001, which suggests that media allocation is efficacious in heightening student involvement and comprehension.

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