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Development of Android-Based Chemistry Virtual Laboratory Media on Acid-Base Materials for 11th Grade High School Students

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Abstract
This study aimed to develop an Android-based virtual laboratory media for chemistry, assess its validity, and determine students' responses to it. The research methodology employed was research and development (R&D) with the 4D development model (Four D Models) according to Thiagarajan, which comprises four stages: define, design, develop, and disseminate. The study was carried out until the development stage. The research instruments used included interview guides, validation sheets, and questionnaires. The media products developed were validated by material and media expert validators consisting of two chemistry lecturers and one chemistry teacher. Limited trials were conducted with a total of 32 11th grade students from Mathematics and Science (MIPA) 3 class at State Islamic Senior High School (MAN) Blitar City. Data analysis techniques involved both qualitative and quantitative methods. The results indicate that the validation scores from the material and media experts were very valid, with an average percentage score of 98% and 95%, respectively. The student's responses to the limited trials were also very good, with an average percentage score of 88%. Overall, the study demonstrated the potential of the developed Android-based virtual laboratory media for chemistry education.

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INTRODUCTION

The concept of learning chemistry is a concept that is considered abstract and contains relationships with three levels of representation, namely macroscopic, submicroscopic, and symbolic (Ainsworth, 2006). At the level of macroscopic representation, namely chemical phenomena in everyday life, so that they can be observed by the student's own experiences. The submicroscopic level of representation is the depiction (representation) of particles that are invisible to the naked eye, for example, molecules, atoms, and electrons. While the level of symbolic representation is a representation that is written or depicted in the form of symbols, for example in chemical reaction equations, formulas, and graphs. Students face difficulties in understanding chemical concepts because these concepts are abstract and cannot be observed directly. Therefore, for students to understand chemistry concepts properly, the three levels of representation must be understood in a balanced way (Zuhroti, Marfu'ah, and Ibnu, 2018). According to the results of the analysis by Omwirhiren researchers, science subjects were seen from student learning outcomes for several years, namely chemistry lessons had the lowest results compared to physics and biology lessons (Omwirhiren, 2015). Based on these problems to be able to improve students' understanding of concepts and science process skills in the learning process, one of which can be done through practicum activities.

Practicum in science learning has an important role in supporting theoretical explanations (Kurbanoglu and Akin, 2012). In general, practicum at the SMA or MA level that is often carried out is confirmative. The term regarding confirmative practicum is a practicum that is carried out directly in the laboratory in real-time guided by the teacher. In the confirmative practicum, students can directly carry out an experiment using a practicum manual or practicum module that has been prepared by the teacher (Bruck, Bretz, and Towns, 2008). Practicum in a real laboratory requires complete equipment and chemicals to support the practicum implementation. In chemistry material that requires practicum at the high school or MA level to be able to improve student understanding of concepts and science process skills, one of which is acid-base material.

Acid-base is material that discusses the notion of acid-base, acid-base properties, acid-base theory, pH, acid-base strength, indicators, and neutralization, so it is classified as material that involves many concepts (Sheppard, 2006). Acid-base material includes material that contains levels of macroscopic, sub-microscopic, and symbolic representations so this material tends to be difficult for students to understand (Ardhana, 2020). Based on the level of macroscopic representation in acid-base material, namely in the form of the concept that acids are substances that have a sour taste and bases are substances that have a bitter taste (Sachin Amreiss & Dinesh Kumar, 2019). The level of submicroscopic representation of acid-base matter is in the form of representations in the form of particles in solution that cannot be seen directly so that this level of representation can explain phenomena at the macroscopic level of representation (Muliani, Khaeruman, and Dewi, 2019). The level of symbolic representation in acid-base materials is the equation for the ionization reaction in an acid or base solution and the formula (Sheppard, 2006). In proving the concept of acid-base material, a practicum is needed (Ischak et al., 2020).

In the process of learning acid-base material which is carried out with confirmative practicum in the laboratory, in general, there are limitations, namely, the teacher still explains verbally and the practicum implementation only proves the results of the experiment in the practicum module (Rahayu et al., 2011). In addition, the confirmative practicum is less effective in helping students to understand concepts at the level of submicroscopic representation which is one of the prerequisites in chemistry lessons to understand acid-base material. According to Bradley et al., the obstacles in carrying out confirmative practicum are, among others; (1) inadequate equipment and chemicals, (2) unavailability of laboratory space, (3) no laboratory personnel, (4) experiments that are considered dangerous, (6) require a long time, (7) students who tend to be active can carry out practicum well, while students who tend to be passive cannot carry out practicum properly (Sutrisno, 2011). Therefore, to overcome the obstacles in carrying out practicum in real laboratories, an alternative solution is needed, namely by using appropriate learning media.

Learning media is a tool used in the learning process to convey complex material into simpler material. Learning media aims to convey what cannot be conveyed by the teacher orally, even with the media it can change abstract material (such as chemical material which contains levels of macroscopic, submicroscopic, and symbolic representations) to become more concrete so that it is easily understood by students (Syaiful Bahri, 2010). The rapid development of technology, information, and communication has had a significant impact on all aspects, one of which is the aspect of education. In the field of education, technology, information, and communication have had an impact on the creation of several new media innovations designed to support learning activities. One of the new media innovations is the virtual laboratory.

A virtual laboratory is a practical simulation media designed to virtually illustrate chemical reactions using a computer, laptop, or Android operating it (Lutfi, 2017). The benefits of using virtual laboratory media in the learning process are more efficient and effective both in terms of time, exploring an experiment, increasing conceptual understanding, science process skills, and student learning outcomes. However, this virtual laboratory cannot be used as a substitute for practicum in a real laboratory. According to researcher Asyhar, the use of virtual laboratory media is practical, efficient, and overcomes misconceptions (Asyhar, 2011). Meanwhile, according to researchers Tatli and Ayas, the effectiveness of using a virtual laboratory is almost the same as the effectiveness of a real laboratory (Tatli & Ayas, 2013). From this description, it can be concluded that the role of virtual laboratories is not to replace real laboratories, but rather as learning media that can support practicum activities in real laboratories and become an alternative means of predicting the unavailability of equipment and chemicals in real laboratories. In addition, seeing the conditions of the Covid-19 pandemic that have not ended yet, this virtual laboratory media is also a solution to overcome the lack of chemistry learning media in acid-based materials.

The virtual laboratory is equipped with interesting animations so that it can increase student learning motivation. In addition, the animation contained in the virtual laboratory can help students understand concepts at the macroscopic and submicroscopic representation levels. The animation that is described at the level of macroscopic representation is when carrying out practical simulations using natural indicators, artificial indicators, litmus paper, and universal indicators. While the animation that is depicted at the level of submicroscopic representation is when an acid solution or a base solution reacts with water (H2O) to produce ion particles (cations (positive ions) and anions (negative ions)). Virtual laboratory media is also one of the supporting factors to enrich the experience and motivate students to conduct an experiment interactively and develop experimental skill activities, to enhance learning process activities to develop skills needed in solving a problem (Scheckler, 2003). According to researcher Edi Elisa et al., in his research, it was stated that developing an appropriate learning media, namely a chemical virtual laboratory media designed to improve students' critical thinking skills and science process skills during the Covid-19 pandemic is very necessary. Virtual laboratory media can also overcome students' difficulties in understanding the levels of macroscopic, submicroscopic, and symbolic representations. The results showed that the average percentage values were 94% and 90.5% obtained from the material and media expert validators with very valid criteria. Meanwhile, based on the results of trials with small group samples and large groups, they obtained an average percentage value of 97.07% and 96.8% with very practical criteria for use (Elisa et al., 2020). The virtual laboratory media that can be used during the learning process can vary, one of which is an Android-based virtual laboratory media.

It is known that many students currently have Android-based cell phones. With the help of Android-based virtual laboratory media, it is hoped that in the future it can make students more interested in learning chemistry, especially in acid-base material, and can learn anytime, anywhere because the application is installed on Android and can be accessed offline. The Android-based virtual chemistry laboratory media developed is different from other virtual laboratories which generally use application assistance in the form of flash, while the virtual laboratory media developed uses application assistance in the form of Microsoft PowerPoint, Powtoon, Chem 3D, iSpringSuite 10, and Web 2 APK Builder.

Based on these problems, as well as the advantages of android-based chemistry virtual laboratory media on acid-base materials that have been described previously, the authors wish to develop android-based chemistry virtual laboratory media products on acid-base materials. The android-based chemistry virtual laboratory media developed by researchers is an overview of the levels of macroscopic, submicroscopic, and symbolic representations that are integrated with one concept. In addition, the developed chemical virtual laboratory media does not use heavy application assistance but uses light application assistance in the form of Microsoft PowerPoint, Powtoon, Chem 3D, iSpring Suite 10, and Web 2 APK Builder.

METHOD

The type of research used in this research is research and development or commonly known as research and development (R&D). In this study, the model used is the 4D development model (Four D Models). The development model was developed by S. Thiagarajan, Dorothy S. Semmel, and Melvyn I. Semmel in 1974, which consisted of 4 stages of development, namely; define, design, develop, and disseminate (Trianto, 2012).

The development procedure carried out by the researcher was based on the 4D model which was modified into a 3D model, namely define, design, and develop can be seen in Figure 1.

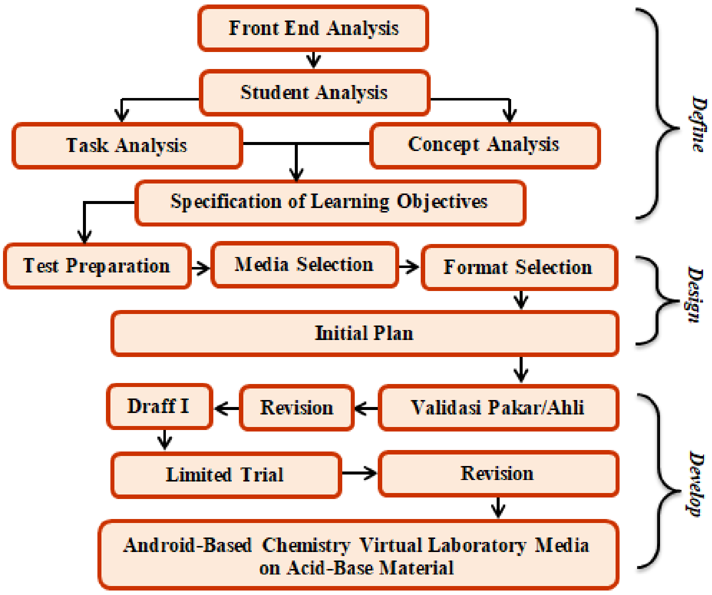

Figure 1. Stages of 3D Model Development

Data collection techniques in this study are literature studies, interviews, validation, and questionnaires. Literature study is carried out by studying national and international journals that are relevant to the problem to be studied. The interviews in this study were carried out at the student analysis stage which aimed to analyze teaching and learning activities, chemistry learning media used by teachers, and find out student problems and student characteristics before developing android-based chemistry virtual laboratory media products. Validation is carried out by validators (material and media experts) whose aim is to test the level of validity of the media that has been developed. The questionnaire in this study aims to determine student responses and responses to Android-based virtual chemistry laboratory media.

Data collection techniques in this study are literature studies, interviews, validation, and questionnaires. The test subjects in this study were 32 students of 11th grade Mathematics and Sciences (MIPA) 3 students who had received acid-base material. The research instruments used in this study were interview sheets, validation sheets (material and media experts), and questionnaires. The instrument uses a Likert scale with 4 rating scales, namely very good (score 4), good (score 3), poor (score 2), and very poor (score 1). Data analysis techniques in the form of qualitative and quantitative data. As for determining the percentage of validity and practicality as follows.

$$P = \frac{\sum \text{score obtained}}{\sum \text{maximum score}} \times 100\%$$

The scale for assessing the validity of media products and student response questionnaires can be seen in Tables 1 and 2.

Table 1. Media product validity rating scale (Riduwan, 2012)

Percentage score (%)	**Category**
81% - 100%	Very valid
61% - 80%	Valid
41% - 60%	Valid enough
21% - 40%	Invalid
0% - 20%	Totally invalid

Table 1. Student Response Questionnaire rating scale

Percentage score (%)	**Category**
81% - 100%	Very good
61% - 80%	Good
41% - 60%	Pretty good
21% - 40%	Not good
0% - 20%	Very not good

RESULTS AND DISCUSSION

Define Stage

The define stage in this study consists of 5 main steps, namely front-end analysis, learner analysis, task analysis, concept analysis, and formulation of learning objectives. The first step in this research is front-end analysis. The analysis was carried out to find out the problems related to the media product to be developed, so the researchers conducted a literature study from both national and international journals.

The next step is learner analysis, in which the researcher analyzes the basic problems in the chemistry learning process at State Islamic Senior High School (MAN) Blitar City. Based on the results of teacher and student interviews, information was obtained that the learning media used included youtube videos and powerpoint. Practicum on acid-base material that is carried out is to test natural indicators, artificial indicators, and litmus paper. The obstacles in carrying out practicum in a real laboratory are equipment and chemicals that are incomplete, there is no laboratory staff, it takes a long time, they do not understand acid-base material at the level of submicroscopic representation, and students who tend to be passive cannot carry out practicum properly. The results of student interviews obtained information that chemistry subjects on acid-base material in the pH calculation section were difficult to understand. It can be seen that acid-base material includes abstract material and contains three levels of representation, namely macroscopic, submicroscopic, and symbolic. Therefore, for students to understand the acid-base material in the pH calculation section properly, the three levels of representation must be understood in a balanced way (Zuhroti et al., 2018). This is in line with research conducted by Bukhori that the errors experienced by students in determining pH calculations were not being careful in calculating and not being able to apply the formula for determining the pH of strong acids and strong bases, as well as the pH of weak acids and weak bases (Buchori et al., 2013).

The learning media that are often used in online learning are in the form of youtube and powerpoint videos which contain explanations and writing without using animated elements in them, causing students to become easily bored in learning and can also affect learning motivation. This is in line with research conducted by Afifah that the learning process using media assistance containing animation can make students more interested in learning acid-base material (Khairani, 2021). Furthermore, students experienced difficulties in determining acid and base reactions according to Lewis's theory. This is in line with research conducted by Meylindra that acids and bases according to Lewis's theory are the most difficult to understand compared to the Arrhenius theory and Bronsted-Lowry theory, this is because the concept of acids and bases according to Lewis's theory is difficult to understand and students do not understand about the transfer of free electrons in acids or Lewis base (Meylindra et al., 2013).

As for the implementation of practicum students have not done it perfectly and there are several obstacles in the real laboratory, namely equipment and chemicals are not complete, there is no laboratory staff and it takes a long time. Based on these problems, the researchers developed an android-based chemistry virtual laboratory on acid-base materials, so that they could overcome the unavailability of equipment and chemicals in real laboratories and help teachers in the teaching and learning process in this Covid-19 pandemic situation.

The step after student analysis is task analysis, which step analyzes Core Competencies (KI), Basic Competencies (KD), and Competency Achievement Indicators (GPA) which refer to the chemistry subject syllabus for SMA/MA 11th grade curriculum 2013. The next step is concept analysis. These steps were carried out to analyze the acid-base material based on the results of the task analysis.

The sub-chapters of acid-base material produced in the task analysis step cover acid-base theory, acid-base reactions, properties of acid-base solutions, and identification of acids and bases. The last step in the define stage is the formulation of specifying instructional objectives. The steps for formulating learning objectives in android-based chemistry virtual laboratory media products are adjusted to the established Competency Achievement Indicators (GPA).

Design Stage

The design stage consists of 4 steps, namely constructing criterion-referenced tests, media selection, format selection, and initial design. Constructing criterion-referenced tests on media products includes questions and quizzes. In the preparation of questions and quizzes, views are based on the levels of macroscopic, submicroscopic, and symbolic representation. This is in line with research conducted by Ahmad Sofyan et al., that the principle of the assessment is based on the value that has been given must be by the learning objectives that have been set (Sofyan et al., 2006).

The second step in the design stage is media selection. This step plays an important role in choosing the applications needed by researchers in developing Android-based chemical virtual laboratory media. The results from the media selection step include Microsoft PowerPoint, Powtoon, Chem 3D, iSpring Suite 10, and Web 2 APK Builder applications. The selected applications are considered easy to use and not burdensome for PCs in making media products. Microsoft PowerPoint is the main application in creating this media product. Microsoft PowerPoint is used in the process of compiling media content and making animations. This is in line with research conducted by Xiao that using the Microsoft PowerPoint application in making animations can be done by teachers to students (Xiao, 2013).

Powtoon is used in making animated videos and the resulting format is MP4. 3D Chem is used to create real molecular images in three dimensions (3D) so that they can fulfill and support the submicroscopic level of representation. In this case, it can reduce students' anxiety in learning chemistry lessons due to the limitations of teaching materials in explaining the level of submicroscopic representations that lack depth.

iSpring Suite 10 is used in the process of making quizzes and changing the PowerPoint Presentation (PPT) format to HTML5. Web 2 APK Builder is the last application used to create media products, so it aims to change the HTML5 format to APK. In the media selection step, interesting images or animations were also produced by the researcher and some were obtained from relevant sources.

The third step is format selection, where in this step a format is generated in the form of APK which is used to operate chemistry virtual laboratory media with the help of Android. The media format in the form of APK can make it easier for students to operate. This is in line with research conducted by Calimag et al., that the advantages of Android-based learning media are that Android devices are small in size, light in weight, and easy to carry anywhere (Calimag et al., 2014).

The last step in the design stage is the initial design. This step was taken to design media products in the form of storyboards which were then asked for approval from the supervisor. After the storyboard was approved by the supervisor, the researcher then created an android-based chemistry virtual laboratory. The results of the media products that have been made are given the name ABS V-LAB. The name of the acronym is Acid-Base Virtual Laboratory so that students can easily recognize android-based chemistry virtual laboratory media applications on acid-base material.

The advantages of Android-based chemistry virtual laboratory media are that there is an overview of the levels of macroscopic, submicroscopic, and symbolic representations that are integrated into one concept, media applications that can be accessed offline on Android, and media applications that have a small file size of 18 MB. Meanwhile, the drawbacks of the Android-based chemistry virtual laboratory media are that the material presented is only acid-base material in the sub-chapters of acid-base theory, acid-base reactions, properties of acid-base solutions, and identification of acids and bases, as well as the type of android used in This media application is at least version 7.0 (Nougat), and versions above (Oreo, Pie, Q, and R). The results of the initial design are as follows.

Figure 2. Application Open Screen V-LAB

Figure 3. Application Menu Display V-LAB

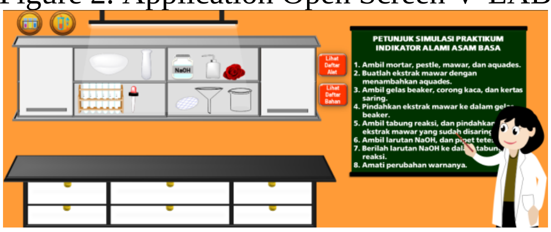

Figure 4. Natural Indicator Practicum Display

Figure 5. Artificial Indicator Practicum Display

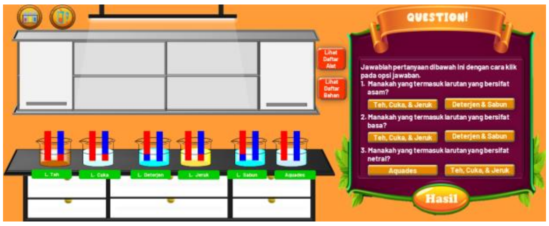

Figure 6. Litmus Paper Practicum Display

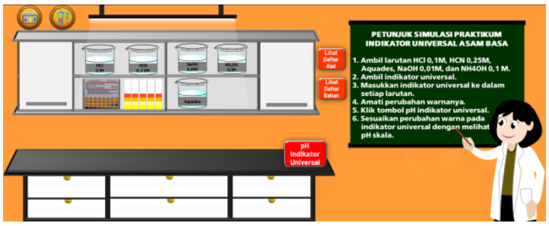

Figure 7. Universal Indicator Practicum Display

Develop Stage

The develop stage in this study includes product validation by material and media experts, as well as limited trials. Percentage based on material expert validation assessment can be seen in Figure 8.

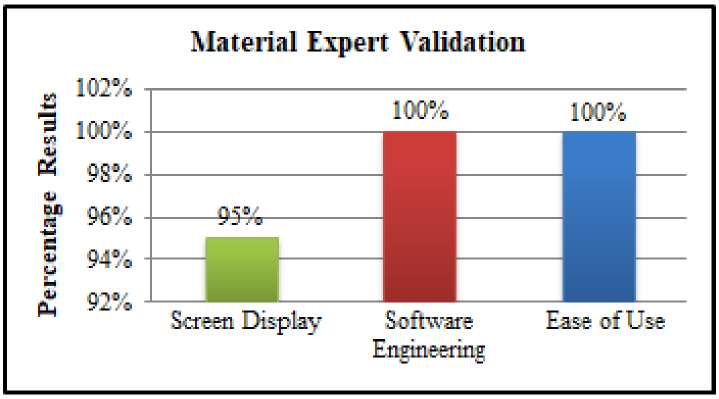

Figure 8. Results of Material Expert Validation Assessment

Based on the results of material validation by the material expert validator in Figure 8, it can be concluded that the content feasibility aspect obtains an average percentage value of 95% with the "very valid" criteria, the presentation feasibility aspect obtains an average percentage value of 100% with the "very valid" criteria. and the aspect of suitability or language accuracy obtains an average percentage value of 100% with the "very valid" criterion. The average total percentage of the results of material validation obtained a value of 98% with the criteria "very valid", while in conclusion the assessment was given with the criteria "valid for use in the field with revisions" meaning that there are suggestions for making improvements. The percentage based on the media expert's validation assessment can be seen in Figure 9.

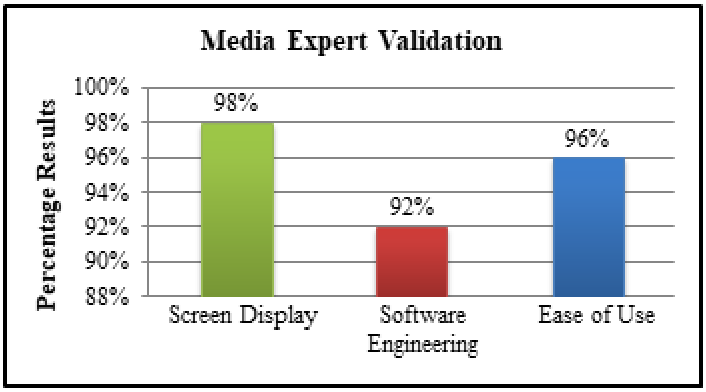

Figure 9. Results of Media Expert Validation Assessment

Based on the results of media validation by the media expert validator in Figure 9, it can be concluded that the screen display aspect obtains an average percentage value of 98% with the "very valid" criteria, the software engineering aspect (learning media) obtains an average percentage value of 92% with the criteria "very valid", and the aspect of ease of use obtains an average percentage of 96% with the criteria of "very valid". The total average percentage of media validation results obtained a value of 95% with the criteria "very valid", while in conclusion the assessment was given with the criteria "valid for use in the field with revisions" meaning that there are suggestions for making improvements.

Based on the validation results of both material experts and media, it can be concluded that the android-based chemistry virtual laboratory media on acid-base materials made by researchers obtained an assessment with very valid criteria, so it means that it is valid to be used as a chemistry learning medium. This is in line with the research conducted by Edi Elisa that developing a virtual chemistry laboratory media also obtained a very feasible assessment after the validity test stage was carried out (Elisa et al., 2020).

Trials

The trial in this study was carried out by distributing questionnaires to student responses to Android-based chemistry virtual laboratory media products online via the Google form. The respondents to this questionnaire were students of 11th grade MIPA 3 at MAN Blitar City. In this trial it was carried out on a limited basis with a total of 32 students in 11th grade MIPA 3. The percentage of student responses in the limited trial can be seen in Figure 10.

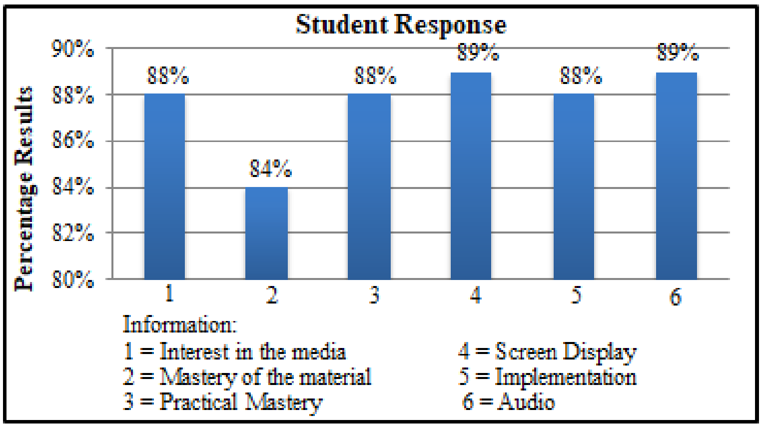

Figure 10. Results of Limited Trials Assessment

Based on the results of the student response questionnaire in the limited trial in Figure 11, it can be concluded that the aspect of interest in the media obtained a percentage value of 88% with the "very good" criteria, the material mastery aspect obtained a percentage value of 84% with the "very good" criteria, the practicum mastery aspect obtained percentage value of 88% with the criteria of "very good", the aspect of the screen display obtains a percentage value of 89% with the criteria of "very good", the implementation aspect obtains a percentage value of 88% with the criteria of "very good", and the audio aspect obtains a percentage value of 89% with the criteria "Very good". The total average percentage of student response questionnaire results in the limited trial obtained a score of 88% with the "very good" criterion.

In the learning process using Android-based chemistry virtual laboratory media, it can attract students' attention, increase learning motivation, increase activeness, independence in learning, and not be boring. This is in line with research conducted by Sakat et al., that using technology-based learning media can train learning independence and increase student motivation, so that the learning process becomes interesting and enjoyable for students (Sakat et al., 2012). In addition, according to researchers Dobrzanski and Honysz that the virtual laboratory is one of the supporting factors in enriching students' experience and motivation in conducting an experiment interactively, as well as developing experimenting skills (Dobrzański and Honysz, 2011).

The Android-based chemistry virtual laboratory media developed by researchers has an APK format that has a file size of 18 MB. This is in line with research conducted by Chuang & Chen that android-based learning media can provide facilities to students, namely being able to study anytime and anywhere, can increase student motivation and memory, because media can be used repeatedly (Chuang and Chen, 2007). In addition, according to researchers Mehdipour & Zerehkafi, using digital-based media in the learning process can provide students with opportunities to learn anytime and anywhere (Mehdipour and Zerehkafi, 2013).

CONCLUSION

In conclusion, this study has successfully developed an Android-based virtual chemistry laboratory media and assessed its validity and students' responses to it. The results demonstrated a high level of validity of the media, as reflected in the average percentage score of 98% and 95% obtained from material and media expert validation, respectively. Moreover, the limited trials revealed very good responses from students, with an average percentage score of 88%.

The development of this Android-based virtual chemistry laboratory media, which incorporates macroscopic, submicroscopic, and symbolic representations, has the potential to enhance students' understanding of acid-base materials. These findings are consistent with previous studies, which highlighted the importance of developing android-based virtual chemistry laboratory media to overcome students' challenges in comprehending acid-base material that involves macroscopic, submicroscopic, and symbolic representations.

Overall, this study contributes to the body of knowledge on innovative technology-based educational tools that can improve the quality of chemistry education. The findings of this study have implications for educators and curriculum developers to consider the integration of virtual laboratory media into chemistry learning processes to enhance students' understanding of complex chemical concepts.

RECOMMENDATIONS

The fourth stage in the 4D model, namely the deployment stage in the development of an Android-based chemistry virtual laboratory media, is expected to be carried out by future researchers to find out the effectiveness of using Android-based chemistry virtual laboratory media. This android-based chemistry virtual laboratory media needs to be developed on other chemistry topics.

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