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# DEVELOPMENT OF A SPREADSHEET-BASED VIRTUAL LABORATORY TO IMPROVE STUDENTS' SCIENCE PROCESS SKILLS

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**ABSTRACT**

The media virtual lab was developed with a spreadsheet that displayed 168 electrolysis reactions and performed reaction calculations. The implementation is done to improve the Science Process Skills (SPS) using the power of media. The design is an application of the model Analysis, Design, Development, Implementation, and Evaluation (ADDIE) of Research and Development (R&D). The VL was validated and revised by three media experts, who gave 88 on a score scale and were categorized as the highly qualified assessment of media, material, and visual communication. VL is used more in experimental classes than in control classes and SPS. Both of these classes include descriptions of tests, while SPS description tests generated normal but distributed data with a value of 0,502>0,05. The Levene test with a value of 0.849>0.05 indicates that the data is homogenous. The VL is there is a significant difference because the result of t test value obtained are 0,000<0x7E>0.05. The percentage score of each indicator from the experimental class is compared with the control class, which has a high percentage of each indicator. The farthest difference is the domain for movement manipulation and procedure implementation skills. This lends evidence to the hypothesis test that using VL can augment SPS.

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## INTRODUCTION

The high school science education system has a chemistry part. Implementing Education 5.0 in all subjects in the industrial era should be regarding curriculum, learning, and supporting tools [1]. For this purpose, it is necessary to cope with the challenges and trends of globalization [2]. Over the years, teachers must master technology and some clever media use. Computer-based media, including science, have been widely applied in education to enhance students' motivation compared to conventional learning [3], [4].

SPS are fundamental skills that serve as indicators and competence for student training [9], [12]. Besides group discussions, SPS on forecasting indicators can be trained through learning and practical activities [5]. It is essential to equip the teachers with the knowledge to accomplish students' SPS relevant to the subjects taught [6]. Teaching practice of science communication skills must connect content to augment students to compete in the age of globalization [7], [8]. SPS improvement correlates positively with students' academic performance [9].

Chemistry material consists of theoretical and practical studies that require learning tools as a medium to support understanding concepts. The practical activities are only allocated time to explain the teachings of the materials, direct practical procedures, or conclude [10]. Learning this problem can hinder the teaching and learning process and students' understanding levels, especially in understanding abstract chemistry learning concepts [11]. The advance of media technology is increasingly visualizing and situating textbook knowledge that was once abstract and difficult. Media are tools to deliver information, which is the essence of learning [12].

Before undertaking practical work, students must know the hazards of using laboratory equipment and materials [13]. Virtual laboratories are a medium that can overcome the difficulty of understanding concepts comprehensively [14]. Students have double-way interaction, which they can repeat if they don't understand it [15]. Teachers play an essential role and thus need effective strategies and resources; computer simulations and animation can be used as pedagogical resources to improve pedagogical and teacher skills [16], [17]. Virtual simulation has advantages over physical learning in investigating unobservable phenomena [18]. The positive influence can serve as a benchmark for infusing technology within Indigenous knowledge in other scientific concepts [19], [20]

According to school observations, many teachers still struggle to conduct scheduled practical sessions. This challenge includes the lack of important tools and material chemicals to conduct practicals, limited time to set up and prepare the practical tools and materials, and the unavailability of laboratory staff or technicians to assist with laboratory activities. These are some of the most important challenges facing chemistry teachers. Low absorption capacity is found in the case of chemistry due to these issues. Particularly for Electrolysis, a practical and well-defined explanation is critical for understanding the concepts associated with chemical reactions.

The Virtual STEM Laboratory (VL) is a tool that can increase students' literacy in STEM and stimulate their creativity [21], which helps these students in their education and skills for work. It has been purposefully developed to investigate students' capacities to represent chemistry ideas by storyboarding content, with a focus on electrolysis cell material [22]. For example, previously developed virtual practicum media were already equipped with features calculation reactions and online bypass media operation [23]. In previous versions of the VL, solution options were limited to six per practical, and only small screens, such as the ones mounted on smartphones, were used, making it prone to error in the practical process [24].

This study presents the development of a virtual electrolysis material laboratory based on interactive spreadsheets. This new iteration has evolved from previous media iterations and introduces key concepts of electrolysis, instructional videos, and crossword games as new interactivity means. The media includes real practicum videos, and students can be exposed to as many as 168 electrolysis reactions for further practical understanding. VL information is used to develop an interactive, spreadsheet-based approach to improve SPS in this interactive case.

## METHODS

### 1.Research Design

The research design is development design, commonly called R & D (research and development). The research method implemented was the development of a VL using spreadsheet software in electrolysis materials with the ADDIE model. ADDIE is a popular design used in the development name changes analysis, design, development, implementation, and evaluate

### 2. Participants and Sampling

The place for researching the development of virtual laboratory media based on a spreadsheet was at the Islamic Boarding School in semester one in November of the 2023/2024 academic year. The school is an integrated Islamic boarding school with a science program. in Aceh Besar.

The population of this study was 105 students of grade XII with four homogeneous class groups of Islamic Boarding Schools. The sampling method used in this research is purposive sampling, and the research samples are classified as class XII-A and XII-B. The first steps were interviews and needs analysis when kicking off this research. The interviews showed information about the obstacles in the school, such as materials that are difficult to understand, models, and learning media that are used. The situation or students' interest in the process of teaching and learning conducted and the learning media used are also studied and analyzed by researchers.

### 3. A Development of Virtual Laboratory

This is the second stage to perform after making the analysis, and in this stage, we already have the design that we would like to create according to the requirements of the product we are going to build. The VL design is interactive and utilizes easy-to-use spreadsheet software patients are familiar with to facilitate understanding of their learning material. A clear description of the research course is given in Figure 1.

Developing a product by modifying the VL to a previously designed configuration. The extractor will provide the developed media to the validator to test the design and material. The validator who analyzes the media is a media, material, and language expert. As experts corrected, virtual labs are enhanced virtual input that can be perfect for production.

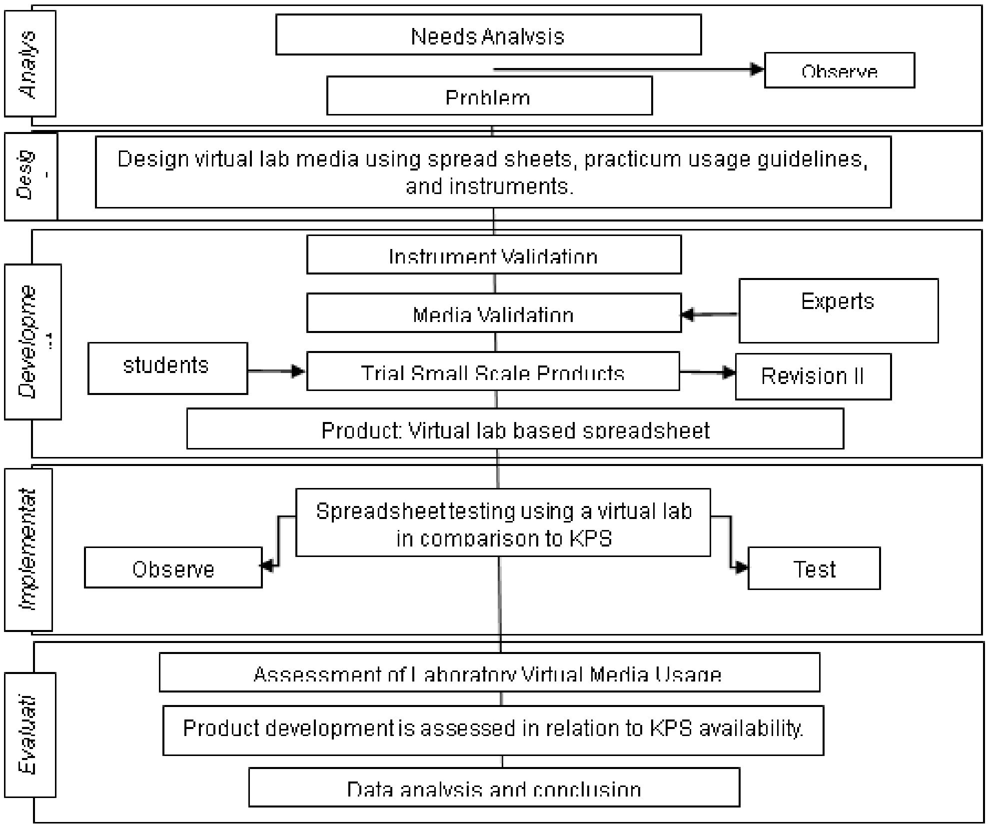


**Figure 1.** Flow diagram

**4. Instruments Development**

Based on the assessment rubric we created earlier, we calculate how many 10 SPS essay questions students will fill in after learning. The questions cover six indicators: observation, recording the data and information, following the instructions, measuring, manipulating movement, and implementing the techniques and procedures, in addition to three expert validators' initial pass of validation, construction, relevance, and clarity test phases. So, 30 students were tested to see the results of their answers. The reliability test results are 0.0704 for the reliability category, from 15 essay questions to 10 questions, which can be used. The experimental class (EC) implements VL in a spreadsheet-based form, while the control class (CC) implements practical video media.

**5. Implementation**

The samples had studied electrolysis material before; classes XII MIA-1 were used as an experiment class, and XII MIA-2 was used as a control class with the total number of samples. The research design at the implementation stage used a nonequivalent posttest-only control group design with a description of the treatment presented in Table 1.

**Table 1.** Research Design

| **Class** | **Treatment** | ***Posttest*** |
|---|---|---|
| Control | $X_K$ | $O_{K1}$ |
| Experimental | $X_E$ | $O_{E1}$ |

In which:
$X_K$ = Treatment without the use of VL media
$X_E$ = Treatment using VL media
$O_{K1}$ & $O_{E1}$ = Posttest experimental and control classes

## RESULTS AND DISCUSSION

### 1. Analysis

According to the results of the questionnaire conducted with the teacher, the lack of chemicals and labs in the laboratory makes it impossible to implement the laboratory. Table 2 shows the outcomes of the requirements analysis.

**Table 2.** Results of needs analysis

| Aspects analyzed | Find Results | Recommendation |
|---|---|---|
| Field Studies | The school already has a computer laboratory and science facility, but the chemical equipment for the practice is still inadequate. | Develop media for virtual practicums as an alternative to a restricted supply of chemical materials and tools. |
| Learning Process | Applied chemistry learning is still centered on the teacher, and the pupil cannot perform the chemical practice until the skill has been trained to see its achievement. | Encourage the media to highlight the accomplishments of the SPS basic students in their educational journey. |
| Teaching Materials | Teaching materials in the learning process include textbooks and chemistry lessons; teachers rarely use other media as a learning resource. | Virtual media development is a VL of teaching materials to facilitate teachers and pupils. |
| Electrolysis Reaction Matter | The material of the electrolysis reaction requires practicum to prove the concept. Electrolysis is an abstract theory that can't explain electrolysis reactions at a sub-microscopic level. | The electrolysis material must be sub-microscopically described using a VL-based spreadsheet that can help describe the reaction clearly. |

The study was conducted on students and teachers of Islamic Boarding School in Aceh Besar using field observation and literature studies. Observations were made to find out how students' and teachers' teaching and learning processes are affected by the results of the observations obtained, which showed that students do not understand and lack skills in chemistry learning, especially the electrolysis material. This is the abstract nature of electrolysis material not to understand electrolysis reactions at the submicroscopic level so students need media in the form of a virtual laboratory.

### 2. Design

Conclusion The laboratory virtual design approach based on the electrolysis material spreadsheet is refined according to the identification of previous needs analysis results. This material is related to electrolysis with a sub-microscopic model of the reaction.

The coverage in this VL includes cover (cover page design with menu option understanding the concept, VL, student worksheets) and framework design. The introduction also presents elementary competencies and indicators that will help clarify the measurable impact. In addition to a video explanation of the electrolysis material, an animation of the electrolysis reaction occurs to clearly show the students' understanding of the concept of learning outcomes obtained. References: Several of the chemical reactions (based on references) we show are also demonstrated as references. It brings the ideas of the content down to the submicroscopic level with explanations of how atoms and molecules fit into the concept. This is according to the visual need to understand abstract notions.

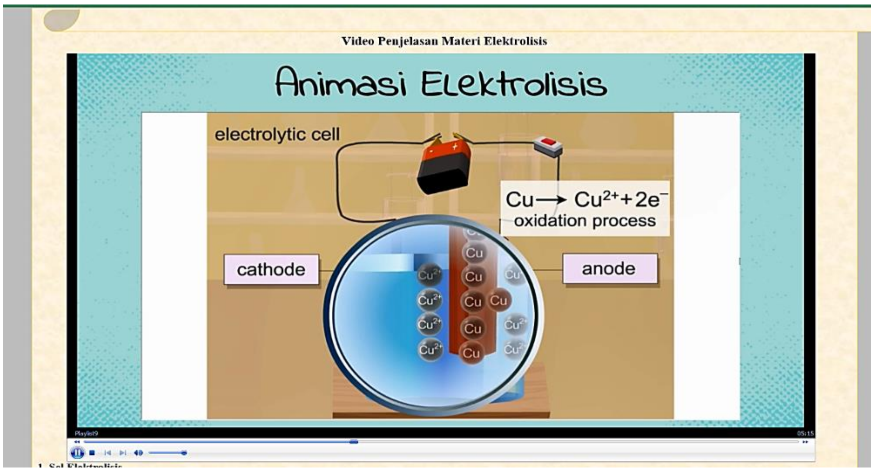


**Figure 2.** Animated video of electrolysis material

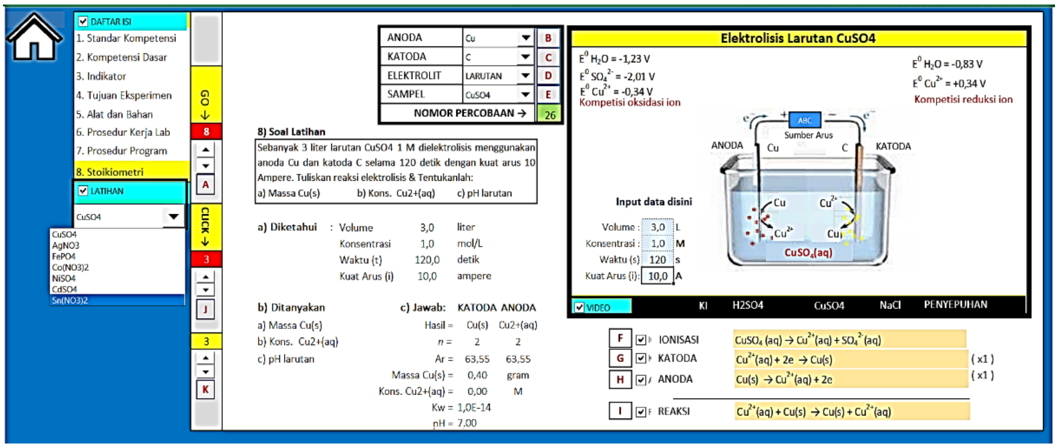


**Figure 3.** Display of electrolysis reactions

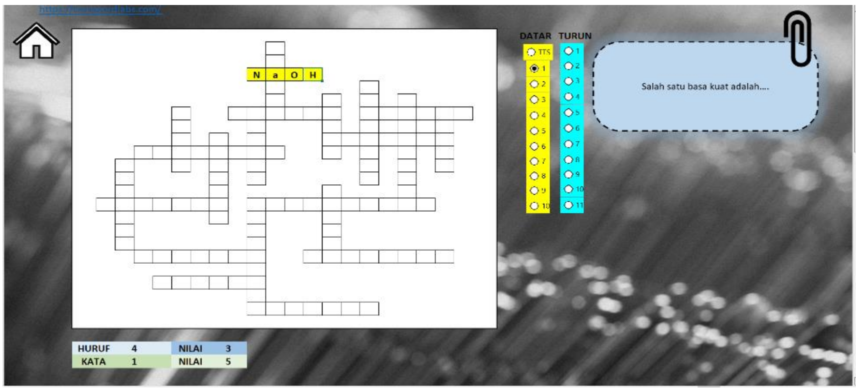

**Figure 4.** Game *crossword*

Relying on the conception of VL that displays sub-microscopic molecules in 2D, there are 168 electrolyze reactions that could emerge through the electrolysis reaction of the solution and decomposition of diverse compounds with electrode type selection.

Electrolysis video practicum of some compounds to enhance the understanding of practicum participants/objects of study in a real way, then game crossword, a word guessing game with some statements related to electrolysis material.

This last is a test question for 20 test questions to see the students take this vocabulary concept teacher responses (choice question).

### 3. Development

#### a. Media Validation

Validation is performed in the developmental phase to approach the applicability of virtual media in the laboratory experimentally. The VL validity test obtained an average score of 88.4 with a very qualified category using a Likert scale, while the media validity tests visual communications and material. New media can be used after testing its validity phase via product reformed with the eligible minimum category [26]. Below is a summary of the validation results by the 15 experts.

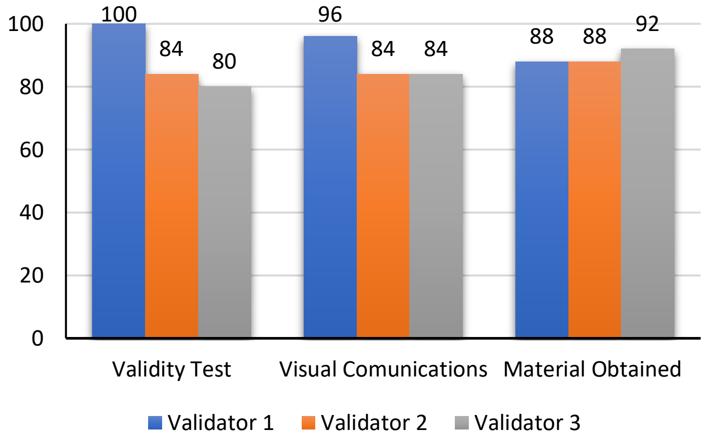


**Figure 5.** Chart results of the validation

This media has been revised twice, based on expert validators' assessments, comments, and suggestions, before being declared a very suitable virtual laboratory media. Validators focused on media appearance and materials, which were aspects of improvement. Here are some comments and recommendations from media experts. This media went through two revision stages based on comments and suggestions from expert validators before finally being declared a virtual laboratory media that was very appropriate for use.

One of the areas that was improved by the validator focused on the visual aspects of communication and materials. The button is a hyperlink placed in the top left corner to easily bring the user back to the main menu to change to other available menus without scrolling. Using input and direction from that validator, we added that the menu icon should link to the home page, and we added descriptions of "Home." Moreover, the output screen on the previous virtual application showed that the index number was incorrect, so the researcher revised the chemical formula by writing the index with subscript letters. So, after the amendment, the battery was placed on both electrodes, giving a frozen description of the competition of oxidation and reduction ion reactions. The displayed tools and weights had been constructed in electrolysis cells based on the submicroscopic description of the response.

Finally, a program showing the calculation results of the virtual laboratory appears to be complete without the assistance of scrolling.

**b. Small Scale Trial**

A small-scale group trial was conducted on 30 students who studied electrolysis content in high school. Respondents populated the assessment on the lift for each variable SUS. The data were analyzed to calculate a total score based on the positive and negative statements formula—Table 3. October 2023 shows SUS scores calculated for each of the respondents.

**Table 3.** Student response results (small scale trial)

| Respondents | SUS Questionnaire Statement Items | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 |
| Number of ratings | 91 | 89 | 89 | 60 | 107 | 106 | 89 | 105 | 99 | 66 |
| % | 76 | 74 | 74 | 50 | 89 | 88 | 74 | 88 | 83 | 55 |
| Total | 750.83 | | | | | | | | | |
| Average SUS Score | 75.08 | | | | | | | | | |

Resulting in a few problems from the test, i.e., some categories E and scale statement 10 categories D. The respondents assume that the users still need expert guidance about learning the system and not much need to learn the material for electrolysis. The suggestions will be considered a final product to be implemented in learning material of chemistry electrolysis.

The usage test steps in the Table 3 above each execute consistent with the SUS calculation guideline. A range of acceptability determines the scoring average of the response values of the student of 75.05 under the interpretations.

**4. Implementation**

The test adopts descriptive question formats to accommodate and evaluate the student's thinking skills, which are validated qualitatively and quantitatively. Validating instrument tests were conducted by 3 experts toward three aspects: assessment construction, relevance, and question item clarity, so the instrument is valid and proper to use.

**Table 4.** The Results of the normality test

| Instructional Media | | Shapiro-Wilk | | |
|---|---|---|---|---|
| | | **Statistic** | ***α*** | **Definition** |
| SPS | Experimental | 0.117 | 0.05 | Normal |
| | Control | 0.502 | 0.05 | Normal |

Program propagates [27] has been applied to test the SPS instrument on the essay questions. According to the calculation results of 15 descriptive questions that are declared valid and feasible for use, 10 questions. The result obtained a reliability value of 0.704, which has a high category (reliable). If data is NOT in a normal distribution, then complete a t-test so that the statistical test will be down. Thus, in this article, normality tests are conducted using the SPSS application, which is evident in Table 4.

Shapiro Test was performed to determine whether the analysis between the two classes was normally distributed—a real level of 0.05, with a sample of 25 in each CC and EC. As can be seen in the above Table, the EC value was 0.117, smaller than the CC for the statistical value. The CC gets the value 0.502 > 0.05. This means we can assume that the aCC class is a wide classification, the two sample classes $a$ > 0.05, applying CC and one at the best accuracy. When the calculated value is greater than 0.05, then $H_o$ is accepted, so it can be concluded that in CC and EC, data are normally distributed.

The t-test and homogeneity test for both sample classes were the next steps. The data on the test result was inputted into the SPSS application for analysis. Table 5 shows the results of this data set for homogeneity of variances to examine whether the two samples are homogenous [28]. The output of two Levene tests using SPSS shows we achieved a value with p = 0.849 (p > 0.05). It means that the two classes compared are quite similar. Therefore, the variance of the two compared classes is homogeneous.

**Table 5.** Homogeneity and T-test

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | |
|---|---|---|---|---|---|---|---|---|
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| SPS | Equal variances assumed | 0.155 | 0.696 | 8.388 | 48 | 0.000 | 16.600 | 1.988 |
| | Equal variances are not assumed. | | | 8.388 | 47.61 | 0.000 | 16.600 | 1.988 |

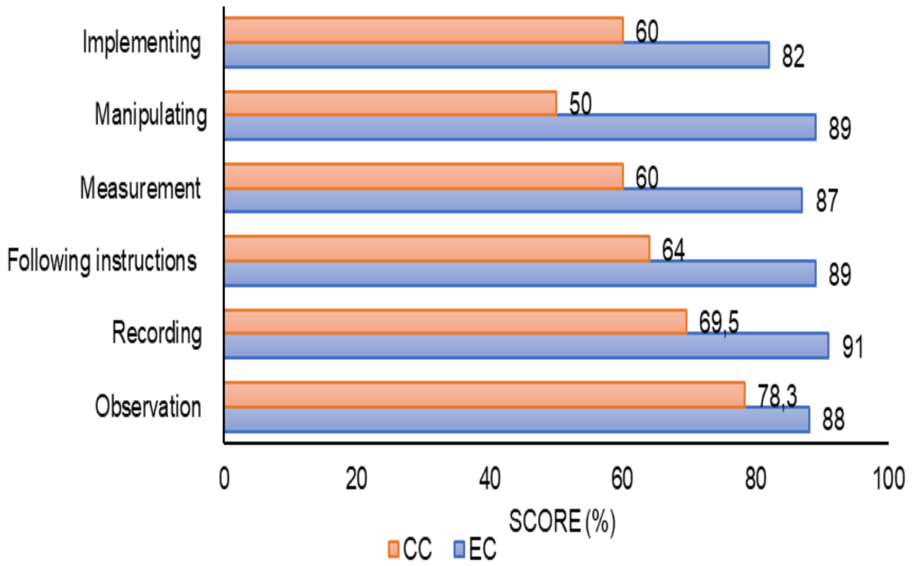


**Figure 6.** SPS outcomes in the CC and EC

The sig. (2-talled) value is 0.000. The p-value is less than this significance output of 0.05. Hence, it can be deduced that $H_o$ is rejected and H1 is accepted. The difference between the results of the science process skills test that utilizes a virtual laboratory is tremendous, with a value of 16.60 [9] compared to the research conducted by Ekici & Erdem [29], which yielded a value of 6.69. So, the result is a significant difference between using VL and SPS. The results were a reference of research [30] that achieved a value of 0.040 < 0.05 in its significance of the difference in CC by utilizing flipped classrooms through e-learning. Therefore, VL media can enhance SPS, which can be concluded accordingly. Now, have a look at the comparison graph below.

The percentage of each indicator for the experimental class is higher than that of the control class. The most significant difference comes in the skill of manipulating movements and executing processes. This further solidifies the hypothesis test, which states that virtual laboratories can improve the SPS.

### 5.Evaluation

The sample was a response to the VL test sheet of 25 students of the Islamic Boarding School. The sample used as respondents is the experimental class that ensured that they had implemented VL in the learning process before filling out the questionnaire sheet. They utilized the media in the learning process before answering the questionnaire sheet. For the category, the percentage strongly agreed at 56.7, agreed at 43, and disagreed at 0.33. The percentage is 89 with the category “very interesting,” based on the fact of lift analysis. Interestingly, respondents who researched developing interactive e-module media also got results with very attractive criteria [31], [32]. The category accomplishment is great since a few components impact it; for instance, the appeal and substance angle, content in recordings that are anything but difficult to comprehend and clear, the illustration used, for example, pictures and video liveliness can give inspiration, movement, and increment client fascination [33]. All three of these studies share a commonality of criteria concerning media development that attains high user satisfaction results.

## CONCLUSION

The VL-based spreadsheet on electrolysis material developed at the revision stage can be used as a medium in the learning process by pupils and educators, with expert validation results of 88% in a qualified category. The student then replies that the virtual lab shows 89.1% from the experiment they worked on, so depicting the answer is very interesting. The media has been applied to Islamic Boarding School students. All classes had completed electrolysis learning before the description test questions. The extracted scores were t-test (p score = 0.000 < 0.05). According to these numbers, the EC and the CC have significant differences. For that reason, a VL could improve the SPS.

## REFERENCES

[1] E. Risdianto, Wachidi, Riyanto, I. Fathurochman, M. Yanto, and A. Asmara, “Feasibility test of learning media with blended learning model and augmented reality assisted MOOCs,” *Indones. J. Soc. Sci.*, vol. 10, no. 1, pp. 149–164, 2022, doi: https://doi.org/10.26811/peuradeun.v10i

1.626.

[2] H. Lisdiana, Y. Rahmawati, and A. Ridwan, "Development of 21st-century skills through STEAM PjBL in salt hydrolysis and buffer solutions," *JKPK (Jurnal Kim. dan Pendidik. Kim.*, vol. 8, no. 2, pp. 280–296, 2023, doi: 10.20961/jkpk.v8i2.76177.

[3] Yusrizal and K. Hanif, "Increasing of students' motivation in learning physics through the use of computer simulation media viewed from parents' employment background.," *J. Soc. Sci.*, vol. 5, no. 2, pp. 201–212, 2017, doi: 10.26811/peuradeun.v5i2.129.

[4] Jabaliah, M. Adlim, M. Syukri, and Evendi, "Learning of multimedia-based physics concept applications to improve students ' motivation and science process skills," *Indones. J. Soc. Sci.*, vol. 9, no. 3, pp. 681–702, 2021, doi: 10.26811/peuradeun.v9i3.557.

[5] A. Elvanisi, S. Hidayat, and E. N. Fadilah, "Analisis keterampilan proses sains siswa sekolah menengah atas," *J. Inov. Pendidik. IPA*, vol. 4, no. 20, pp. 245–252, 2018, doi: 10.21831/jipi.v4i2.21426.

[6] M. Adlim, R. Nuzulia, and C. Nurmaliah, "The Effect of conventional laboratory practical manuals on pre- service teachers ' integrated science process skills," *J. Educ.*, vol. 15, no. 4, pp. 116–129, 2018, doi: 10.12973/tused.10250a.

[7] I. Damopolii, U. Keley, D. T. Rianjani, J. H. Nunaki, E. Nusantari, and N. Y. Kandowangko, "Potential of inquiry-based learning to train student ' s metacognitive and science process skill," *Indones. J. Soc. Sci.*, vol. 8, no. 1, pp. 83–98, 2020, doi: 10.26811/peuradeun.v8i1.351.

[8] N. P. L. C. Dewi and S. Atun, "The Effect of science technology society ( STS ) learning on students ' science process skills," *Indones. J. Soc. Sci.*, vol. 7, no. 1, pp. 113–124, 2019, doi: 10.26811/peuradeun.v7i1.288.

[9] S. Dolapcioglu and M. Subası, "The Relationship between scientific process skills and science achievement : a meta-analysis study," *J. Sci. Learn.*, vol. 5, no. October 2021, pp. 363–372, 2022, doi: 10.17509/jsl.v5i2.39356.

[10] A. H. Maksum and Y. Saragih, "Analisis penerapan virtual laboratorium versus reality laboratorium," *J. TIARSIE*, vol. 17, no. 2, p. 47, 2020, doi: 10.32816/tiarsie.v17i2.72.

[11] N. Maksimenko, A. Okolzina, A. Vlasova, C. Tracey, and M. Kurushkin, "Introducing atomic structure to first-year undergraduate chemistry students with an immersive virtual reality experience," *J. Chem. Educ.*, vol. 98, no. 6, pp. 2104–2108, 2021, doi: 10.1021/acs.jchemed.0c01441.

[12] H. R. Widarti, M. I. Hakim, and D. A. Rokhim, "The Development of a virtual laboratory on qualitative chemical practicum analysis," *Indones. J. Soc. Sci.*, vol. 10, no. 3, pp. 785–804, 2022, doi: 10.26811/peuradeun.v10i3.760.

[13] H. Xu *et al.*, "Thermal perception method of virtual chemistry experiments," *Virtual Real. Intell. Hardw.*, vol. 2, no. 4, pp. 305–315, 2020, doi: 10.1016/j.vrih.2020.07.003.

[14] S. M. Reeves, K. J. Crippen, and E. D. McCray, "The varied experience of undergraduate students learning chemistry in virtual reality laboratories," *Comput. Educ.*, vol. 175, no. March, p. 104320, 2021, doi: 10.1016/j.compedu.2021.104320.

[15] Anizar, A. Gani, I. Khaldun, and M. Bahi, "The Development of a module with microsoft excel-based interactive media on the topic of buffer solution," *J. Phys. Conf. Ser.*, vol. 1088, 2018, doi: 10.1088/1742-6596/1088/1/012119.

[16] F. Beichumila, B. Bahati, and E. Kafanabo, "Computer simulations and animations in the teaching and learning of chemical kinetics , equilibrium , and energetics : Assessing teachers ' pedagogical skills in Tanzania secondary schools," *J. Math. Sci. Technol. Educ.*, vol. 18, no. 11, pp. 1–17, 2022, doi: 10.29333/ejmste/12498.

[17] W. C. Lee, N. W. Leng, D. Chen, and T. Lin, "Fostering changes in teacher attitudes toward the use of computer simulations: Flexibility, pedagogy, usability and needs," *Educ. Inf. Technol.*, no. 162, 2021, doi: 10.1007/s10639-021-10506-2.

[18] L. A. Warning and K. Kobylianskii, "A Choose-your-own-adventure-style virtual lab activity," *J. Chem. Educ.*, vol. 98, no. 3, pp. 924–929, 2021, doi: 10.1021/acs.jchemed.0c01241.

[19] A. D. Rahmat, I. Wilujeng, and H. Kuswanto, "The Effect of mobile learning integrated traditional games egrang to improve multiple representation skills," *J. Sci. Learn.*, vol. 6, no. September, 2023, doi: 10.17509/jsl.v6i4.57961.

[20] F. Öztop, "A Meta-analysis of the effectiveness of digital technology-assisted STEM education," *J. Sci. Learn.*, vol. 6, no. March, pp. 136–142, 2023, doi: 10.17509/jsl.v6i2.52316.

[21] N. F. Rahmadani, S. Retno, D. Ariani, S. Mulyani, and N. Y. Indriyanti, "Effectiveness of virtual stem laboratories for enhancing high school students ' creativity and stem literacy," *JKPK (Jurnal Kim. dan Pendidik. Kim.*, vol. 8, no. 1, pp. 26–36, 2023, doi: 10.20961/jkpk.v8i1.64548.

[22] A. K. Ilahi, C. Z. Subarkah, and Y. Sukmawardini, "Penerapan media pembelajaran laboratorium virtual untuk meningkatkan kemampuan representasi kimia pada materi sel elektrolisis," *Pros. Semin. Nas. Kim.*, vol. 7, pp. 25–37, 2022, [Online]. Available: https://conferences.uinsgd.ac.id/index.php/gdcs/article/view/602.

[23] P. Sutanto, *Praktikum maya untuk mendukung pembelajaran jarak jauh di SMA*. Jakarta: Direktorat Sekolah Menengah Atas, 2020.

[24] F. Solikhin, K. H. Sugiyarto, and J. Ikhsan, "The Impact of virtual laboratory integrated into hybrid learning use on students ' achievement," *Indones. J. Soc. Sci.*, vol. 7, no. 1, pp. 81–94, 2019, doi: 10.26811/peuradeun.v7i1.268.

[25] C. Lyundzira, W. A. Sari, and F. I. Hasanah, *Langkah SPSS : uji hipotesis perbedaan rata- rata atau uji T*. Yogyakarta: Universitas Gadjah Mada, 2019.

[26] A. Ramdani, A. W. Jufri, and J. Jamaluddin, "Pengembangan media pembelajaran berbasis android pada masa pandemi covid-19 untuk meningkatkan literasi sains peserta didik," *J. Kependidikan J. Has. Penelit. dan Kaji. Kepustakaan di Bid. Pendidikan, Pengajaran dan Pembelajaran*, vol. 6, no. 3, p. 433, 2020, doi: 10.33394/jk.v6i3.2924.

[27] I. Khaldun, "ProAnaltes 22." Direktorat jenderal kekayaan intelektual, banda aceh, 2022, [Online]. Available: https://e-hakcipta.dgip.go.id/index.php/c?code=ZjU2ZTQ3ZWE0NWFlYjVmMDQ3NWY2ZThiZGIwYWVmNjEK.

[28] S. Belia, "The Effect of the model of experiential learning model towards students' science process skill in natural science learning at SD pembangunan laboratorium padang state university," *TOFEDU: The Future of Education Journal*, vol. 1, no. 2. pp. 111–123, 2022, doi: 10.61445/tofedu.v1i2.30.

[29] M. Ekici and M. Erdem, "Developing science process skills through mobile scientific inquiry," *Think. Ski. Creat.*, vol. 36, p. 100658, 2020, doi: 10.1016/j.tsc.2020.100658.

[30] A. Ibrahim, M. Elfeky, T. Saleem, Y. Masadeh, M. Yasien, and H. Elbyaly, "Advance oranizers in flipped classroom via-elearning management system and the promotion of integrated science process skills," *Think. Ski. Creat.*, vol. 35, pp. 1–31, 2020, doi: 10.1016/j.tsc.2019.100622.

[31] R. Hayanum, R. Permana sari, and nurhafidhah, "pengembangan media pembelajaran e-modul interaktif dengan menggunakan aplikasi exe-learning," *KATALIS J. Penelit. Kim. dan Pendidik. Kim.*, vol. 5, no. 2, pp. 7–17, 2023, doi: 10.33059/katalis.v5i2.6970.

[32] F. Rahmawati, I. P. Leksono, and U.

Rohman, "Pengembangan e-modul mata pelatihan pemetaan kompetensi dan indikator berbasis flip PDF corporate edition dengan menggunakan model ADDIE pada pelatihan metodologi pembelajaran di balai diklat keagamaan Surabaya," *EDUKASIA J. Pendidik. dan Pembelajaran*, vol. 4, no. 2, pp. 1647–1656, 2023, doi: 10.62775/edukasia.v4i2.469.

[33] Marlina and Riyanto, "Developing animation video-based demonstration experiments on the topic solubility and solubility product," *JKPK (Jurnal Kim. dan Pendidik. Kim.*, vol. 6, no. 2, pp. 163–172, 2021, doi: 10.20961/jkpk.v6i2.52044.