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THE DEVELOPMENT OF A VIRTUAL LABORATORY ON QUALITATIVE CHEMICAL PRACTICUM ANALYSIS

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Abstract

In practical activities, it is necessary to have media that can provide multi-representation explanations, namely macroscopic, microscopic and submicroscopic, especially in qualitative analytical chemistry for group I and II cations. It takes an innovation of practicum learning media that can explain multiple representations to prepare students for practical activities well. An alternative solution is to use learning media as a virtual laboratory. The objectives of this research and development were to develop a virtual laboratory in qualitative chemical analysis practicum for group I and II cations based on multiple representations with internet integration and describe the feasibility of a virtual laboratory in the practicum of qualitative chemical analysis of group I and II cations based on multiple representations with internet integrated. This research and development used the R & D (research and development) method with a 4D (four-D) development model. The results showed that media expert validation was 87.8% (very valid), and material validation was 82.7% (very valid). The readability test results obtained percentage values of 91.1% and 92.3% (Very Valid). The virtual laboratory explained multiple representations that can help students in practical activities well.

Keywords: *Virtual Laboratory; Cation I and II Analysis; Multiple Representations.*

A. Introduction

Chemistry studies the compositions, structures, properties, changes in matter, and the energy that accompanies these changes (Purba, 2006). Chemistry is a branch of science with characteristics including chemistry as a product (chemical knowledge in the form of facts, concepts, principles, laws, theories, and scientists' findings) and chemistry as a process with scientific work processes (Widarti et al., 2019). One of the branches of chemistry is analytical chemistry which studies the qualitative analysis of group I and II cations. Qualitative analysis studies the presence of an element or compound in the sample.

The results of observations made on analytical chemistry teachers at SMKN 7 Malang in 2020 revealed that qualitative analytical chemistry is one of the problematic materials to teach. The results of research conducted by Fathonah et al. (2015) reported that learning outcomes in qualitative analytical chemistry tend to be low. The results of a needs questionnaire distributed to 30 students of SMK Bhakti Mulia Wonogiri showed that 53.33% of students stated that qualitative analysis material was challenging to understand (Fathonah et al., 2015). The concepts discussed in analytical chemistry are primarily abstract and involve complex mathematical calculations (Fardani et al., 2017). Several representations can help students to understand analytical chemistry well. In chemistry, there are multiple representations, namely macroscopic, submicroscopic, and symbolic (Nadi et al., 2016).

The existence of multiple representations of chemistry can help students to understand chemistry as a whole, especially analytical chemistry (Widarti et al., 2019). It is evidenced by research conducted by Hasibuan & Sari (2018); Doyan et al. (2018), who said that the understanding of multiple representations has a positive effect on learning, especially in learning chemistry with abstract concepts (Hasibuan & Sari, 2018) and (Doyan et al., 2018). To provide a meaningful chemistry learning experience, practicum activities are often chosen as a learning method (Bortnik et al., 2017). Practicum is an activity that cannot be left behind in chemistry learning, especially analytical chemistry.

Conventional practical activities still have some limitations. The limitations include the limited availability of tools and materials and adequate laboratory space to carry out practicum activities fully. Conventional practicum is not enough because students can only observe from a macroscopic and symbolic point of view. As stated by Widarti et al. (2019), the ongoing chemistry practicum learning has not been able to provide multiple representation explanations to students (Widarti et al., 2019). The Covid-19 outbreak this year has also caused practicum activities cannot be carried out because learning is done online.

Practical activities in analytical chemistry learning are generally limited to primary studies. As a result, students generally do not have a complete understanding of the material being studied and the procedures; students cannot be creative to try experiments in different conditions or practice skills before carrying out practical activities (Widarti et al., 2021). So far, practical learning has not allowed students to try tools and materials freely in the laboratory (Rokhim et al., 2020). It is done to anticipate the dangers posed during the experimental process. Based on these problems, practical learning becomes essential to development. An alternative solution that can be done is to use learning media in the form of a virtual laboratory.

The virtual laboratory is one of the practical learning innovations that can be developed based on information technology. The results of research conducted by Dyberg et al. (2017) reported that virtual laboratories could improve learning preparation and motivation so that students become more confident and comfortable doing practicum. (Dyrberg et al., 2017). Virtual laboratories have been proven to increase students' understanding (Widarti et al., 2019) and can improve their thinking skills for students (Widowati et al., 2017). A virtual laboratory allows students to do online practicum anytime and anywhere without time and space restrictions (Vasiliadou, 2020).

There are many virtual laboratory developments, one of which is the result of the development carried out by (Rokhim et al., 2020). The developed virtual laboratory is still limited to practical simulation videos. Students cannot move tools or materials in the practical simulation process. The virtual laboratory that has been developed also has not integrated the explanation of multiple representations of chemistry, but only the macroscopic and symbolic aspects. The integration of information technology in the form of a virtual laboratory is a topic that is widely researched in the current effort to develop practical learning (Dwiningsih, 2018). It shows that information technology provides an alternative learning environment that can contribute to a meaningful learning process (Gambari et al., 2018).

Based on the problems above, it is necessary to develop a development entitled "Development of Learning Media for Virtual Laboratory of Qualitative Chemistry Analysis Practicum of Cations Groups I and II Based on multiple representations with Integrated Internet".The purpose of this research is to develop a virtual laboratory in qualitative chemical analysis practicum for group I and II cations based on multiple representations with internet integrated and describe the feasibility of a virtual laboratory in the practicum of qualitative chemical analysis of group I and II cations based on multiple representations with internet integrated.

B. Method

This research and development use the R&D (Research and Development) method by adopting the 4-D (four D) development model recommended by Thiagarajan (1974: 5). This research includes R&D because it produces a product in the form of a virtual laboratory based on multiple representations in analytical chemistry practicum material. The stages of the Four-D model are the stage of defining, designing, developing, and disseminating.

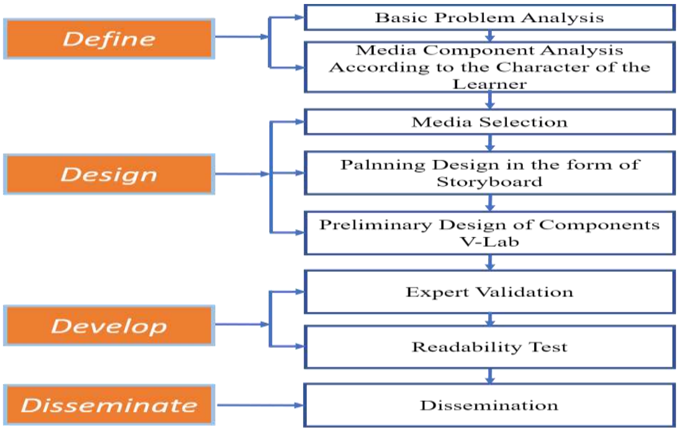

Figure 1: Development (4D) chart

The development procedure that adopts the 4-D model is described as follows.

1. Defining stage (define)

   The steps in the definition stage are front-end analysis, learner analysis, task analysis, concept analysis, and specifying instructional objectives. At this stage, an analysis of the fundamental problems and analysis of students' character regarding analytical chemistry is carried out. At this stage, interviews were conducted with high school chemistry teachers related to analytical chemistry learning for group I and II cation analysis. This is done to find out what is needed and can help students and teachers in the learning process.

2. Stage of design (design)

   The steps at the design stage are the selection of the media used, the selection of the format or design in the form of storyboards, and the initial design related to the components of the virtual laboratory media. The results of interviews with high school chemistry analyst teachers are then used as a reference for selecting what tools or media are suitable to overcome existing problems. At this stage, a series of initial media is made in a storyboard as a 2D image with its component features. The results from the storyboard are then used as a reference for the initial design of making virtual lab applications in the form of applications.

3. The development stage (develop).

   The steps in the development stage are expert validation. Five aspects are tested at the expert validation stage, including media format, language, media content, graphics, and aspects of the existence of the media, as well as development trials carried out with readability tests. At this stage, an assessment is carried out by the validator by filling out an assessment questionnaire on the v lab application media that has been made. In addition, at this stage, a trial of media development is carried out for students by filling out the questionnaire provided.
4. Stage of Dissemination (Disseminate)

   The steps in the dissemination stage are empirical validation, packaging, deployment and use. The dissemination stage was not carried out due to the limited time and cost of the researcher.

The product trial phase is carried out with content validation and readability testing, as well as the implementation of the developed product. It is an assessment or response from the validator to know the feasibility of the product that has been developed. Content validation is carried out by providing questionnaires/validation sheets to lecturers in the chemistry department at the State University of Malang who are experts in analytical chemistry and the field of learning media. In the readability test, an assessment is carried out by students and students of chemical analysis Vocational School.

The validator carries out product expert validation. Validator criteria for lecturers are as follows: Experience in guiding practicum activities, especially analytical chemistry practicum, master all analytical chemistry material contained in the practical manual, understand or are experts in developing a learning media. The readability test criteria were carried out on chemical analyst high school students and a teacher in charge of chemical analysis subjects, especially cation analysis.

The data was obtained in the form of qualitative and quantitative data. Qualitative data in the form of comments, criticisms, and suggestions from the validator as a reference for improving and revising the developed product. While quantitative data in the form of numbers obtained from the results of filling out a questionnaire/ product validation sheet using a Likert scale (5,4,3,2,1).

The data collection instruments used media validation questionnaires, material validation questionnaires, and legibility test questionnaires. The assessment questionnaire sheet used in this study contains a series of statements that the validator and students will assess by giving a score of 1-5; besides that, the questionnaire sheet also contains comments, suggestions and input related to the product being developed. The data analysis technique used is the average calculation technique based on the formula proposed by Riduwan, that to determine the percentage of eligibility or validity is to add up the total value of the validator's answers divided by the total value of the highest answer (Riduwan, 2012). The formula for calculating the average put forward is as follows:

$$P = \frac{\Sigma x}{\Sigma xi}\ x\ 100\%$$

With:

P = Percentage of eligibility or validity
Σx = Total score of validator answers
Σxi = Total score of the highest answer

A range of validation criteria is used to find out the conclusions from the average calculation above. To describe the data from the readability test, you can use the eligibility criteria in Table 1.

Table 1: Criteria for Validation Results (Riduwan, 2012)

Percentage (%)	Validity Criteria
81 – 100	Very Valid
61 – 80	Valid
41 – 60	Quite Valid
21 – 40	Less Valid
0 - 20	Invalid

C. Result and Discussion

1. Result

The research and development resulted in a virtual laboratory learning media for analytical chemistry practicum group I and II cation analysis based on multiple representations with internet integration. The developed virtual laboratory application is equipped with an explanation of multiple representations ranging from macroscopic, submicroscopic, and symbolic aspects that are integrated with the internet so that it can be connected between students and teachers and can be used anytime, anywhere, without time and space restrictions. An internet connection is required to access the developed application.

This virtual laboratory application was developed to create an innovative learning media for practicum activities that can overcome problems or things that cannot be obtained and cannot even be done in a natural laboratory so that the developed media products can be used to overcome existing problems. For example, the fundamental problem is that there is no explanation of multiple representations in practicum activities that must be given in chemistry learning. Another example is the problem of the Covid-19 condition, which causes activities in the laboratory not to be carried out.

The virtual laboratory application developed was named Inter-VAL: Interactive Virtual Analytical Laboratory. The product developed is an android virtual laboratory application that can be accessed using smartphones and laptops/ PCs for students and teachers equipped with an explanation of multiple representations. The developed virtual laboratory application is designed with an attractive appearance and is interactive to increase student interest in learning, especially in group I and II cation analysis practicum activities. The product developed is divided into two parts: the teacher account and the student account. The teacher's account contains several menus in the form of profiles, consultations, class admins, access permissions, questions, and data admins. There are five menus in the student account: the profile, consultation, glossary, material, and v-lab.The results of the development of virtual laboratory application products are described as follows.

a. Teacher Account

On the teacher account, there are five menus. The initial screen for logging in to the teacher account is shown in Figure 2. The five menus in the teacher account are described as follows.

Figure 2: The initial view of the teacher account login

First, the profile menu contains the teacher's data, and there are two sub-menus, namely the logout menu to exit the account and the change password menu. The profile menu display is shown in Figure 3.

Figure 3: Profile menu display

Second is the consultation menu. This menu allows teachers to communicate and respond to student problems in real time. The profile menu display is shown in Figure 4.

Figure 4: Consultation menu display

Third, the class admin menu. Through this class admin menu, the teacher can find the number of students in the class along with the attendance list of students at each meeting and create several new classes if the teacher holds several classes to teach. The class admin menu display is shown in Figure 5.

Figure 5: Class admin menu display

Fourth, the admin menu of questions and data. In this menu, the teacher can provide a test of students' knowledge skills in the form of a pretest and post-test. Teachers can create and give questions as they wish. In this menu, teachers can also correct the results of student assignments and directly provide scores which will later be sent to each student's account. The admin menu display of questions and data is shown in Figure 6.

Figure 6: Display admin menu questions and data

Fifth, access the permission menu. In this menu, the teacher can grant permission to several student account features, such as v-lab, pretest/ post-test, attendance, and uploading practicum reports. The access permission menu display is shown in Figure 7.

Figure 7. Access permission menu display

b. Student Account

On the student account, there are five menus, namely menu. The initial screen for logging in to the student account is shown in Figure 8. The five menus on the student account are described as follows.

Figure 8. The initial view of the student account login

First is the V-lab menu. Students can perform practical simulations of group I and II cation analysis in this menu. Students can choose their tools and materials as needed. Students can also see the experimental procedure as a guide to doing the practicum. After selecting the appropriate tools and materials, students can enter the practicum simulation room and do it by moving the tools and materials themselves. The occurrence of a reaction in this simulation is indicated by the appearance of a precipitate or a change in the colour of the solution of a substance.

After experimenting correctly, a discussion menu will appear that provides an explanation regarding the simulation carried out, and a submicroscopic menu will appear which provides an overview of a chemical

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reaction in the submicroscopic aspect in the form of molecules and ions equipped with a background that explains the phenomenon. In this V-lab menu, there is also an observation data feature that students can fill in directly after each treatment during the experiment. Observation data that has been filled in can be saved and sent to the teacher's account automatically for correction and assessment. Through this V-lab, students can observe practical phenomena ranging from macroscopic, submicroscopic, and symbolic aspects. The features in the V-lab menu are shown in Figures 9-16.

Figure 9: Display of experimental objectives

Figure 10: V-lab menu display

Figure 11: Display of tools and materials

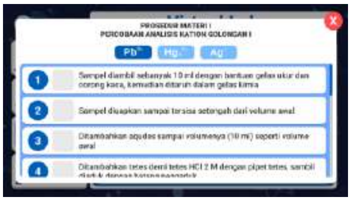

Figure 12: Display of the experimental procedure

Figure 13: Display of observation data

Figure 14: Display of practical simulation

Figure 15: Submicroscopic menu display

Figure 16: Discussion menu display

The second is the profile menu. This menu contains student self-data, and eight sub-menus will be described as follows. 1) Attendance menu, used as a sign of attendance or a sign that is participating in learning activities. 2) Change the password menu, to change the password. 3) Logout menu, to log out of the account. 4 and 5) Pretest and post-test menu, students can do pretest and post-test to test understanding before and after experimenting. 6) Value data menu, through this feature, students can find out information about the data on the value of the work they have done, such as pretest, post-test assignments, practicum reports, and practicum journals. 7) In The menu of observation data results, students can determine whether the teacher has received the data from practical observations. 8) Menu upload practicum report, students can collect the results of the practicum report from the teacher by uploading a file in pdf format. The profile menu display is shown in Figure 17.

Figure 17: Student profile menu display

Third, the consultation menu. In this menu, students can conduct consultations related to problems encountered related to the learning of group I and II cation analysis practicum activities. Students can communicate in real-time with the teacher regarding the issues being consulted. The consultation menu display is shown in Figures 18 & 19.

Figure 18: Consultation menu display

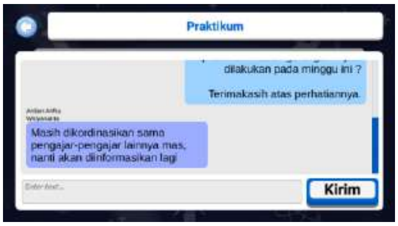

Figure 19: Chat menu display

Fourth is the glossary menu. This menu contains important chemical terms related to cation analysis practicum. The glossary menu display is shown in Figures 20 & 21.

Figure 20: Consultation menu display

Figure 22: Chat menu display

Fifth, students can access this menu as a source of knowledge or reading resources related to group I and II cation analysis experiments. The display of the material menu is shown in Figure 22.

Figure 23. material display

The validation data from the validator related to developing the virtual laboratory product shows the percentage of material content, 82.7%, indicating that the material contained in the virtual laboratory is very valid. The data from the validation results in media obtained a percentage of 87.8%, indicating that the developed media belongs to very valid criteria. From the data from the validation results, the developed virtual laboratory is feasible to use. However, revisions are still being made according to the comments and suggestions given by the validator.

One of the suggestions is that on the V-lab menu, 1) simulations or practical experiments can be carried out randomly, 2) users can experiment freely with the V-lab menu, not only just moving tools but also materials following the given procedure. Suggestions from the validator become a reference for improving the V-lab menu, and researchers have improved according to these suggestions, but it is limited to some experimental procedures.

In terms of material content, several improvements were made by the input and suggestions given by the validator, such as some pictures and chemical terms in the glossary menu, background sound on submicroscopic features, and the suitability of the animation of molecules.

After the revision process is complete, the next step is to test the product with students and teachers. Aspects assessed in this readability test include aspects of media presentation, clarity of information, program use, media effectiveness, material content presented, and the overall virtual laboratory media developed. The value of the students' readability test results obtained a percentage of 92.3%, which indicates that it belongs to the very valid criteria. In comparison, the teacher's readability test results show a percentage value of 91,1%, which also indicates that the media developed is classified in the very valid category.

The comments and suggestions given by the students stated that the virtual laboratory media developed was very good and interactive and could be used to assist practical activities in actual laboratories. In addition, students feel happy that their virtual laboratory is helped in understanding and conducting an experiment. Comments from the teacher also said that the developed virtual laboratory media was good, could be applied in schools, and could help teachers and students increase interest in learning.

2. Discussion

This application developed in addition to helping practicum activities can also help the administrative system in practicum activities. The presence of this developed virtual laboratory will later be able to fill the gaps in the natural laboratory; in other words, the developed laboratory becomes a supporter and complement to activities in a natural laboratory. Many of the benefits of developing this virtual laboratory are conveyed by several researchers as follows. Virtual laboratories have been proven to develop science process skills and improve students' understanding and memory in the experimental process (Darby-white et al., 2019) (Peffer et al., 2015). The virtual laboratory is also used as an additional medium for

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developing skills in carrying out practical activities (Bortnik et al., 2017). Virtual laboratories significantly affect students' learning motivation in practical activities (Adi & Iqbal, 2016) (Tüysüz, 2010).

The existence of an explanation of multiple representations in a virtual laboratory developed by students can observe the experimental process from macroscopic, submicroscopic, and symbolic aspects. It is supported by the statement of Herga & Dinevski's (2012) in their research, which states that virtual laboratories can be used for learning chemistry because it allows the integration of multiple representations of understanding chemistry through visualization and simulation processes in the experimental process (Herga & Dinevski, 2012). The existence of an explanation of multiple representations in the virtual laboratory helps students understand abstract chemistry concepts, especially in analytical chemistry. As revealed by Hasibuan & Sari (2018) in their research, the explanation of multiple representations in chemistry can describe abstract material and help the discovery of a concept so that it makes it easier for students to learn it (Hasibuan & Sari, 2018). Therefore multiple chemical representations are an essential component in studying chemistry. Multiple representations can build understanding to encourage students to interpret and analyze in-depth situations (Doyan et al., 2018).

An example of an explanation of multiple representations in a virtual laboratory was developed when identifying the presence of group I cations such as Pb^{2+} in a solution with a specific reagent in the form of potassium coma (K_2CrO_4). Macroscopically, the presence of Pb^{2+} ions is indicated by the presence of a yellow precipitate resulting from the reaction of Pb^{2+} ions with CrO_4^{2-} ions (submicroscopically) from K_2CrO_4 to produce a yellow precipitate of $PbCrO_4$ which can be written symbolically as follows.

$$PbCl_2(aq) + K_2CrO_4(aq) \longrightarrow PbCrO_4(s) + 2KCl(aq).$$

The virtual laboratory is not a substitute for practicum activities but is part of a natural laboratory that is used to complement and assist, as well as improve weaknesses that are difficult to overcome in a natural laboratory, as revealed by Nurrokhmah (2013) and Vasiliadou (2020) that virtual laboratories certainly cannot be used to replace practicum activities in natural laboratories because they cannot train students' processing skills (IE Nurrokhmah, 2013) (Vasiliadou, 2020). However, apart from that, the virtual laboratory can provide students with an overview of the practicum. In addition, by explaining multiple representations in this virtual laboratory, students can observe an experimental process in terms of macroscopic, symbolic, and submicroscopic aspects that cannot be observed in a practicum in a natural laboratory.

Virtual laboratories can also be combined with practical activities in natural laboratories, such as the virtual laboratory developed by (Rokhim et al., 2020). In this case, the virtual laboratory can be used as a complement to the natural laboratory. The research results of combining a real laboratory with a virtual laboratory can positively affect student learning by increasing students' knowledge (Hurtado-bermúdez & Romero-abrio, 2020). In other words, a virtual laboratory is an imitation of a natural laboratory used in the learning process to emphasize a concept or deepen the concepts of the material being studied, especially in the qualitative analysis chemistry of group I and II cation analysis.

The limitations in the research and development carried out are that the laboratory applications developed are limited to practicum material for qualitative analysis of group I and II cation analysis. In addition, the development of virtual laboratory applications cannot be carried out until the product is distributed due to time and cost limitations. Simulation of practical experiments on each procedure can not all be done randomly, they still follow the procedures that have been provided, and the treatment must be by the given procedure. However, some essential procedures can be carried out randomly or freely by mixing one substance with other substances, such as the precipitation of group I and II cations from samples and the identification test for the presence of group I and II cations. So, Students can choose the appropriate solvent or reagent for use. The following limitation is that the developed virtual laboratory application can only be used on the Android smartphone and computer/ laptop system and cannot be used on IOS systems such as the iPhone. The developed virtual laboratory application also cannot be accessed in offline mode.

D. Conclusion

This virtual laboratory media was developed to understand multiple representations in qualitative analysis practicum activities for group I and II cations. This developed product can help students understand a concept in the experiments carried out. According to experts, the research results on the development of virtual laboratory media stated that they were very valid or feasible to use, with percentage values of 87.8% and 82.7%. The results of trials by teachers and students also stated that the virtual laboratory media developed was very valid or feasible, with percentage values of 91,1% and 92.3%, respectively. The developed laboratory media products are helpful and can support practical activities.

Bibliography

Adi, W. C., & Iqbal, M. (2016). *Virtual Laboratory*. *4*(4), 130–136.

Bortnik, B., Stozhko, N., Pervukhina, I., Tchernysheva, A., & Belysheva, G. (2017). Effect of Virtual Analytical Chemistry Laboratory on Enhancing Student Research Skills and Practices. *Research in Learning Technology*, *25*(1063519), 1–20. https://doi.org/10.25304/rlt.v25.1968

Darby-white, T., Wicker, S., & Diack, M. (2019). Evaluating the Effectiveness of Virtual Chemistry Laboratory (VCL) in Enhancing Conceptual Understanding: Using VCL as Pre-Laboratory Assignment. *Journal of Computers in Mathematics and Science Teaching*, *38*(1), 31–48.

Doyan, A., Taufik, M., & Anjani, R. (2018). *Pengaruh Pendekatan Multi Representasi Terhadap Hasil Belajar Fisika Ditinjau dari Motivasi Belajar Peserta Didik*. *4*(1).

Dwiningsih, K. (2018). *Pengembangan Media Pembelajaran Kimia Menggunakan Media Laboratorium Virtual Berdasarkan Paradigma Pembelajaran di Era Media Based on the Global Era Learning Paradigm*. *06*(02), 156–176.

Dyrberg, N. R., Treusch, A. H., & Wiegand, C. (2017). Virtual Laboratories in Science Education: Students' Motivation and Experiences in Two Tertiary Biology Courses. *Journal of Biological Education*, *51*(4), 358–374. https://doi.org/10.1080/00219266.2016.1257498

Fardani, R. A., Ibnu, S., & Utomo, Y. (2017). Pengaruh Pembelajaran Inkuiri Terbimbing Berbantuan Peta Konsep Bernuansa Green Chemistry terhadap Keterampilan Bernalar Ilmiah Mahasiswa pada Materi Analisis Volumetri. *Jurnal Pendidikan Teori, Penelitian, Dan Pengembangan*, *2*(12), 1620–1624.

Fathonah, R., Masykuri, M., & Saputro, S. (2015). Pengembangan Multimedia Simulatif Kimia Berbasis Inkuiri Terbimbing pada Materi Analisis Kualitatif Kation Golongan 1. *Jurnal Inkuiri*, *4*(3), 2252–7893.

Gambari, A. I., Kawu, H., & Falode, O. C. (2018). Impact of the Virtual Laboratory on the Achievement of Secondary School Chemistry Students in Homogeneous and Heterogeneous Collaborative Environments. *Contemporary Educational Technology*, *9*(3), 246–263. https://doi.org/10.30935/cet.444108

Hasibuan, M. P., & Sari, R. P. (2018). *Penerapan Kompetensi Kimia Sma Menggunakan Pendekatan Pendidikan Kimia Pendahuluan Ilmu Pengetahuan Alam (IPA) Berkaitan dengan Cara Mencari Tahu Tentang Gejala Alam Secara Sistematis, Sehingga IPA Bukan Hanya Penguasaan Kumpulan Pengetahuan yang Berup*. *1*(2).

Hayuni retno widarti Sutrisno, Darsono sigit, octavia sulistina. (2019). *Persepsi Guru MGMP Kimia SMA dan SMK Kabupaten Malang terhadap Pembelajaran Berbasis Laboratorium dan Non Laboratorium*. *2*(1). http://journal2.um.ac.id/index.php/jki/article/view/8259/3926

Herga, N. R., & Dinevski, D. (2012). *Virtual Laboratory in Chemistry – Experimental Study of Understanding, Reproduction and Application of Acquired Knowledge of Subject's Chemical Content*. *45*(3), 108–116. https://doi.org/10.2478/v10051-012-0011-7

Hurtado-bermúdez, S., & Romero-abrio, A. (2020). The Effects of Combining Virtual Laboratory and Advanced Technology Research Laboratory on University Students' Conceptual Understanding of Electron Microscopy. *Interactive Learning Environments*, *0*(0), 1–16. https://doi.org/10.1080/10494820.2020.1821716

IE Nurrokhmah, W. S. (2013). Pengaruh Penerapan Virtual Labs Berbasis Inkuiri Terhadap Hasil Belajar Kimia. *Chemistry in Education*. https://doi.org/10.1111/j.1949-8594.1902.tb00418.x

Nadi, C. Y., Setyowati, W. A. E., & Saputro, S. (2016). Pengaruh Metode Problem Solving Secara Algoritmik Kelarutan dan Hasil Kali Kelarutan Kelas XI Mia di SMA N 5 Surakarta. *Jurnal Pendidikan Kimia (JPK)*, *5*(1), 125–133.

Peffer, M. E., Beckler, M. L., Schunn, C., Renken, M., & Revak, A. (2015). Science Classroom Inquiry (SCI) Simulations: a Novel Method to Scaffold Science Learning. *PLoS ONE*, *10*(3), 1–14. https://doi.org/10.1371/journal.pone.0120638

Purba, M. (2006). *Kimia untuk SMA Kelas XI.* Jakarta: Erlangga.

Riduwan. 2012. *Pengantar Statistika Sosial*. Bandung: CV Alfabeta.

Rokhim, D., Asrori, M., & Widarti, H. (2020). Pengembangan Virtual Laboratory pada Praktikum Pemisahan Kimia Terintegrasi Telefon Pintar. *JKTP: Jurnal Kajian Teknologi Pendidikan*, *3*(2), 216–226. https://doi.org/10.17977/um038v3i22020p216

Thiagarajan, S., Semmel, D.S., & Semmel, M .I. Instructional Development for Training Teachers of Exceptional Children: a Sourcebook. Indiana: Indiana University. ERIC (online), (https://eric.cd.gov/?id=ED090725), diakscs 28 Oktober 2020. 1974

Tüysüz, C. (2010). The Effect of the Virtual Laboratory on Students' Achievement and Attitude in Chemistry. *International Online Journal of Educational Sciences*, *2*(1), 37–53. https://doi.org/13092707

Vasiliadou, R. (2020). Virtual Laboratories During Coronavirus (COVID-19) Pandemic. *Biochemistry and Molecular Biology Education*, *48*(5), 482–483. https://doi.org/10.1002/bmb.21407

Widarti, H. R., Rokhim, D. A., Muchson, M., Budiasih, E., Sutrisno, S., Pratama, R. W., & Hakim, M. I. (2021). Developing Integrated Triplet Multi-Representation Virtual Laboratory in Analytic Chemical Materials. *International Journal of Interactive Mobile Technologies (IJIM)*, *15*(08), 119. https://doi.org/10.3991/ijim.v15i08.21573

Widowati, A., Nurohman, S., & Setyowarno, D. (2017). Development of Inquiry-Based Science Virtual Laboratory for Improving Student Thinking Skill of Junior High School. *Jurnal Pendidikan Matematika dan Sains*, *5*(2), 170–177. https://doi.org/10.21831/jpms.v5i2.16708