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Development of Triple Representation Based on Virtual Laboratory Media on the Chemical Equilibrium Experiment in Online Learning Era

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Abstract

The purpose of this research is to produce virtual laboratory media to support laboratory-based learning with the features mentioned above to make students become scientists with comprehensive understanding competencies and laboratory engineering skills. The virtual laboratory media was developed using the Lee & Owens development method consists of five stages: analysis, design, development, implementation, and evaluation. The virtual laboratory based on triplet representations on chemical equilibrium material fulfils very feasible criteria for students to use as a learning resource. The percentage of product eligibility as a learning media is 86.15%, and in terms of the material, it is 85.71%. The results of small group trials in class XI students of SMAN 3 Sidoarjo showed that the virtual laboratory developed had met the very feasible criteria with an average percentage of 86.40%. The final result of this virtual laboratory has been revised based on comments and suggestions from validators and test subjects. Practically, the media developed is very useful to support practicum learning.

Keywords: virtual laboratory; triple representation; chemical equilibrium

Abstrak

Tujuan dari penelitian ini adalah untuk menghasilkan media laboratorium virtual untuk mendukung pembelajaran berbasis laboratorium dengan fitur-fitur tersebut di atas untuk menjadikan mahasiswa menjadi ilmuwan dengan kompetensi pemahaman dan keterampilan teknik laboratorium yang komprehensif. Produk media laboratorium virtual yang dikembangkan dengan menggunakan metode pengembangan Lee & Owens yang terdiri dari lima tahap yaitu assessment/analisis, design, development, implementasi, dan hasil evaluasi di hasilkan bahwa laboratorium virtual berdasarkan representasi triplet pada materi kesetimbangan kimia memenuhi kriteria sangat layak untuk digunakan sebagai sumber belajar bagi siswa. Persentase kelayakan produk sebagai media pembelajaran sebesar 86,15% dan dari segi materi sebesar 85,71%. Hasil uji coba kelompok kecil pada siswa kelas XI SMAN 3 Sidoarjo menunjukkan bahwa laboratorium virtual yang dikembangkan telah memenuhi kriteria sangat layak dengan persentase rata-rata 86,40%. Hasil akhir dari laboratorium virtual ini telah direvisi berdasarkan komentar dan saran dari validator dan subjek uji. Secara praktis, media yang telah dikembangkan sangat bermanfaat untuk menunjang pembelajaran praktikum.

Kata kunci: laboratorium virtual; representasi ilmiah; kesetimbangan kimia

Introduction

The use and application of Information Technology have increased every year. It has triggered the development of innovation in education to integrate technology to improve the quality of education (Rahmani et al., 2017). Technology facilities allow the provision of material outside the classroom, and application and feedback are carried out (Esson, 2016), especially on science material. One example of technology in science education is software such as Moodle, Wiki, Edmodo, or other e-learning media (Franklin & Smith, 2015), which supports mastery of 21st-century skills (Kimianti & Prasetyo, 2019). The 21st century is marked by the rapid development of science and technology, so science and technology are an essential foundation in nation-building. One of the technological developments that underlie the development and advancement of science is chemistry. Chemistry is a branch of science that is very close to practicum activities in learning to provide meaningful learning experiences (Bortnik et al., 2017).

Practicum is an activity to provide understanding to students about a material. Students can understand and solve problems related to concepts taught in class and gain a deep understanding through the scientific process in practicum activities (Lang, 2012; Makransky et al., 2016). Practicum is significant to support theoretical explanations in chemistry learning (Kurbanoglu & Takunyaci, 2021). Practical activities in chemistry learning are generally practicum types at the level of confirmative inquiry, which carry out practicum activities based on problems, procedures, analysis techniques, and data interpretation that have been prepared by the teacher in the form of practical manuals (Seery et al., 2019). But in its implementation, it is not uncommon for practicum to have obstacles that result in practicum activities not running optimally, such as inadequate tools and materials and limited time so that students do not understand the practicum process that has been carried out. These things cause teachers to replace practicum activities or do demonstrations not to understand and master the material. According to Herga et al. (2016), one of the efforts that can be made to reduce these obstacles is by utilizing visualization elements.

Visualization can help students overcome difficulties in understanding the submicroscopic level in chemistry. Visualization techniques can be applied through interactive multimedia. Interactive multimedia is a medium composed of various visual components that can make it easy for users to build and understand the concept of a science or material. According to Fathonah et al. (2015), interactive multimedia combines several media elements such as images, text, animation, audio, video, etc., which are synergistic and symbiotic into a single unit resulting in the ultimate benefit of one of the media elements. Another opinion was expressed by Muchson et al. (2019) that activities involving interactive multimedia are expected to improve the construction process of students in understanding the concept. Based on these expert opinions, interactive multimedia can improve concept understanding, critical thinking skills, and genetic science skills. One of the interactive multimedia is a virtual lab.

Virtual labs are a form of visual media that can make it easy for students to learn chemical material independently and help students understand higher cognitive levels of analysis, synthesis, and evaluation (Dyrberg et al., 2016; Rokhim et al., 2020). This is in line with Muchson et al. (2019) that the virtual lab can be an alternative solution that helps students understand concepts through practicum simulations. Each visual media has advantages and disadvantages as well as virtual labs. According to Rosen et al. (2020), virtual labs can provide freedom of time and place in their implementation and reduce constraints in the laboratory. Another advantage put forward by Kolil et al. (2020) is that virtual labs can be used as safe and affordable media or teaching facilities.

The development of a virtual lab can become one of the technological updates in education by using applications on

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computers and laptops as learning media. The development of computer technology makes virtual labs accessible on computers or notebooks based on Windows or Mac OS. Without the need for the internet, easy to carry everywhere and can be learned anytime and anywhere. To facilitate students in learning and improve understanding of concepts in cognitive aspects. The advantage of virtual labs is that they can make it easier for students to learn and enhance conceptual or cognitive understanding. Meanwhile, the weakness of the virtual lab is that it can only be run on specific systems and does not emphasize psychomotor processes. The development of a virtual lab as a learning medium to improve students' conceptual understanding can be maximized by integrating three levels of representation, also known as triplet representation.

In chemistry, triplet representation is at the macroscopic, sub-microscopic, and symbolic levels (Zidny et al., 2015). Macroscopic aspects in chemistry can be shown in changes in the colour of solutions, changes in the shape or physical form of a substance, and the appearance of deposits. Sub-microscopic aspects are how the movement or interaction between molecules, elements, or ions is involved in a reaction. While the symbolic aspect can be shown in the relationship of a variable or reaction result through graphs of reaction equations. Combining the three levels in the virtual lab will improve students 'understanding of chemistry concepts and develop students' experimental skills so that students have the concept of chemistry with the same results by doing practical or direct experiments in the laboratory (Astuti & Mulyatun, 2019).

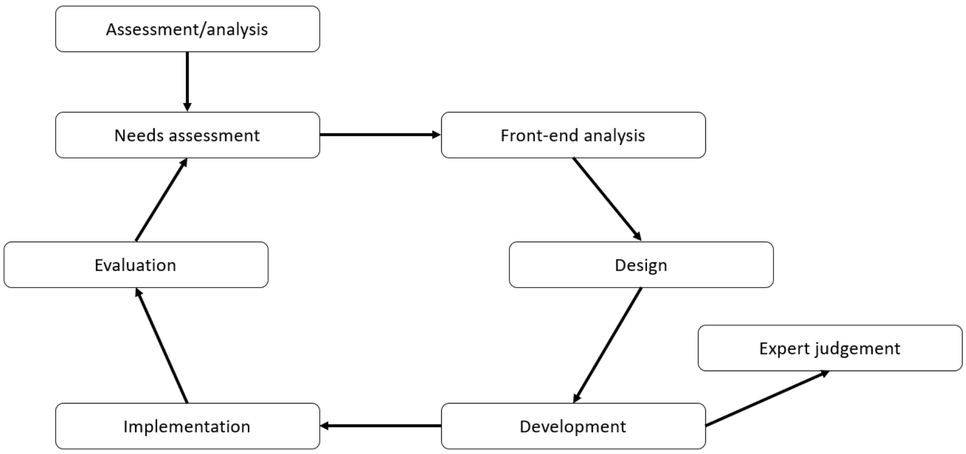
One of the materials in general chemistry practicum at the school level is chemical equilibrium. Chemical equilibrium requires simple concepts to build more complex concepts (Indriani et al., 2017). In addition, in the learning process, students still lack an understanding of the basic concepts of chemical equilibrium material. They tend to remember that learning the concept can be done in class and need to be done in the laboratory by doing a practicum. In chemical equilibrium material, students must understand concepts in the form of an equilibrium constant, determining the direction of the equilibrium reaction and the factors that affect chemical equilibrium. The existence of practicum in this material will make students better understand the verbal concepts that have been conveyed by the teacher in learning in the classroom. Some cases often appear in chemical equilibrium practicums: are that not all practicums that discuss chemical equilibrium can be done, especially practicums that involve substances with a gas phase, besides that students still feel that they are lacking in writing the discussion according to the practicum carried out, there are still errors in writing the equation reaction and determine the direction of the shift in the equilibrium reaction. As previously discussed, every practicum has obstacles. Therefore researchers try to overcome these obstacles by implementing a triplet representation-based virtual lab to maximize students studying chemistry, especially in chemical equilibrium material, which can be accessed via computers or laptops and learned anywhere.

This research aims to produce a virtual lab media consisting of visual elements in the form of a game to build students' interest in understanding the concept of chemical equilibrium practicum and present the three levels of representation on the macroscopic submicroscopic and symbolic.

Research Method

This research is a research development (research development). This research produced a virtual lab learning media product based on triplet representations. The development model used in this study is the development model according to Lee & Owens (2004: 3). This development model is a multimedia learning design model that includes five stages: analysis, design, development, implementation, and evaluation. The flow chart for research and development is shown in Figure 1.

Figure 1
Media Development Procedure for Adaptation of Learning Multimedia Design Model According to Lee & Owens (2004: 3)



The analysis has two main stages: assessment, interview with the teacher to convey a concept, finding out learning practices, and students' conceptual understanding. Analysis interviews with students at SMAN 3 Sidoarjo revealed that some students had difficulty understanding the chemical equilibrium material, and the learning media was less interesting. The researcher concludes that it is necessary to develop virtual lab interactive learning media combined with three levels of chemical representation.

The technology used to support this development is based on the technical analysis carried out by at least a Windows 7 computer and Mac OS. At the same time, the sub material in the virtual lab is determined from a review of material from various literature, namely basic chemistry books on specific materials in chemistry.

The learning achievement objectives are arranged through the objective analysis stage, which includes several indicators of learning achievement that prioritize cognitive aspects rather than psychomotor aspects, namely: (1) explaining the concept of equilibrium; (2) understanding the conditions for chemical equilibrium reactions; (3) analyzing the influence of factors that influence the shift in the direction of the equilibrium reaction; and (4) analyzing and concluding the experimental results of chemical equilibrium reactions. In the next stage, media analysis shows that the virtual lab being developed will be packaged in an application with the final EXE format that can be run on Windows and Mac OS computers. The Virtual Lab that will be developed will contain a chemical equilibrium practicum simulation accompanied by a pretest and posttest consisting of a combination of interactive media components in the form of text, images, sound, and animation. This analysis made considerations in choosing the Adobe Flash CS5 and Adobe Illustrator programs to display existing features in the developed virtual lab. These programs were quite effective in presenting the concepts and content provided in the virtual lab.

The second stage is the design which consists of designing the material structure with a virtual lab—starting from implementing the pretest, the practicum simulation, posttest stages and feasibility testing of media and material aspects by experts.

The third stage is development, making storyboards that aim to design and present every view contained in the virtual lab development and programming stage, which aims to determine which programs can be used in Adobe Flash CS5 and Adobe

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Illustrator applications published in EXE format.

The fourth stage is implementation, which aims to assess the feasibility of the media and the feasibility of the material. The feasibility assessment is carried out by experts in chemistry and experts in the field of digital learning media. The data collection instrument used was a questionnaire containing a checklist, comments, and suggestions column, which included a media and material feasibility assessment questionnaire and a test questionnaire for teachers and students using a five-level Likert scale shown in Table 1.

Table 1
Likert Scale Criteria

Score	Criteria
1	The media has not good / not appropriate / not easy / unclear / invalid / uninteresting criteria
2	The media has not too good / less appropriate / less difficult / less clear / less valid / uninteresting criteria
3	The media has pretty good / appropriate / easy / clear / valid / interesting criteria
4	The media has good / appropriate / easy / clear / valid / interesting criteria
5	The media has very good / very appropriate / very easy / very clear / valid / very interesting criteria

Types of data obtained from the results of the feasibility assessment are quantitative and qualitative data. Quantitative data were obtained from the score of the feasibility assessment questionnaire arranged in a five-level Likert scale. Qualitative data was comments and suggestions from experts with data analysis techniques in percentages with eligibility criteria based on Table 2.

Table 2
Eligibility Criteria

Percentage (%)	Eligibility Criteria
0-20	Poor
21-40	Bad
41-60	Adequate
61-80	Good
81-100	Very good

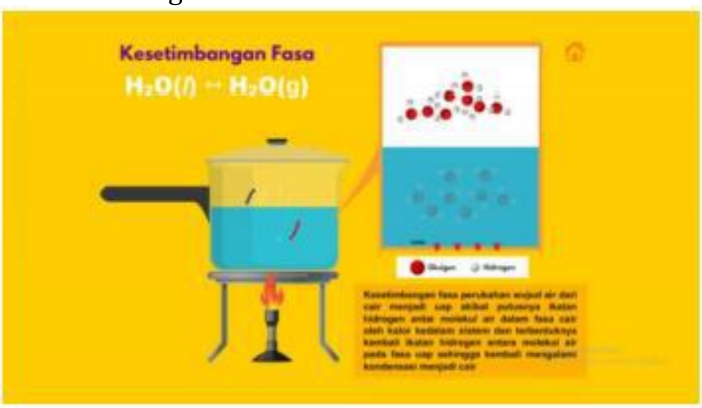
Virtual lab media that have passed the feasibility assessment then revised based on comments and suggestions from experts to obtain a better virtual lab. Products that have been fixed then tested on a limited basis for science class students of SMAN 3 Sidoarjo to get assessments from students regarding media presentation, clarity of information, levels of usefulness, and ease of virtual use developed lab. The last stage is evaluation (evaluation) aims to evaluate virtual lab products designed and oriented at the feasibility level of product development through media feasibility assessment, material feasibility assessment, and product trial results.

Results and Discussion

The results of developing a triplet-based virtual lab representation of Chemical Equilibrium Material in the form of interactive simulations are packaged in EXE format, which contains interactive simulations equipped with explanations based on triplet representation aspects, namely macroscopic, submicroscopic, and symbolic. The first main menu is the material menu which consists of several materials or theories that underlie the topic of chemical equilibrium before users can carry out practicum simulations. The purpose of the material menu is to provide students with initial or basic knowledge on specific topics to know how to learn the concepts before doing a practicum. The Material Menu page consists of the initial material page, material 1, material 2, material 3, and simulation. The start-up page consists of material that discusses the definition of a chemical equilibrium reaction and its characteristics, as shown in Figure 2, and particulate simulations that describe the submicroscopic reaction in Figure 3.

Figure 2
Main Menu Page

Figure 3
Simulation Page



The second main menu is the factor menu for the shift in the chemical equilibrium direction, which provides information to students about how the system can adjust its reaction state if there is a disturbance given to a balanced system. The trouble in question is temperature, concentration, volume, and pressure. The equilibrium shift factor menu consists of the direction menu, the pretest, the temperature fluctuation factor, the concentration addition factor, the volume and pressure addition factor, and the simulation of each factor. A pretest on this menu aims to determine students' initial abilities before learning a concept in the chemical equilibrium practicum. The factor menu page for the shift in the direction of chemical equilibrium is shown in Figure 4, the pretest page is shown in Figure 5, and the sample page for the factor simulation is shown in Figure 6.

The third main menu is the practicum simulation menu which is the core part of the virtual lab that presents interactive practicum simulations that resemble the actual practicum. This practicum simulation aims to assist students in understanding the procedures and concepts of chemical equilibrium material. The practical simulation consists of four practicums, namely the effect of adding $FeCl_3$, KSCN, and HCl solutions on the equilibrium of the $[Fe(SCN)_6]^{3-}$ complex, the effect of adding $CuSO_4$, NH_3, and HCl solutions to the equilibrium of the complex $[Cu(NH_3)]^{2+}$, practicum the effect of adding NaOH, $CaCl_2$, and HCl solutions to the equilibrium of a saturated $Ca(OH)_2$ solution and practicum the effect of adding NaOH and HCl solutions to the equilibrium of the HIn indicator solution. Each practicum is equipped with a discussion based on three aspects of representation: the change in the colour of the solution and the appearance of the sediment (macroscopic), the interaction between elements, molecules and ions (submicroscopic), the relationship between variables and the reaction equation and the pH range (symbolic). An example of a practical simulation page is shown in Figure 7. While an example of a discussion page that shows three aspects of triplet representation is shown in Figure 8.

Figure 4
Chemical Equilibrium Shift Menu Page

Figure 5
Pretest Page

The last main menu contained in the virtual lab is the posttest menu. A posttest is given to measure the knowledge that students have achieved after conducting a chemical equilibrium practicum simulation consisting of several questions that students must answer. After working on all the posttest questions, students can see the final results according to the questions that have been answered to find out their abilities after using and studying the material using the virtual lab. The posttest page is shown in Figure 9.

The results of the feasibility assessment of the development product in terms of learning media were found to be 86.15%. If a comparison is made with the eligibility criteria shown in Table 2, the development product as a learning medium is included in the very feasible criteria. Meanwhile, the results of the feasibility assessment of the product developed in terms of material obtained were valued at 85.71%. If a comparison is made with the eligibility criteria shown in Table 2, the development product as a learning medium is included in the very feasible criteria.

Figure 6
Example of Factor Simulation Page

Figure 7
Example of Practicum Simulation Page

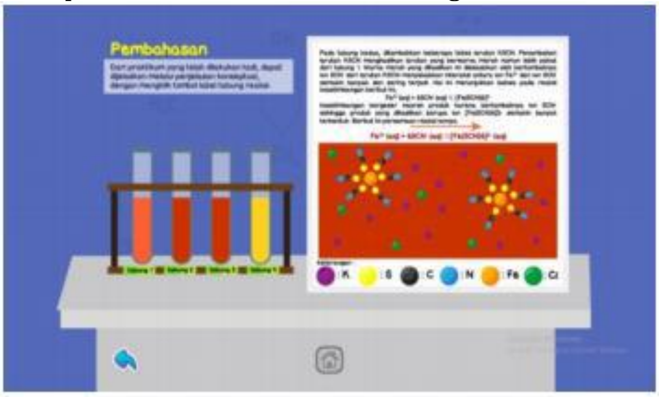
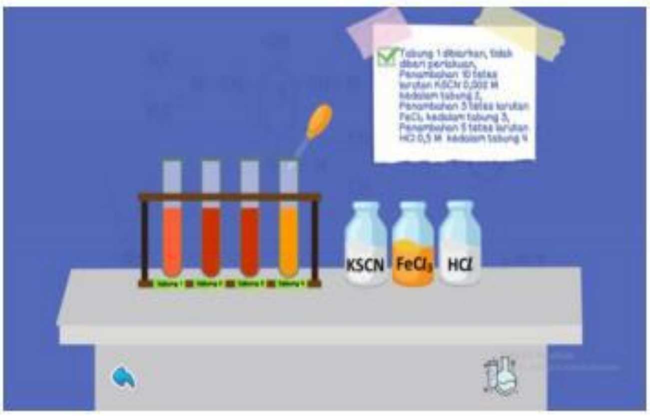
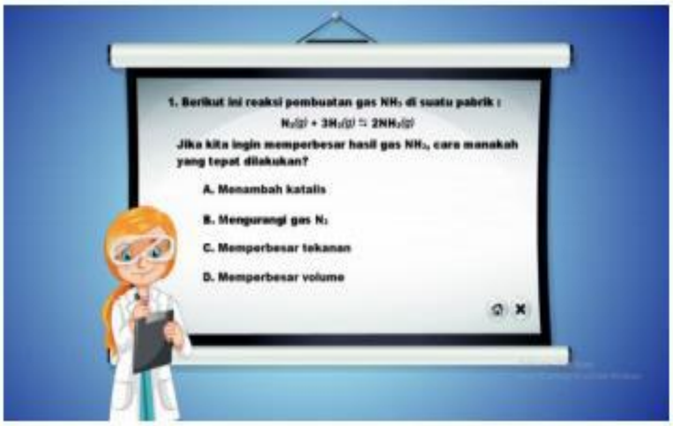


Figure 8
Example Discussion Page



In addition to obtaining data on feasibility results, an assessment of the correctness and accuracy of the concept was also obtained in the form of a yes and no assessment instrument. The material in developing products based on yes and no assessment instruments is entirely correct in concept. Small group trials were carried out using development products that had passed the revision stage based on comments and suggestions from experts. The test subjects were science class students 10 grade at SMAN 3 Sidoarjo. The feasibility of developing products based on the trial results was 86.4%. The data from the small group trial results in an average value of 86.40%, which indicates that the development product has met the very feasible criteria.

Figure 9
Posttest Menu Page



Based on the revised virtual laboratory product, the advantages it has to include: the virtual laboratory media for chemical equilibrium practicum contains representative triplets in chemistry, and there are operational instructions in this virtual laboratory so that users can operate independently, there are pictures, videos, and animations that can help students understand the material. Based on the research results Mamang et al. (2020), it is known that 84.62% of students stated that video could help increase their understanding of the subject matter taught by the teacher. So, the use of videos in learning is feasible and effective.

In addition, the advantages of this virtual laboratory are attractive, equipped with evaluations that the results can be known directly, and virtual laboratories can help teachers in practicum learning or are used by students integrative learning resources. These advantages can support the needs of students in independent learning where students can repeat the practicum as often as desired because generally, the speed of learning for each student is different. Faour & Ayoubi (2018) suggests that virtual labs allow students to repeat poorly understood simulations or as reviews for exams and can support the ability to do lab work with things that are too dangerous and take too long to be done in the laboratory. This research is also reinforced by research by Achuthan& Murali (2015) that users can repeat virtual lab simulations many times.

Repeating the practicum also becomes more efficient because it does not require additional tools or materials. It is confirmed by the opinion of Jong et al. (2013), which states that practicum that is done virtually is more efficient than physical practicum because it requires shorter time with correct instant results. As a result of virtual use in pre-lab, students' activities during practicum become smooth (Nolen & Koretsky, 2018). In chemistry learning, virtual labs represent chemical concepts (including multiple representations), and students' self-preparation for practicum becomes mature (Kollöffel & de Jong, 2013). The advantage of virtual labs is that they can display visual models to reach concepts with representations down to the submicroscopic level, which is expected to support and improve students' conceptual understanding through practicum activities, especially chemical equilibrium material.

These advantages are generally not owned by conventional laboratories. Dalgarno et al. (2012) stated that virtual labs had been used for two purposes of learning chemistry. First, a virtual lab is used to show and provide chemical concepts to students in visual representations. Second, the virtual lab is used to prepare students for laboratory activities. This statement is corroborated by the opinion of Herga et al. (2016) that the use of a virtual lab that presents visualization at the sub-microscopic level can act as a way to attract students' interest in learning a concept that is considered boring. Through simulation exercises doing practicum using virtual labs, students are expected to be better prepared when doing a practicum in real laboratories. When real laboratory learning is facilitated with a virtual lab, students become more aware of the details of laboratory procedures or techniques being worked on (Khairudin et al., 2019). In addition to making practicum time more efficient, students are also more focused on developing higher-order thinking skills. This virtual laboratory for chemical equilibrium practicum will have meaningful uses if teachers and students already know how to operate the Virtual laboratory. In addition, teachers should guide or observe students in using virtual laboratories in class so that learning runs effectively. A virtual laboratory requires internet access, so it is highly recommended to provide internet / Wi-Fi access in the classroom for virtual laboratory operations. This virtual laboratory is suitable for Senior High School (SMA) / Vocational High School (SMK) by paying attention to the characteristics of students and the school concerned. This virtual laboratory can provide additional information and insight to teachers or academics engaged in chemistry.

Conclusion

Based on the data analysis and discussion results, the developed virtual lab is a simulative application accompanied by a pretest and posttest. The initial part of the virtual lab consists of a start page with four main menus, namely material, equilibrium factors, practicum, and pretest. The content consists of simulations of each factor that affect chemical equilibrium: volume and pressure factors, temperature factors, and concentration factors accompanied by discussions that discuss macroscopic aspects such as changes in gas or solution colour, submicroscopic aspects that show reactions at micro-level and symbolic aspects in the form of reaction equations and pH ranges that can assist users or students in building basic concepts about chemical equilibrium. The final part of the virtual lab consists of posts and pages about the developer profile and help pages or information from the virtual lab. The feasibility of a triplet representation-based virtual lab product in the chemical equilibrium lab showed the feasibility of the product as a learning medium with an average percentage value of 86.71%.

In comparison, the product feasibility results in the material were 85.71%. Based on the results obtained, the development product has met the very feasible criteria in terms of media and material aspects. In the small group trial, the virtual lab showed an average percentage of 86.40%, which indicated that the virtual lab had very appropriate criteria as a student learning resource. Thus, it can be concluded that the triplet representation-based virtual lab in the chemical equilibrium practicum is very feasible to be used as a source of student learning.

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