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Virtual Cosmetic Chemistry Lab Design for Bilingual STEAM-Based, Disability-Friendly Learning to Enhance Adaptive Skills

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Abstract: Digitalization is growing rapidly along with the development of industrial revolution 4.0 and society 5.0. One of these digitalization products is a digital platform. Current advances in educational technology to improve the quality of learning in educational institutions include using PhET (Physics Environment Technologies) which is a type of virtual laboratory. This research aims to produce a development product in the form of a FORCHEM (Formulation Chemistry Learn and Challenge) application in Virtual Laboratory with a bilingual class system on cosmetic chemistry material at high school level. The research method used is RnD to produce certain products and test the effectiveness of these products in relation to scientific literacy, and FORCHEM innovative learning platform is designed in the form of a virtual laboratory-based application with an online bilingual class system which is equipped with several superior features, one of which is the virtual lab feature and SiBi Microteaching in it, in addition to transferring knowledge and implementing it, it also introduces and brings generation Z into entrepreneurship through the creation of cosmetic products. which is carried out and provides character values in the midst of area megatrends, in order to form a golden generation in 2045 through expanding opportunities for access to higher and better quality education. FORCHEM is able to form 4C (Critical Thinking and Problem Solving, Communication, Creative and Innovation, and Collaboration) through scientific literacy, as well as innovative learning platforms that are disability-friendly and sustainable.

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1. INTRODUCTION

Digitalization is growing rapidly with the development of the Industrial Revolution 4.0 and Society 5.0. One product of this digitalization is the digital platform. A platform, simply put, is a platform for running a system with a pre-planned program [1]. These platforms have covered various fields, including communication, education, and economics. The development of platforms has increasingly facilitated communication. Digital educational and buying and selling activities through platforms are popular with the public due to their ease and practicality [2] [3]. The rapid development of platforms has prompted technology experts to further develop platforms, namely digital platforms [4]. A digital platform is a collection of software that runs a specific system. These digital platforms can be run on PCs or Android devices in the form of applications. Since then, many digital platforms in the form of applications have become freely available. The public can freely use these various applications to meet their needs [5].

The development and advancement of science and technology can produce new innovations for students' knowledge and skills [6] [7]. The development of educational technology is considered ideal if it can be used comprehensively, including for people with disabilities. They have equal opportunities to develop their potential through quality, technology-based inclusive education. Curriculum, teachers, and the learning process are key components of successful education [8]. Every learning requires approaches, techniques, and learning resources that can influence students [9]. This is done to ensure that student achievement improves and the expected national education goals are achieved [10]. Many materials in science learning require experimental activities to achieve learning objectives, thus improving the quality of education, as is the case in practical and theory-based science learning in improving the quality of science learning. According Saleh et al., [11] and [12] reported that some schools do not conduct practicums due to teachers' lack of awareness of the importance of conducting practicums to practice skills and the lack of availability of necessary tools and materials. As a result, students do not gain the experience and knowledge expected from practicums. Virtual experiments present virtual practicums operated by computers. This type of experiment allows each student to overcome the limitations of real-world experiments. One type of virtual laboratory that improves the quality of learning in educational institutions is PhET (Physics Environment Technologies).

Virtual laboratories present interactive science situations assisted by computer applications, such as science experiment simulations [13], [14]. Virtual laboratories can be used to support the learning process and improve student understanding of the material [15]. Teachers can also anticipate student unpreparedness in a real-world laboratory. A virtual laboratory, according to [16], is an interactive experience in which students observe and manipulate items, systems, data, or phenomena to achieve learning objectives. According to [17], this virtual laboratory is superior because it can be used anywhere and anytime, requires no tools or chemicals, and allows for molecular analysis, such as the use of cosmetic-grade ingredients. The dosage of added ingredients must comply with BPOM and halal certification standards, and the impact on skin health and the environment must be taken into account. Therefore, it can be considered with consideration of criticism, suggestions, and so on. Furthermore, teachers and parents can help find references regarding ingredient use and

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appropriate dosages by considering ingredient composition data, as well as testing the quality of cosmetics required to meet BPOM and halal certification requirements [18]. Continuous learning not only improves students' practical skills but also provides education that can foster a creative generation through the products they create. One example is providing education on cosmetic product creation through a virtual laboratory based on cosmetic chemistry, including a cosmetic manufacturing guide. This is due to the high demand for cosmetics in the public and supports the creation of a creative generation through the creation of cosmetic products.

Cosmetic supplies are increasing along with the encouragement the growth of the cosmetics industry in Indonesia [19]. This will result in an increase in the number of types and brands of cosmetics available on the market. One ingredient that needs to be anticipated in cosmetic products is mercury, commonly found in products such as lotions, body scrubs, and lipsticks. Mercury is a heavy metal that is toxic and carcinogenic, harmful to human skin. In addition to mercury, synthetic dye additives that are often misused, such as Rhodamine B, have negative impacts on internal organ health, such as disrupting liver function and being carcinogenic, harmful to internal organs. Furthermore, hydroquinone can cause hyperpigmentation and skin irritation [20]. One preventative measure that can be taken to educate the public and students about the use of hazardous cosmetic ingredients is by providing guidance on the use of cosmetic-grade ingredients, considering the correct dosage, how to use cosmetics, and producing safe, skin-friendly cosmetics.

Education that can also assist people with disabilities through the use of virtual cosmetic chemistry laboratories, so that students not only have the ability to understand the material but also to implement and create products based on their learning. Thus, "FORCHEM" was created as a digital-based renewable learning media designed in the form of a virtual laboratory-based application with a bilingual (Indonesian-English) online class system equipped with several superior features, one of which is the virtual lab feature and SiBi Microteaching for deaf users in it, in order to transfer knowledge and introduce and bring generation Z to entrepreneurship through the creation of cosmetic products that are carried out and provide character value provisions in the megatrend era. This research aims to produce a development product in the form of a FORCHEM (Formulation Chemistry Learn and Challenge) application in a Virtual Laboratory based on a bilingual class system with a virtual laboratory presentation on high school chemistry material to improve understanding not only in theory but also in practice to create products in the megatrend era targeting high school students who receive high school cosmetic chemistry material.

2. METHODOLOGY

The development of FORCHEM (Formulation Chemistry Learn and Challenge) media in a virtual laboratory using a bilingual class system for cosmetic chemistry at the high school level used quantitative and qualitative approaches. The research method used was Research & Development, employing the five stages of development from the Lee and Owens model, which include analysis, design, development, implementation, and evaluation, as shown in Figure 1.

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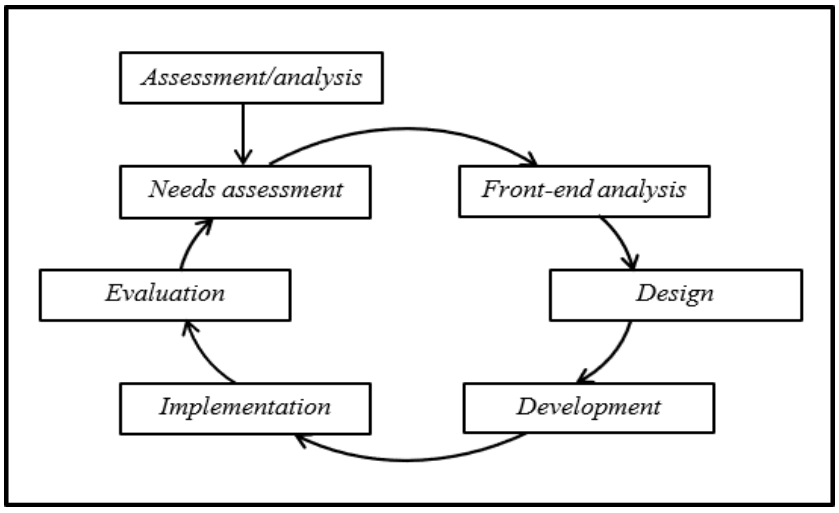


Figure 1. Lee and Owens Development Model (Source: [21])

Detailing each stage will facilitate understanding the context of the problem, needs, and determining the appropriate interactive multimedia for development [22]. Furthermore, it facilitates the determination of each research procedure to be undertaken.

Implementation Stage

The media implementation stage was conducted using a quasi-experimental method with a nonequivalent pretest and posttest control group design. The population of this study were students of SMA Negeri 2 Pasuruan, SMAN 4 Pasuruan, and SMAN 6 Malang with research samples of grades X-XII spread across SMA Negeri 1 Purwosari, SMA Negeri 2 Pasuruan, SMAN 4 Pasuruan, and SMAN 6 Malang with the number of samples of each institution as many as 104 students with 5 students with hearing impairments divided into 3 classes, namely class X MIPA 1, XI MIPA 2, and XII MIPA 7. The control and experimental classes were determined by random sampling with a draw after an equivalence test using ANOVA. The negative control class was taught conventionally with the method of providing an explanation of the material as a whole and a test was conducted to test students' understanding (guided inquiry) [23], the positive control class was taught using the FORCHEM virtual practicum based on the bilingual system. The FORCHEM media implementation research design is shown in Table 1.

Table 1. Research Design Implementation Stage

Pre-test	Treatment	Post-Test
O1	Guided Inquiry-Based Practical Work	O2
O3	FORCHEM (Virtual Laboratory & Bilingual Class System)	O4
O5	Guided Inquiry-Based Conventional Work	O6

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Note:

1. FORCHEM virtual laboratory and bilingual class system: using virtual laboratory media + materials
2. FORCHEM media: class using practical work media (positive control).
3. Conventional: class not using practical work media (negative control)
    a. O1, O3, and O5: pre-test scores for cognitive learning outcomes
    b. O2, O4, and O6: post-test scores for cognitive learning outcomes and retention

Data collection process for cognitive learning outcomes and retention the students were drawn from the pretest results of the experimental and control classes. Learning was then conducted using the developed interactive multimedia. During the learning process, observers followed the learning process to determine the effectiveness of the learning. After the learning process, students were given a questionnaire to assess their responses to the developed interactive multimedia, and a post-test was conducted to assess cognitive learning outcomes in the experimental and control classes. A retention test was conducted two weeks after the post-test. The data analysis technique used in the implementation of interactive multimedia was descriptive quantitative. The average score given by the validator was calculated to determine the validity and practicality of the media. Data analysis used inferential statistics, analysis of covariance (ANOVA), with a 5% significance level, was performed using SPSS 23.0 for Windows. If the ANOVA results were significant, the BNT test was conducted. Before analyzing the data using ANOVA, normality and homogeneity of variance were tested. Normality was tested using the One-Sample Kolmogorov-Smirnov test, and homogeneity was tested using the Levene Test of Equality of Error Variances.

Evaluation Stage

The evaluation stage aims to assess the media and the processes implemented. This stage will determine the evaluation criteria used and select the evaluation tools. The evaluation stage encompasses various considerations in assessing the evaluation, both from the perspective of learning media and educational technology, as follows:

Determining Evaluation Criteria

Evaluation criteria are determined at each development stage. In the analysis stage, the needs analysis questionnaire is evaluated. In the development stage, validation is conducted by subject matter experts, media, questions, and field practitioners. In the implementation stage, pre-test and post-test results are measured, as well as the effectiveness of the learning process.

Media Validation

Media validation is conducted using a material and media feasibility assessment rubric based on Table 2. The validation results qualification criteria are measured by measuring the level of validity based on the percentage obtained to determine whether revisions are necessary.

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Table 2. Validation Results Qualification Criteria

No.	Percentage	Validity Level
1.	X=100	Very valid, can be used without revision
2.	80 >X < 100	Valid, can be used with minor revision
3.	60 >X < 80	Less valid, not recommended for use, moderate revision
4.	40 >X < 60	Invalid, major revision, should not be used
5.	20 >X < 40	Very invalid, should not be used, major revision

Source: [24]

Implementation of Learning Syntax

Measurement of the implementation of learning syntax uses the percentage of implemented learning steps based on the results of the implementation observation sheet for learning syntax. The implementation criteria for learning syntax are shown in Table 3 [25].

Table 3. Criteria for Implementation of Learning Syntax

No.	Percentage of Implementation	Validity Level
1.	76% - 100%	Very Valid
2.	51% - 75%	Valid
3.	26% - 50%	Less Valid
4.	1% - 25%	Not Valid

Implementation Results

The pre-test and post-test results of student learning outcomes consisted of 20 multiple-choice questions and 5 essay questions. Knowledge improvement can be determined through effectiveness testing. Effectiveness testing was obtained from the pre-test and post-test results of scientific reasoning and cognitive learning outcomes. These results were tested using the Anacova test. This test was used to determine whether there were differences in the sample groups after being given the treatment. The purpose of conducting pre-tests and post-tests was to evaluate student learning outcomes.

Evaluation

Evaluation activities were conducted at each stage of development using the results of data analysis obtained to determine the achievement of development objectives and follow-up actions taken to improve the developed media.

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3. RESULTS AND DISCUSSION

FORCHEM in the Virtual Laboratory



Figure 2. Initial Display and Menus in FORCHEM



Figure 3. Internal Display Design of FORCHEM

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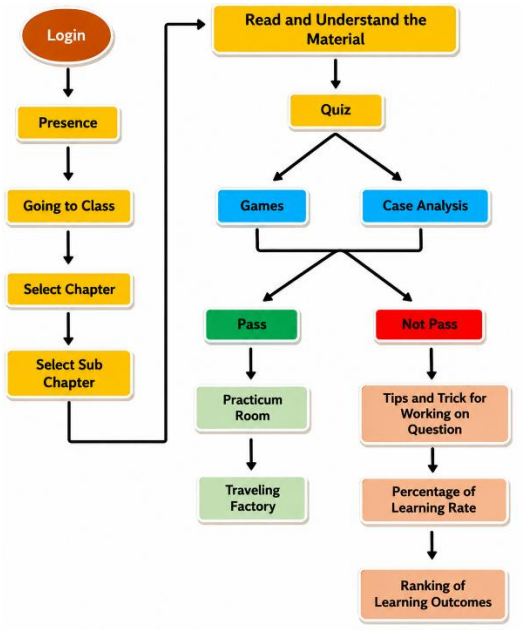


Figure 4. FORCHEM Programming in the Virtual Laboratory

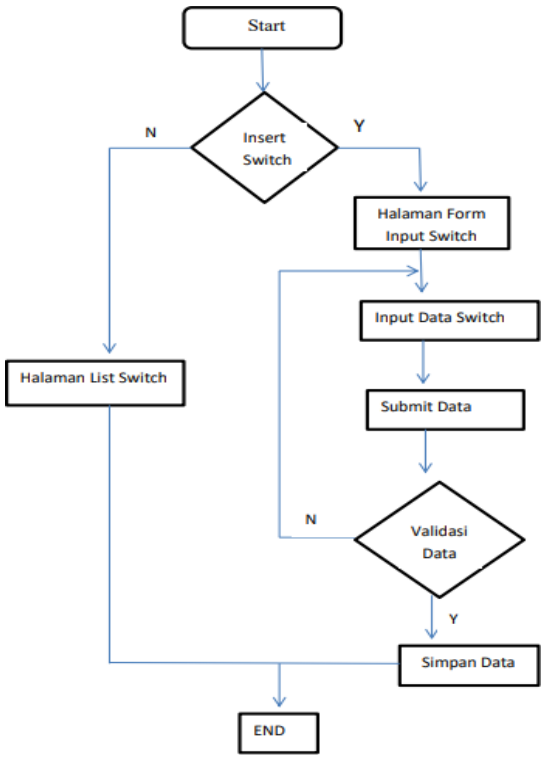


Figure 5. Switch Flowchart

Based on Figure 3 (switch flowchart), the validation used is input validation to check whether the inputted data meets the requirements and to validate whether the inputted data does not already exist in the database to avoid data redundancy. After the validation process, the data will be saved in the database.

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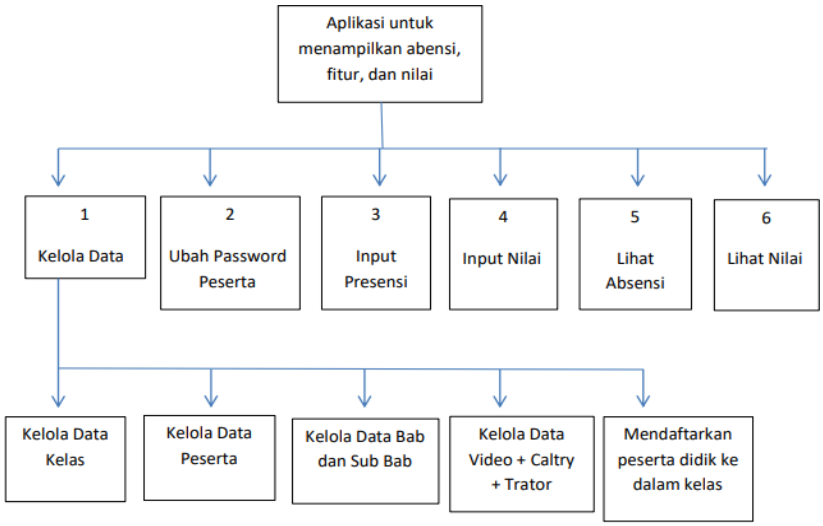


Figure 6. Decomposition Diagram

Based on the decomposition diagram, the goal is to make it easier for students to use the FORCHEM in the Virtual Laboratory website to solve or study chemistry material in a well-structured manner. Furthermore, the application of this diagram addresses issues, particularly in chemistry learning, that are considered difficult, and facilitates understanding through the website.

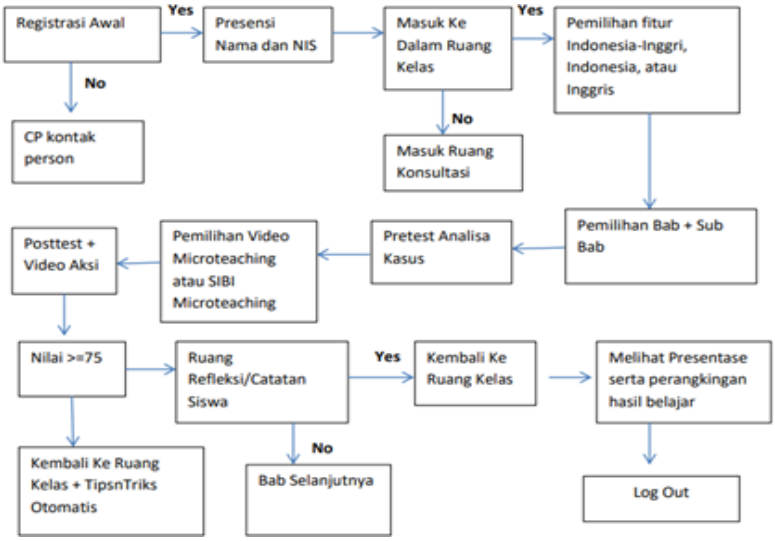


Figure 7. Participant Flowchart in Virtual Laboratory

Based on the flowchart, it helps students process data when using the FORCHEM in Virtual Laboratory website, ensuring that new students are not confused in its application. FORCHEM in Virtual Laboratory is an interactive, website-based learning application designed to resemble an international classroom, specifically in the field of chemistry. It aims to develop a generation of intelligent, active, and responsive young chemists in facing challenges and supporting the sustainability of the 2030 SDGs by providing theoretical knowledge, applied concepts, and introducing Indonesian local wisdom through engaging chemistry materials. This is one of the goals of sustainable education, as shown in Figures 6

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and 7. FORCHEM in Virtual Laboratory is a virtual laboratory designed and provided for all high school students in chemistry learning.

Digital Technology Product Design

Use of Dual Language Features

FORCHEM was designed as an online international class implementation for high school students specifically for structured chemistry subjects. Therefore, the use of dual language features, Indonesian and English, is an innovation unprecedented in Indonesia for virtual laboratories.

Classroom Attendance and Mini Library

Upon opening the application, there is a classroom feature. Each student entering the class after registration must complete a learning reflection before proceeding to the next feature, with the goal of making their learning methods and time more effective and efficient. The classroom is equipped with a mini library that stores several chemistry-related journals, both domestic and international, that can be accessed. A video of the Attendance and Classroom features can be accessed through the following link: https://bit.ly/3MKwYmM.



Figure 8. Classroom Mini Library Menu Display

SiBi Microteaching Feature for Students and People with Disabilities

This feature provides selected chemistry chapters that are considered difficult. After or before viewing the material summary and several videos in the form of micro-teaching animations and SIBI (English-language micro-teaching with subtitles), students will then be directed to a pre-test and post-test containing several questions relevant to the previously accessed material. There will be a standard assessment for those who pass the course, with a minimum score of 75. Those below that score will be deemed unsuccessful and unable to proceed to the next level.

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Figure 9. SiBi Microteaching Feature Display

Virtual Laboratory Feature

After completing the subtest and being declared successful, students can access the virtual laboratory feature, where they can conduct online practical work.



Figure 10. Lab Room View

Student Achievement Check and Reflection Feature

Number 5 has another feature in FORCHEM that allows you to see whether students' learning percentages for different materials are increasing, remaining the same, or decreasing. It also provides a student reflection room feature to provide online consultation through the provided platform. The reflection feature contains several motivational and tips for more effective learning.

Ranking and Job Fair Feature

The ranking feature is used to view students' highest to lowest scores over the course of a month during the learning process. The job fair is a website that provides information on job openings for high school or vocational school graduates specializing in chemistry.

Product Formulation Design Feature

This feature is one of the available features, containing several unique facts related to the product description process, how to use it, and the advantages of each product, such as lip balm, aromatic scrubs, and other products used in daily life. Furthermore, it provides a BPOM (National Agency of Drug and Food Control) guide, ingredient usage, and proper formulation according to BPOM and halal criteria. This feature allows students to understand the criteria for cosmetics around us, analyze ingredients, and use instructions. Students can then switch to a discussion session to learn how to use cosmetics properly according to BPOM criteria.

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Figure 11. Product Formulation Design Display

Activity Minutes Feature

This feature contains minutes of FORCHEM activities in collaboration with credible and valid media outlets, such as Jatim Satu News, UM Public Relations, UM Chemistry, and other minutes to summarize activities undertaken to ensure that the expected outcomes can be accounted for in developing the FORCHEM application. This feature allows for evaluation of activities undertaken to improve the quality of education in Indonesia.

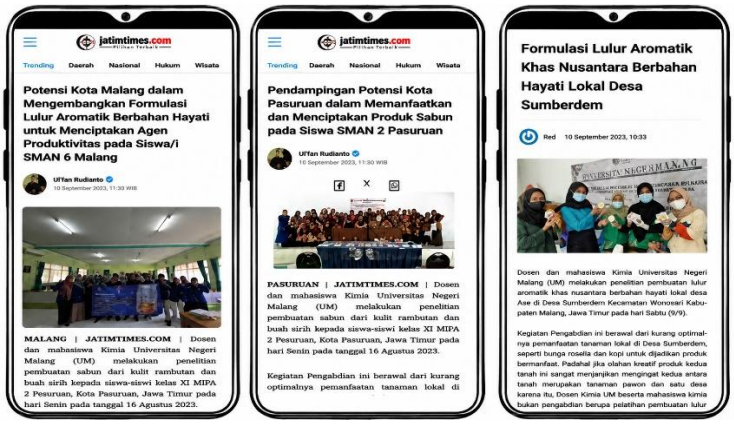


Figure 12. Activity Minutes Display

Cosmetic Chemistry Lab Guidebook Feature

This feature is one of the available features, containing a cosmetic chemistry lab guidebook from FORCHEM, considering economical materials and tools for following this cosmetic chemistry lab guide. It is hoped that this guidebook can be used to practice making cosmetic products from natural ingredients that are safe and meet BPOM criteria.

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Figure 13. Cosmetic Chemistry Lab Guidebook Display

Discovery Learning Syntax Model

The learning model used in this virtual laboratory is the discovery learning syntax model. This choice makes students the main characters in this learning system, enabling them to discover a concept and draw conclusions independently. This learning model begins with problem identification, data collection, and proving the problem. Project-based learning will demonstrate the philosophy and background of the website, determine the activity schedule, and monitor learning through the available virtual laboratory so that conclusions can be drawn. Based on the conclusions obtained, the following can be formulated as a benchmark for evaluating and developing the virtual laboratory:

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Table 4. SWOT Analysis of FORCHEM

Strength (S)	Weakness (W)
1. The concept of chemistry learning centers on students, from problem identification and laboratory activities to recording results, enhancing understanding of chemistry material in real-life situations. 2. A single virtual laboratory learning application combines learning videos, video analysis, a real-life laboratory, visual language features, student cosmetic product creation activities, and evaluation questions all in one place. 3. Chemistry learning integrates the STEAM (Science, Technology, Engineering, Art, and Mathematics) method to enhance the 4Cs (Critical Thinking and Problem Solving, Creativity, Communication, Creativity and Innovation, and Collaboration).	1. Chemistry material is linked to the application of events or management in everyday life. 2. Students are equipped with an entrepreneurial spirit through training in independent cosmetic product creation through online laboratory activities.
Opportunities (O)	**Threats (T)**
1. Adaptation of cosmetic chemistry learning technology to improve language skills and enhance skills in line with the objectives of the Merdeka Curriculum. 2. Effective, simple, and efficient operation of FORCHEM.	1. The increasing development of various chemistry learning media, such as the Smart Chemistry application. 2. The lack of use and understanding of English as an international language, in other words, does not exclude Indonesian as the primary language.

FORCHEM Advantages

The advantages of the FORCHEM application as a STEAM (Science, Technology, Engineering, Art, and Mathematics)-based Virtual Laboratory for high school students are as follows:

1. FORCHEM encourages students to familiarize themselves with and practice their English language skills through English-language chemistry learning materials.
2. FORCHEM not only provides students with a thorough understanding of chemistry but also provides practical understanding in the field, fostering an entrepreneurial spirit through the cosmetic products produced by the students.
3. FORCHEM strengthens the analytical and critical thinking (problem-solving) skills of high school students and those with disabilities by solving problem-solving packages

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designed to prepare a future generation of active and competent young chemists in the field of natural cosmetics.

4. The online learning method, which is implemented through an international class-based website, is an innovative learning method.

4. CONCLUSION

This study successfully developed FORCHEM, a bilingual STEAM-based virtual laboratory designed to enhance students' understanding of cosmetic chemistry concepts while providing an inclusive learning environment for students with disabilities. The results demonstrate that FORCHEM effectively improves cognitive learning outcomes, scientific literacy, and students' abilities to apply theoretical knowledge through virtual practicum activities. The integration of microteaching videos, virtual experiments, and product formulation features also promotes the development of 4C skills critical thinking, creativity, communication, and collaboration while encouraging entrepreneurial awareness among Generation Z learners in line with megatrend-era demands. However, this study has several limitations. The implementation was conducted only in selected high schools, and the sample size for students with disabilities particularly those with hearing impairments was relatively small, which may limit the generalizability of the findings. In addition, students' varying levels of digital literacy and limited English proficiency could influence their engagement with the bilingual features of the platform. Future research is recommended to involve a broader and more diverse population, including other types of disabilities, to further evaluate accessibility features. Improvements in system responsiveness, integration of adaptive learning analytics, and the development of more diverse cosmetic chemistry modules are also suggested to enhance the platform's effectiveness and sustainability as an innovative digital learning tool.

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