

## DEVELOPMENT AND IMPLEMENTATION OF VIRTUAL EXTRACTION LABORATORY IN BUILDING HIGH-LEVEL THINKING SKILLS (HOTS) TO IMPROVE LEARNING OUTCOMES.

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### ABSTRACT

Development and Implementation of Virtual Extraction Laboratory in Building High-Level Thinking Skills (HOTS) to Improve Learning Outcomes. This study aimed to develop and implement a virtual laboratory media on the topic of extraction to enhance higher order thinking skills (HOTS) and improve students' learning outcomes. The research used a Research and Development (R&D) approach with the 4D model (Define, Design, Develop, Disseminate). The subjects were two classes of chemistry education students: an experimental group using the virtual laboratory and a control group using conventional methods. Instruments included a learning achievement test, expert validation questionnaires, student response questionnaires, and a HOTS rubric. Results showed the media was highly feasible, with an N-Gain score of 0.74 (high category) for the experimental group and an average HOTS score of 90.53 (very high category). It can be concluded that the virtual laboratory is effective in improving learning outcomes and developing students' higher order thinking skills.

**Keywords:** *Virtual Laboratory, Extraction, HOTS, Learning Outcomes.*

### A. INTRODUCTION

Teaching chemistry at the higher education level often faces challenges in delivering complex and abstract subject matter effectively to students. One common approach to address this issue is the use of laboratories as a medium for practical learning. Through hands-on experiments, students are expected to gain a concrete understanding of chemical concepts. However, in practice, various limitations such as time constraints, operational costs, and access to conventional laboratory facilities often hinder the implementation of laboratory-based instruction. In this context, virtual laboratories have emerged as a promising and relevant alternative in the digital era. By utilizing detailed interactive simulations, virtual laboratories enable students to conduct chemistry experiments online. These media not only enhance conceptual understanding but also promote the development of higher-order thinking skills (HOTS), including analysis, evaluation, creativity, and problem-solving (Situmorang *et al.*, 2018).

Chemistry is a crucial discipline within the higher education curriculum, playing a significant role in shaping students' scientific and critical thinking skills. However, traditional methods of teaching chemistry still encounter several obstacles, such as difficulties in grasping abstract concepts, limited interaction with chemical materials, and high levels of stress experienced by students during physical laboratory experiments. Therefore, the application of virtual laboratories can serve as an effective solution to bridge the gap between theory and practice, particularly in challenging topics such as extraction (Kolil *et al.*, 2020). The advancement of information and communication technology has enabled the creation of increasingly realistic and interactive virtual labs. These simulations can replicate chemical experiments with high accuracy, provide clear visualizations of processes, and generate experimental data that can be analyzed directly by students. Moreover, the flexibility of accessing learning at any time and from any location aligns well

with the needs of modern education, which is no longer confined by physical constraints (Donasari & Silaban, 2021).

The advantages of virtual laboratories go beyond resource efficiency, offering an in-depth learning experience. Students can repeat experiments without concerns about equipment availability, time restrictions, or safety risks. This is particularly beneficial for topics like extraction, which require a comprehensive understanding of separation procedures. Through virtual simulations, students can explore various scenarios and adjustable variables, thereby gradually building contextual and conceptual comprehension. In addition to strengthening conceptual knowledge, virtual labs also foster students' critical and analytical thinking skills. Recent research findings show that the implementation of virtual laboratories in chemistry instruction significantly improves learning outcomes in both cognitive understanding and practical skills (Lestari *et al.*, 2023).

Teaching extraction faces challenges due to limited opportunities for students to practice independently. In conventional labs, large group work, equipment shortages, and time constraints reduce individual learning. Brief demonstrations by instructors are often insufficient, leaving many students struggling with concepts and techniques. Virtual labs specifically for extraction are still scarce, as most focus on other topics such as titration, spectrophotometry, electrochemistry, distillation, chromatography, and organic synthesis. Thus, developing virtual laboratories for extraction is essential to address this gap and support learning.

Virtual laboratories also offer advantages in terms of safety and comfort. In experiments involving hazardous chemicals or risky reactions, virtual labs minimize the likelihood of accidents, providing a safer and more controlled learning environment. Moreover, these platforms often include instant and detailed feedback features that help students identify and correct their mistakes. This is crucial for mastering laboratory skills that demand accuracy, in-depth understanding, and reflective thinking (Ilahi *et al.*, 2022). By integrating simulation, interactivity, and feedback, virtual laboratories serve not only as a substitute for physical labs but also as tools that enhance the overall quality of learning experiences.

In light of the challenges and opportunities discussed above, this study aims to develop and implement a virtual extraction laboratory as an innovative medium for chemistry learning. The primary objective is to foster students' higher-order thinking skills (HOTS) and improve their learning outcomes. The virtual laboratory is expected to serve as a strategic alternative to address the limitations of conventional laboratory practice and contribute to more effective, efficient, and technology-integrated chemistry education.

## **B. RESEARCH METHOD**

This section of the methods must explain the research methods used, including the location, timing of the research, and how the procedures were carried out. The tools, materials, media, or research instruments must be explained clearly. If necessary and important, there is an attachment regarding the outline of the instruments or excerpts of the materials used merely to provide examples for the readers. If there are statistical formulas used as part of the research method, it is advisable not to write down formulas that are already commonly used. For example, specific provisions set by the researchers for the purpose of collecting and analyzing research data can be explained in this methods section. Writers are advised to provide references for the methods used.

### **Research Method**

This research was conducted in the Chemistry Education Study Program, Department of Chemistry, Faculty of Mathematics and Natural Sciences, State University of Medan, in the

even semester of the 2024/2025 academic year. The approach used was research and development (R&D) which aims to produce learning media in the form of a virtual laboratory on extraction material, as well as testing its effectiveness in improving students' learning outcomes and high-level thinking skills (HOTS). The development of the virtual laboratory was carried out using the 4D model, which consists of the stages of defining (define), designing (design), developing (develop), and disseminating (disseminate) as explained by Mesra *et al.* (2023) and Rachman *et al.* (2024).

### **Data Collection and Data Analysis Techniques**

The population of this study was all students taking the Analytical Chemistry Separation course in the 2024/2025 academic year. Samples were taken in total (total sampling) from two available classes, and then divided into a control group and an experimental group. The experimental group received learning using an Android-based virtual laboratory (*Apk*), while the control group used conventional methods through a physical/real laboratory. The research design applied was a pretest-posttest control group design involving two groups that were given different treatments. The initial test and final test were used to determine the increase in student learning outcomes through the calculation of the N-gain score.

The research instruments consist of test and non-test instruments. The test instrument is in the form of 20 multiple-choice questions for the extraction material that has been validated in advance according to the provisions according to Silitonga (2011). While the non-test instrument consists of an expert validation questionnaire and a student response questionnaire to the learning media.

The validation questionnaire was compiled referring to the BSNP (2010) standard which includes four aspects: content feasibility, language feasibility, presentation feasibility, and graphic feasibility. Two validators, namely material experts and media experts, assessed the virtual laboratory product. The assessment was carried out using a Likert scale with a score range of 1 to 4 points, which was then calculated for an average value based on the formula proposed by Sugivono (2014). The following presents the results of the assessment score range based on the Likert scale:

**Table 1. Score Range Based on Likert Scale**

<b>Score</b>	<b>Alternative Answers</b>
4	Very Worthy
3	Worthy
2	Not Feasible
1	Very Unworthy

In addition, students as media users also provide responses through questionnaires. Student responses are used to evaluate their views on aspects of interest, enjoyment, ease of understanding the material, and learning motivation after using the virtual laboratory. The following is an interpretation based on the student response assessment scale proposed by Sugivono (2014):

**Table 2. Interpretation of Response Scales**

<b>Mastery Level</b>	<b>Letter Value</b>	<b>Weight</b>	<b>Predicate</b>
86% - 100%	A	4	Very Good
76% - 85%	B	3	Good
60% - 75%	C	2	Enough
55% - 59%	D	1	Less
< 54%	TL	0	Very Less

The implementation of media in the learning process begins with the implementation of a pretest, in both groups. The experimental group then received an introduction to the material and interactive simulations. using a virtual laboratory, while the control group followed conventional practical learning using a physical/real laboratory. After the treatment, both groups were given a posttest to measure the improvement in learning outcomes. Students' HOTS skills were also evaluated through the preparation of practical reports, which were assessed using a rubric designed based on indicators of analysis, evaluation, creation, and problem solving.

Learning outcome data were analyzed using descriptive and inferential techniques. Pretest and posttest scores were used to calculate the N-gain value. Furthermore, normality and homogeneity tests were carried out as a measure for hypothesis testing. Hypothesis testing was carried out to determine significant differences between the experimental and control groups as according to Silitonga (2014). HOTS skills assessment was carried out through proof report analysis, using an analytical rubric containing four main indicators of analysis, evaluation, creativity, and problem solving.

The entire research process was carried out systematically, starting from media design to hypothesis testing, to ensure that the virtual laboratory media developed was not only theoretically and technically feasible, but also proven effective in improving the quality of learning in analytical chemical extraction material.

### **C. RESULTS AND DISCUSSION**

This study uses the Research and Development (R&D) method with a 4-D development model consisting of four main stages, namely Define, Design, Develop, and Disseminate. The product developed is a We developed a Virtual Laboratory for extraction that provides interactive simulations to explore compound separation techniques. This media supports active learning and engages students in higher-order thinking activities such as analyzing the processes that occur, evaluating the results of virtual experiments and producing conclusions about the ongoing extraction process.

#### **Define Stage**

The Define stage is conducted to analyze learning needs and establish the basis for developing virtual laboratory media. Several analyses are conducted, namely: (1) Front-end analysis, which identifies obstacles in learning extraction material in Separation Analytical

Chemistry, such as minimal practice due to limited tools, which has an impact on the lack of HOTS development of students; (2) Student analysis, to understand the characteristics of students who are accustomed to using digital devices but are not yet familiar with interactive virtual laboratory media, and have varying initial mastery of extraction concepts; (3) Task analysis, to identify important competencies that include understanding the working principles of extraction to practical calculation skills; (4) Concept analysis, which maps core materials such as distribution principles, types of extraction, and their application in a laboratory context; and (5) Formulation of learning objectives, which emphasizes mastery of extraction concepts and the development of high-level thinking skills such as analysis, evaluation, and solution creation in the context of compound separation.

### **Design Stage**

The Design Stage aims to systematically structure the learning media based on the results of the analysis of the previous stage. The activity begins with the preparation of a benchmark test that measures HOTS achievement through multiple-choice questions and non-test instruments, which are validated by material experts. Furthermore, the selection of media in the form of a virtual laboratory based on interactive simulations is carried out, which is in accordance with the visual and procedural characteristics of the extraction material. The media format is selected in the form of desktop-based using Adobe Animate or Flash to support structured interactivity and navigation. Finally, an initial design is prepared in the form of a storyboard and screen sketches that include navigation flow, material sequence, and simulation of extraction procedures as a basis for further development.

### **Develop Stage**

The Develop stage aims to realize the media design into a Virtual Extraction Laboratory prototype using Adobe Animate or Flash. Development is carried out iteratively and refined through validation and trials. Validation is carried out by material experts and media experts to assess the suitability of content, appearance, interactivity, and relevance to HOTS. Furthermore, limited trials are carried out on students to evaluate the functionality, understandability, and effectiveness of the media in supporting learning. Input from these two stages is used to revise and refine the media before being implemented widely.

### **Disseminate Stage**

The Disseminate Stage is the final phase of development, namely the distribution of media to students to test its effectiveness in the context of real learning. There are three main components: (1) Validation testing, which evaluates the impact of media on learning outcomes, engagement, and HOTS development through trials on broad target groups. (2) Packaging, namely the preparation of media in the final format in the form of an application (Apk) that can be accessed offline, equipped with an intuitive interface and user guide, and (3) Diffusion, and adoption, in the form of distributing media to a wider educational environment through publication, training, and promotion. This stage ensures that the media can be used sustainably in improving the quality of analytical chemistry learning separation.

### Media Feasibility Based on Expert Validation

The feasibility of virtual laboratory media is assessed by two validators, each a media expert and a material expert, based on four aspects of feasibility according to BSNP standards, namely the feasibility of content, presentation, language, and graphics.

**Table 3. Virtual Laboratory Media Validation Assessment Percentage Results Extraction**

Number	Assessment Aspect	Average Percentage		Average (%)
		Lecturer 1	Lecturer 2	
1.	Content Suitability	3,84	4	3,92
2.	Presentation Suitability	3,53	4	3,76
3.	Language Suitability	3,55	4	3,77
4.	Graphic Suitability	3,57	4	3,78
<b>Average (%)</b>				<b>3,8075</b>
<b>Result Criteria</b>				<b>Very Good</b>

From the research percentage table above, the results of the 4 assessment aspects obtained an average of 3.8075% with very good result criteria. The average percentage above was obtained from the evaluation of lecturers from the Chemistry Department of Medan State University, where overall the results of expert validation identified that the virtual laboratory media developed was considered very feasible to be applied to the learning process.

This validation also confirms that the content of the media is in accordance with the learning achievements of the Analytical Chemistry Separation course, both in terms of scientific accuracy, depth of material, and presentation that supports active student involvement. According to BSNP (2010), a feasible learning media must be able to present content logically, systematically, and in accordance with technological developments and student characteristics.

### Student Responses to the Media

Student responses to the media were measured through a closed questionnaire containing 25 statements with a 4-point Likert scale. The recapitulation results showed that the average percentage score reached 80.91%, which was categorized as "very positive." Students stated that the use of virtual laboratories helped them better understand the extraction procedure. clarify the visualization of abstract concepts. increase student interest in learning.

Many students also mentioned that the use of simulation-based media allows them to learn flexibly, not depending on physical laboratory schedules, and can carry out repeated experiments without fear of making mistakes or running out of materials. This is in line with the opinion of Donasari & Silaban (2021) who stated that virtual laboratories can increase learning efficiency, provide direct feedback, and increase students' learning independence.

### Student Learning Outcomes

The effect of using virtual laboratories on student learning outcomes was measured by comparing pretest and posttest scores in two experimental groups (using virtual laboratories) and control (using physical laboratories). Analysis of learning outcome improvements was conducted using the N-Gain calculation.

**Table 4. Average N-Gain Value of Student Learning Outcomes**

Group	N-Gain	Category
Experiment	0,745	High
Control	0,3	Medium

The N-Gain value of the experimental group showed a relatively high increase in learning outcomes, while the control group only showed a moderate increase. This means that students who use virtual laboratories experience a more significant increase in understanding compared to students who use conventional methods. These results indicate that interactive simulation-based media are more effective in helping students internalize abstract concepts such as the extraction separation process.

**Normality Test, Homogeneity Test, and Hypothesis Test**

Before the t-test was conducted, statistical assumption testing was conducted in the form of normality test and homogeneity test. The normality test using chi square showed that the data was normally distributed ( $X^2$  count <  $X^2$  table).

**Table 5. Normality test results**

Class	$X^2$ Count	$X^2$ Table	Description
Experimen	5,455	11,07	Normally Data Distributed
Control	9,89	11,07	Normally Data Distributed

The homogeneity test shows that both groups have the same variance ( $F$  count <  $F$  table). Thus, the data meets the requirements for a t-test.

**Table 6. Homogeneity test results**

Class	s	$s^2$	F Count	F Table	Description
Experimen	5,91	34,99	1,25	1,788	F Count < F Table, then both data are homogeneous
Control	6,62	43,95			

Hypothesis testing shows that there is a significant difference in learning outcomes between the experimental and control groups. Where the results obtained for  $12.3 > 1.997$  so that  $H_0$  is rejected and  $H_a$  is accepted.

**Table 7. Student Learning Outcome t-Test Results**

Class	s	s <sup>2</sup>	t Count	t Table	Description
Experimen	5,91	34,99	12,3	1,997	Ho rejected dan Ha accepted
Control	6,62	43,95			

This finding is consistent with the research results of Lestari *et al.* (2023) who found that virtual laboratory media can improve student learning outcomes on various chemical topics such as titration, chromatography, and electrochemistry.

### Higher Order Thinking Skills (HOTS)

Students' high-level thinking skills are measured based on four main indicators: analysis, evaluation, creativity, and problem solving (Sutiani *et al.*, 2021). The assessment was carried out through the HOTS rubric on the extraction practicum project report developed after using the media. The results of the analysis showed that the overall average HOTS value reached 90.53, which is classified as very high.

**Table 8. Student HOTS Values**

HOTS Indicators	Average
Analysis	89
Evaluation	92
Creativity	90,3
Problem Solving	91,3
<b>Total</b>	<b>90,53</b>

This value shows that the use of virtual laboratories is not only effective in improving conceptual knowledge, but also able to develop students' high-level thinking skills as a whole. Students are able to evaluate scenarios, analyze simulation data, and propose solutions to problems presented in laboratory simulations.

Chemistry learning generally requires direct laboratory experience to help students concretely understand abstract concepts. However, limitations such as equipment availability, hazardous chemicals, and accident risks often hinder conventional laboratory activities. Therefore, virtual laboratories offer an effective alternative. In this study, a virtual extraction laboratory was developed to assist students in understanding the topic of extractive separation, which is often difficult to access practically. This medium serves not only as a practicum simulation but also as a visual tool to help construct analytical chemistry concepts.

The virtual laboratory was designed to be interactive, featuring accurate visual simulations of liquid-liquid extraction processes. Students could explore each stage—such as mixing solvents, phase separation, and monitoring target compounds—without physical risks. This aligns with Gungor *et al.* (2022), who stated that virtual labs allow flexible experimentation, repetition of procedures, and reduce fear of mistakes. Such features enhance scientific process skills and critical thinking among students.

Test analysis showed a significant increase in post-test scores following the use of the virtual laboratory. Normality and homogeneity tests confirmed that the data were normally distributed and homogeneous, allowing the use of a two-tailed t-test. The t-test results revealed a significant difference between the experimental and control groups, indicating the positive impact of the virtual laboratory on students' learning outcomes. These findings are supported by Sriyani *et al.* (2021), who found that technology-based interactive media significantly improve conceptual understanding and academic performance.

The experimental group achieved an average N-Gain score of 0.74 (high category), while the control group scored 0.30 (moderate category). This reflects a significant improvement in the learning process. According to Hendrajanti (2022), virtual laboratories support discovery learning, which stimulates active and reflective thinking, making them suitable for complex topics like extraction, especially in institutions with limited physical lab facilities.

Survey responses yielded a highly positive interpretation, with a score of 80.91. Students reported that the virtual lab helped them better understand extraction material, boosted their confidence, motivation, and interest in learning. These findings align with Gunawan *et al.* (2019), who noted that simulation-based learning media increase student engagement, particularly in abstract or complex subjects.

In terms of Higher Order Thinking Skills (HOTS)—including analytical thinking, evaluative thinking, creative thinking, and problem solving—students achieved highly satisfactory results, with an average score of 90.53. They demonstrated the ability to analyze extraction stages, evaluate procedures, and propose alternative strategies to improve compound separation. This reflects the success of virtual laboratory-based learning in promoting critical and creative thinking. Chi *et al.* (2024) emphasized that developing HOTS in science education requires experiential learning with high cognitive engagement, such as interactive simulations, as also supported by Erdem *et al.* (2019), who highlighted the benefits of exploratory and problem-solving approaches in virtual environments.

Overall, virtual laboratories are not merely complementary tools, but have the potential to become integral components of modern chemistry learning strategies. They offer flexible, resource-efficient teaching and enhance learning quality. Based on improved learning outcomes, strengthened HOTS, and positive student responses, the implementation of virtual laboratories is highly recommended and should be expanded more widely in higher education.

The use of digital media such as virtual extraction laboratories has proven to be not only a substitute for conventional laboratories, but also an innovation that expands students' learning space. In addition to solving the constraints of limited tools and materials, virtual media allows for more flexible and personal learning, and is oriented towards achieving learning outcomes and developing 21<sup>st</sup> century competencies.

#### **D. CONCLUSION**

This study proves that the development of a virtual laboratory based on the 4D model (Define, Design, Develop, Disseminate) produces a feasible and innovative learning media for extraction materials. The media developed was considered "very feasible by material and media experts based on the criteria. BSNP. The implementation of virtual laboratories

can significantly improve students' learning outcomes and high-level thinking skills (HOTS). This is indicated by the average N-Gain value of the experimental group of 0.74 (high category), compared to the control group of 0.30 (moderate category). In addition, the use of this media also increases students' interest and understanding of the material more interactively and effectively than conventional methods

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