

Development of Interactive Multimedia Assisted of The HPLC Simulator to Enhance Student's Analytical Thinking Skills

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Abstract

This research aims to develop interactive multimedia by utilizing HPLC simulators to train students' analytical thinking skills, which will support dry lab practicum activities to be more meaningful. The research method is development research with a 4-D model design, defining, designing, developing, and disseminating. However, this research stage is limited to the development stage. The instruments used in this study include test and non-test instruments in student satisfaction questionnaires and observation of learning outcomes. The results showed that MMI assisted by an HPLC simulator helped students increase students' motivation and interest in studying HPLC material. In line with that, learning with the HPLC simulator can develop analytical thinking skills in the matching and classifying aspects, but has not trained in 3 other aspects, namely error analysis, generalizing, and specifying. It is recommended to use a learning approach such as STEM, which accommodates learning needs with the stages of inquiry, Engineering Design Process, and Product development to overcome the lack of development of analytical thinking skills in the aspects of analysis error, specifying, and generalizing.

Keywords: MMI HPLC; simulator; analytical skills

Abstrak

Tujuan penelitian ini adalah mengembangkan multimedia interaktif dengan memanfaatkan simulator HPLC untuk melatih keterampilan berpikir analitis mahasiswa yang akan mendukung aktivitas praktikum dry lab menjadi lebih bermakna. Metode penelitian adalah penelitian pengembangan dengan desain model 4-D, yaitu *define*, *design*, *develop*, dan *disseminate*. Namun pada tahapan penelitian ini dibatasi sampai dengan tahap develop atau 3-D. Instrumen yang digunakan dalam penelitian ini mencakup instrumen tes dan non tes berupa angket kepuasan mahasiswa dan observasi hasil pembelajaran. Hasil penelitian menunjukkan penggunaan MMI berbantuan simulator HPLC secara akademis membantu mahasiswa dalam meningkatkan motivasi dan minat mahasiswa mempelajari materi HPLC. Sejalan dengan itu, belajar dengan simulator HPLC dapat mengembangkan keterampilan berpikir analitik pada aspek *matching* dan *classifying*, namun belum melatih 3 aspek lainnya, yaitu *analysis error*, *generalizing*, dan *specifying*. Direkomendasikan penggunaan pendekatan pembelajaran seperti STEM yang mengakomodasi kebutuhan belajar dengan tahapan *inquiry*, *Engineering Design process*, dan *Product development* untuk mengatasi kurang berkembangnya keterampilan berpikir analitik pada aspek *analysis error*, *specifying*, dan *generalizing*.

Kata kunci: MMI HPLC; simulator; keterampilan analitik

Introduction

The COVID-19 pandemic that has hit the world, including Indonesia, has caused the learning process to experience a virtual change in methods by utilizing various existing information technologies. Of course, this is a different obstacle in the learning system in higher education, especially for practical learning that requires mastery of student practical skills directly.

High-Performance Liquid Chromatography (HPLC) is one of the separation engineering materials which is an essential part of analytical chemistry in the undergraduate chemistry curriculum, chemistry education, or chemical engineering. The practicum also needs to understand the system and how the HPLC instrumentation works well in practice and material. HPLC is an important subject because it is the most widely used in industry due to its superiority in qualitative and quantitative analysis processes (Holler et al., 1996).

Students must master appropriate concepts, techniques and understand the principles, parameters, and preparation of chromatographic samples, HPLC instruments' operation, and results analysis. However, for students, the relationship between experimental variables that affect the analysis results creates difficulties. Because several parameters (physicochemical properties, molecular weight of the solute, properties, composition, temperature, pH, and flow rate of the solute) affect the separation quality (Irwanto et al., 2017), mastery of the proper technique is needed. Students can do this through many experiments.

Considering that all practicum activities during the pandemic are abolished, another alternative is needed to equip students with practical skills with dry lab practicum activities. A dry lab is a laboratory-based on information and communication technology in a distance learning system (Prastyo et al., 2020). The development of the Dry Lab software is an extraordinary achievement in the development of HPLC analysis that has taken

place in the last 16 years. DryLab, which constantly changes according to user needs, never develops.

HPLC simulation software is one development that can be recognized as an effective educational tool in dry training labs. Some of the advantages of the HPLC Simulator are that it is easy to use, inexpensive, has no risk of damage, uses no materials or solvents, requires no supervision, and provides instant feedback. So it's more interesting than running a real HPLC instrument. The development of inexpensive computer-based HPLC instruments and HPLC simulators has been reported (Beek et al., 2018; Armbruster et al., 2014; Pirok et al., 2017; and Dvořák et al., 2018), but most of these are no longer available or are no longer compatible with modern computers. Several previous commercial HPLC simulators help develop efficient methods with limited initial trials and better understand HPLC principles. However, these simulators have the disadvantage of being difficult to use and expensive.

In 2013, Boswell et al. reported the results of developing an HPLC simulator based on open source, free, and easily accessible by anyone with various HPLC mastery skills. The developed HPLC simulator features intuitive controls with indicators for different experimental conditions.

The HPLC simulators only develop practical skills. There are few essential features for educational purposes, so it is necessary to develop teaching materials that can also train students' analytical thinking skills to make dry lab practicum activities more meaningful. The researchers developed interactive multimedia by utilizing HPLC simulators in instrument analytical chemistry lectures to learn HPLC material.

Research Method

The type of research used is development research with a 4-D model design developed by Thiagarajan et al. (1974), namely define, design, develop, and disseminate. However, this research stage is

limited to the development stage. Data collection techniques used were expert judgment sheets, questionnaire sheets, and test and non-test instruments. Then data were analyzed using quantitative and qualitative data analysis techniques. Quantitative data were obtained from the judgment sheets and questionnaires. Then the numbers are quantified to obtain the instrument's feasibility level. Qualitative data in the form of suggestions, criticisms, and responses from the validator were used as considerations in revising the instrument, followed by testing the use of media on 11 students. In comparison, the test instrument was carried out on 40 students who had received HPLC material.

Results and Discussion

Stage I: Define (Defining)

The define stage is the stage to determine and define the learning requirements. This defined stage includes five main steps, with the following results:

a. front-end analysis

Based on the results of the initial and final analysis of the learning carried out, it was found that the teaching materials used were still conventional. So far, understanding HPLC material is only limited to mastery of concepts, and practical activities for HPLC material are not carried out because of the unavailability of these instruments in universities.

b. learner analysis

The analytical thinking skills test results of 15 prospective chemistry teacher students were 27% very poor, 13% poor, 53% moderate, and 7% good. At the same time, the average analytical thinking skill test result is 63, which is in the less category.

The analytical thinking skills of prospective chemistry teacher students presented are indicators of analytical thinking skills developed by Robert Marzano, which consist of matching, classifying, error analysis, generalizing, and specifying. Of the 20 questions given, 15 of them have a low average (the number of students who can answer correctly is less than 60%), so based on these analytical indicators, the aspects of

analytical skills that are low (in a row) are specifying, generalizing, analyzing error, matching, and classifying.

c. Task analysis

At the task analysis stage, the activities carried out are analyzing the tasks given by the lecturer to students. Based on the results of observations, the tasks assigned by the lecturers were mostly in the form of summarizing tasks and practice questions. Such assignments cannot measure students' analytical thinking skills due to the current conditions that require all online learning activities.

d. Concept analysis

The purpose of concept analysis is to find out the types of concepts that exist in the material, plan the arrangement of concepts according to the sequence in learning, find out the level of concept achievement that is expected to be mastered by students, and determine learning methods that are in accordance with the characteristics of the concept.

Concept analysis activities are carried out by analyzing course learning outcomes (CPMK), Sub CPMK, and achievement indicators. The results of this concept analysis are in the form of a concept hierarchy analysis table, macrostructure, and concept map.

e. Specifying instructional objectives

At this stage, it is carried out to determine the desired learning objectives so that the teaching materials developed are in accordance with CPMK, Sub CPMK, and learning achievement indicators and adjust to student needs.

Stage II: Design

The design stage is compiling dry-lab practicum instruments in the form of interactive multimedia. The design is based on the flowchart and storyboard that has been prepared. MMI HPLC was developed using the Microsoft Sway application to be opened by students via a shared link quickly without installing software and is compatible for use on laptops or cellphones. The content in the MMI HPLC consists of a brief description of the material for each meeting or learning activity equipped with videos and pictures related to the subject matter, practice questions for each sub-material to

improve students' analytical thinking skills individually, and discussion sheets. Using an HPLC simulator, groups in journal analysis, video representation, and problem-solving. The lecturer guides the use of MMI HPLC during the learning process to direct and determine student activity. The HPLC simulator is used as a media aid in verifying the results of student analysis of the questions being worked.

Stage III: Develop

The development stage is the stage to produce product development which is carried out through two steps, namely: (1) expert assessment which is then revised, (2) limited trial. This development stage aims to produce the final form of learning tools after

revisions based on input from experts/practitioners and test data. The steps taken at this stage are as follows:

a. Validity test

A validation test is an activity of assessing product design whether it is effective and feasible to use or not. This validation test is an assessment that is guided by field facts and rational thinking. A validation test is an assessment carried out by experienced experts in their respective fields to assess the designed product. Experts provide an evaluation with the aim of developers knowing the strengths and weaknesses of their products. The results of the expert validation test are shown in Table 1.

Table 1
Expert Judgment Validation Test Results

Validity test	Average Score	Criteria
Technical Aspect	86	Worthy
Presentation	90	So worth it
Contents	87,62	Worthy

Based on the results of the expert judgment, the criteria are feasible and very feasible, the MMI HPLC development can be used, and no revision is needed. All of the judgment results are in the very feasible category according to Sugiyono (2017) eligibility criteria. The presentation aspect is included in the very feasible category, meaning that the material presented is coherent. There are practice questions, answer keys, and conclusions according to the 2014 BNSP criteria. Furthermore, the technical and material aspects show the results of the appropriate category, meaning that technically MMI HPLC assisted by a simulator can be used with ease and compatibility with all existing devices. In contrast, the appropriateness of the content/material means that the material contained in it is in accordance with the learning objectives, does not cause many

interpretations, and presents natural phenomena around which can be observed by Sukmadinata (2006). Thus, the next stage can be carried out, namely development trials.

b. Developmental testing

Field trials were conducted to obtain the results of the feasibility test for using MMI and student responses to the MMI that had been prepared. According to Thiagarajan, trials, revisions, and re-trials continue to be carried out until a consistent and effective device is obtained. The test carried out was a test of the question instrument in an essay to measure students' conceptual understanding and analytical thinking skills. The instrument test was conducted on 40 students who had received the instrument analytical chemistry course, with the results as shown in Table 2.

Table 2
Test Results of Question Instruments

No Item	Validity	Reliability	Power difference	Difficulty level
1	Valid	Reliable	Good	Difficult
2	Valid	Reliable	Good	Difficult
3	Valid	Reliable	Good	Difficult
4	Valid	Reliable	Good	Difficult
5	Valid	Reliable	Good	Difficult
6	Valid	Reliable	Medium	Difficult
7	Valid	Reliable	Good	Difficult
8	Valid	Reliable	Good	Difficult
9	Valid	Reliable	Medium	Difficult
10	Valid	Reliable	Good	Difficult

The MMI HPLC trial was carried out on 11 students given learning treatment using MMI assisted by an HPLC simulator. The use of HPLC MMI in Instrumental Chemistry learning aims to make students more active during the online learning process, being involved in every stage of learning. Such as observing, collecting data, analyzing data, and communicating the discussion results. It is in line with the research results of Widayat et al. (2014). Interactive multimedia can increase students' interest and enthusiasm because interactive multimedia can visualize abstract concepts so that they are easy to understand in the learning process make it easier for students to understand.

In this study, monitoring of learning activities was carried out virtually and through WhatsApp groups. To train students' competitive spirit, filling out quizzes is given a specific time limit, about 5 minutes for each

set of questions. After all the questions are answered, the lecturer immediately provides feedback. While the discussions carried out by students were analyzing journals, representing videos, and solving problems from a case. Students can develop skills, identify problems, organize, analyze, evaluate, and communicate information between group members in the discussion room.

In learning the material about HPLC, it is divided into 4 main sub-materials, namely (1) principles and instrumentation of HPLC, (2) HPLC parameters, (3) HPLC elution method, and (4) qualitative and quantitative analysis. To be able to implement learning well, it takes 3 meetings. The difference in students' concept mastery results before and after using MMI assisted by the HPLC simulator is indicated by the N-Gain value, which is 0.42 (medium category), as shown in Table 3.

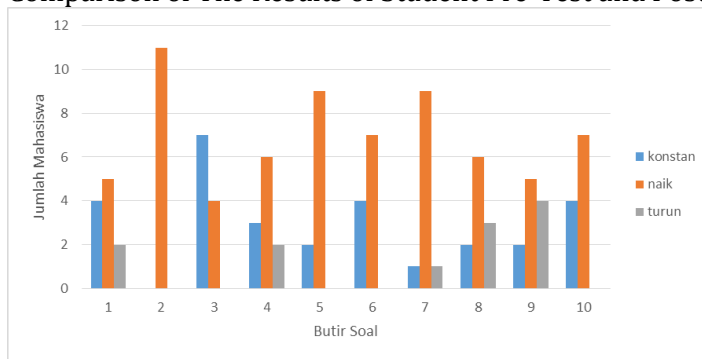
Table 3
Results of N-Gain Concept Mastery on MMI Trial assisted by HPLC Simulator

Average Pre Test Score	Average Post Test Score	N-Gain	Category
39.3	64.3	0.42	Medium

Based on the student's concept mastery test results, the use of MMI assisted by the HPLC simulator increased students' understanding of the HPLC material. Before

and after learning the implementation, the test results showed an increase for each item done by students, as shown in Figure 1.

Figure 1
Comparison of The Results of Student Pre-Test and Post-Test for Each Item



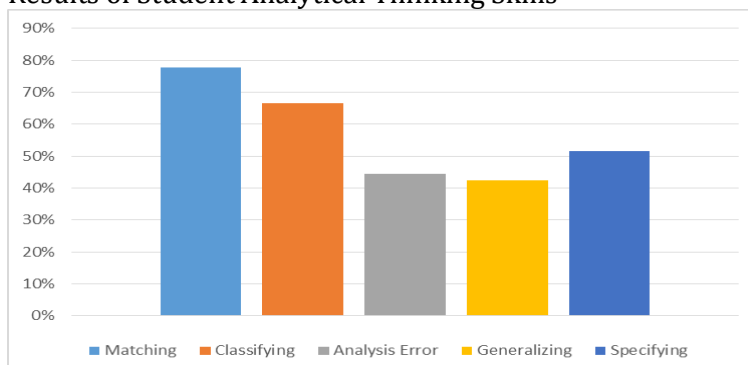
The highest achievement in problem-solving is in Number 2, where the post-test results of all students have increased, while in item number 3 the number of students who have increased results is only 4 people, and 7 other people do not experience an increase. It is because question number 3 is related to determining the most optimal efficiency from several known retention time data and the width of the base of the chromatogram peak. In answering these questions, most of the students answered by determining the number of theoretical plates (N) from the known data and concluding the optimal efficiency based on the most significant theoretical plate value. Whereas in the problem, the length of the column is known so that in determining the most optimal efficiency, the minimum efficiency

value or HETP can be calculated with the smallest value.

It is in line with Sutarno (2011) research, showing that interactive multimedia in magnetic field learning can effectively improve students' generic science skills. Furthermore, the research results conducted by Doyan et al. (2019) showed that the increase in generic science skills of students who used interactive multimedia learning models was significantly higher than that of students who received conventional learning.

In addition to conducting trials to determine students' mastery of concepts, an analysis was also conducted on students' analytical thinking skills in using the HPLC simulator in the learning process for each sub-material. The results obtained are as described in Figure 2.

Figure 2
Results of Student Analytical Thinking Skills



Based on Figure 2, the aspects of students' analytical thinking skills from the highest to the lowest are (1) matching with an average of 78%; (2) classifying with an

average of 67%; (3) specifying with an average of 52%; (4) analysis error (analysis of errors with a mean of 44%); and (5) generalizing (conclude) with a mean of 42%.

The data above indicates that the matching and classifying skills have shown good results, with an average of 78% and 67%. While the other 3 aspects are still relatively low. Students generally still encounter difficulties in error analysis, specifying, and generalizing. Students are expected to conclude by linking relationships comprehensively in the generalizing aspect. For example, in studying column behaviour in isocratic or gradient elution by modifying the flow rate and adjusting the theoretical plate height value versus the linear velocity of the mobile phase according to the Van Deemter equation, analyzing the effect of solute structure and mobile phase organic modifier on retention and resolution.

Three other analytical thinking skills, namely analysis error, specifying, and generalizing, can be maximally developed if supported by prior knowledge or relevant prior knowledge. It can be done by ensuring that students have a comprehensive understanding of the basic principles of chromatography so that they can use the simulator and practice error analysis, specifying, and generalizing skills. It is what must be ensured by the teacher in advance so that students can carry out simulation activities better.

According to Dong et al. (2008), prior knowledge is necessary because the amount and quality of previous knowledge positively affect knowledge acquisition and capacity to apply higher-order cognitive problem-solving skills. Prior knowledge is defined as a multidimensional and hierarchical entity that is dynamic and consists of various types of knowledge and skills (Han & Sim, 2019). Meaning that the learning carried out today is based on previous knowledge and skills. If the prior knowledge is inadequate, then it is feared that the emergence of misconceptions or obstacles to understanding the following material.

Several learning models can be recommended to overcome the weaknesses in implementing this simulator. For example, project-based learning begins with lectures with PBL to acquire more critical HPLC basic concepts. In addition, contemporary approaches such as STEM have the potential

to be used by following the stages of the inquiry process (Cresswell & Loughlin, 2015), Engineering Design Process (EDP) (Hafiz & Ayop 2019), and Product/Project Development (PD) (Santos et al., 2017) as a lecture approach. Strengthening the basic understanding of HPLC or Chromatography is obtained at the inquiry process stage while enhancing analytical skills will be accepted at the EDP and PD stages.

Although analytical thinking skills have not been maximally developed, there has been a positive response in the use of MMI assisted by the HPLC simulator. Students' perceptions were revealed in this study to what extent they enjoyed learning with the simulator-assisted HPLC MMI. The closed questionnaire collected data with assessment indicators that strongly agree, agree, quite agree, disagree, and strongly disagree. The summary of the results of data analysis on student perceptions is presented in Figure 3, namely student perceptions of each aspect of the lecture, where each aspect consists of 2 to 4 indicators. Some aspects of student perceptions carried out in this study are also described in Figure 3.

Data analysis on student perceptions can explain that students positively respond to MMI HPLC. According to them, the HPLC simulator is appropriate to use, can support learning outcomes, and is according to the learning materials. Students are still a bit "stuttering" with the use of this simulator, so students expect a more significant role for lecturers in guiding its use. Students generally agree that HPLC simulators increase interest and motivation.

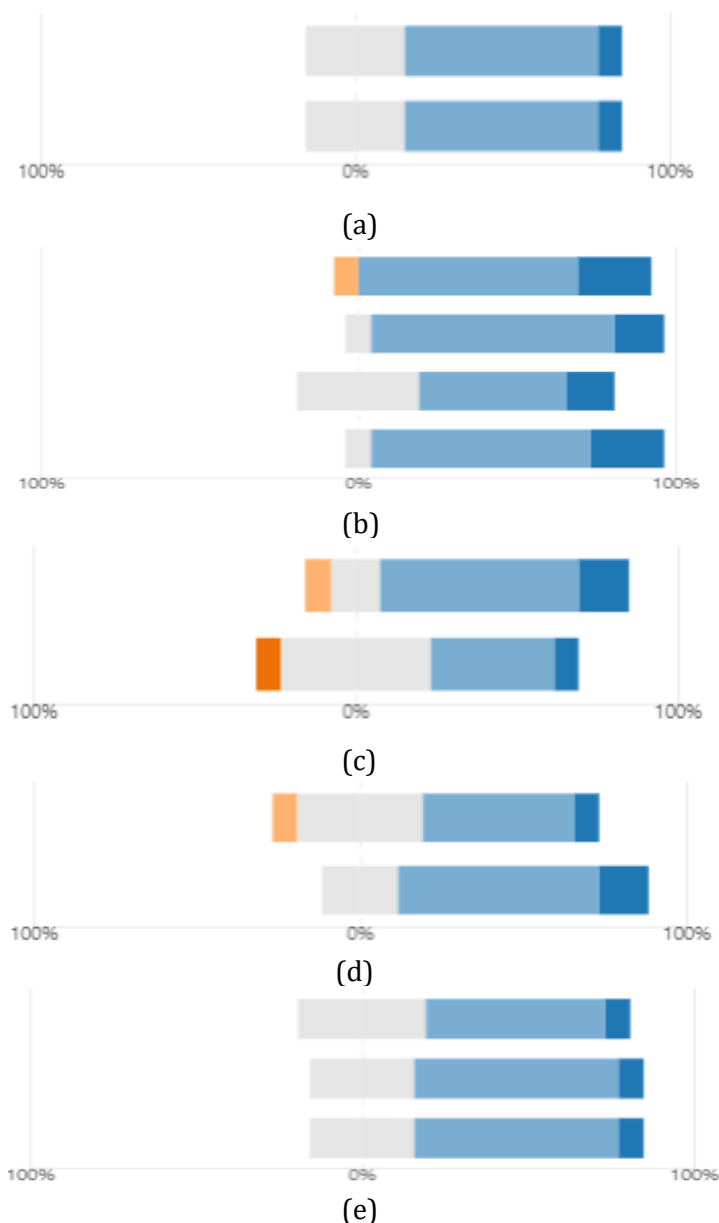
Prior knowledge is needed related to the basic principles of chromatography and HPLC as reflected in the questionnaire results, which stated that the material presented was still too complex. In addition, they also reasoned that most of the material presented was not supported by a practicum process, which impacted the meaningfulness of the material and cognitive strategies for some students. In this study, the practice of operating the HPLC was not carried out considering the conditions of the Covid-19 pandemic. In the end, students could not imagine how the basic techniques of

operating HPLC were direct. Practicum in analytical chemistry is very important in Analytical Chemistry lectures because

competence in analytical chemistry practicum is a vehicle for developing thinking and creativity skills (Bowen, 2018).

Figure 3.

The results of students' perceptions of the learning process using the HPLC simulator include 5 aspects of assessment, namely: (a) the suitability of the use of media to achievements and learning materials, (b) the role of lecturers in the learning process, and utilization of learning media, (c) the role of the HPLC simulator towards increasing interest and motivation, (d) the suitability of the media with student conditions, (e) the use of media according to its function



In addition, in practicum activities, a complete performance assessment can be carried out, namely through exercises that will direct students to interpret what students should do and prepare according to

the criteria contained in the performance assessment. Furthermore, concepts obtained through practical activities will have a long-term memory effect (Sudrajat et al., 2017). Kovarik (2016), the use of inquiry-based

laboratory experiment guides/Guided-Inquiry Laboratory Experiments (Giles) gives students the freedom to design and carry out experiments to stimulate student achievement and interest in studying science, technology, engineering, and mathematics.

Conclusion

The development of MMI assisted by the HPLC Simulator is highly recommended in the learning process. Based on the expert judgment test results, MMI HPLC is feasible in the learning process. The trials' results show that the use of MMI HPLC assisted by the HPLC simulator can improve students' conceptual mastery and analytical thinking. Two aspects of skills that have developed quite well are matching and classifying skills, while error analysis, specifying, and generalizing skills have not developed as expected. It is advisable to ensure students' prior knowledge of the basic concepts of chromatography and the operation of HPLC instruments. STEM learning is highly recommended to overcome the lack of development of analytical thinking skills in the aspects of error analysis, specifying, and generalizing.

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