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Programmable Logic Controller Analog Input Learning Module: An Expert-Based Evaluation

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Abstract

This study aims to validate the analog input learning module of programmable logic controller (PLC). This module was developed using the OMRON CP1H PLC type which has analog input and analog output configurations. Scientific studies on the quality standards of learning modules are the basis for the development of this instrument. The content validity test was carried out by evaluation experts, while media and material experts evaluated the printed media and PLC material aspects. The results of the study showed an assessment of the media side with an average score of the format aspect of 14.5, the organizational aspect of 27.5, the shape and size of the letters of 13.0, and the consistency aspect of 29.5 which was categorized as "Very Eligible", while the average score of the attractiveness aspect was 22.0 and the space aspect of 12.5 was categorized as "Eligible". The assessment results from the material side with an average score of the self-instruction aspect of 57.0, the adaptive aspect of 6.5, and the user-friendly aspect of 14.0 which is categorized as "Very feasible", while the average score of the self-contained aspect of 13.5 and the stand-alone aspect of 6.5 is categorized as "Eligible". This module is considered feasible for learning PLC analog input with satisfactory assessment results.

Keywords*: Learning Module, Analog Input PLC, Expert-based Evaluation*

Abstrak

Penelitian ini bertujuan untuk memvalidasi modul pembelajaran input analog *programmable logic controller* (PLC). Modul ini dikembangkan menggunakan tipe PLC OMRON CP1H yang memiliki konfigurasi input analog dan output analog. Kajian ilmiah tentang standar kualitas modul pembelajaran menjadi dasar pengembangan instrumen ini. Uji validitas isi dilakukan oleh ahli evaluasi, sementara ahli media dan materi mengevaluasi aspek media cetak dan materi PLC. Hasil penelitian menunjukkan penilaian sisi media dengan skor rata-rata aspek format sebesar 14,5, aspek organisasi sebesar 27,5, aspek bentuk dan ukuran huruf sebesar 13,0, dan aspek konsistensi sebesar 29,5 yang dikategorikan “Sangat Layak”, sedangkan skor rata-rata aspek daya tarik sebesar 22,0 dan aspek ruang spasi sebesar 12,5 dikategorikan “Layak”. Hasil penilaian dari sisi materi dengan skor rata-rata aspek *self-instruction* sebesar 57,0, aspek *adaptive* sebesar 6,5, dan aspek *user-friendly* sebesar 14,0 yang dikategorikan “Sangat layak”, sedangkan skor rata-rata aspek *self-contained* sebesar 13,5 dan aspek *stand-alone* sebesar 6,5 dikategorikan “Layak”. Modul ini dinilai layak untuk pembelajaran input analog PLC dengan hasil penilaian memuaskan.

Kata kunci: Modul Pembelajaran, Input Analog PLC, Validasi Ahli

Introduction

Industrial automation in the era of the industrial revolution 4.0 has become a key element driving work efficiency and productivity. Automation aims to integrate manufacturing processes to optimize worker and workpiece safety, reduce worker errors, and increase efficiency, quality, and productivity [1]. Industries widely use programmable logic controllers (PLCs) to control industrial machines and production processes. Research shows that the implementation of industrial 4.0 technology and automation in industries extensively utilizes programmable devices like PLCs and industrial robots [2]. PLC technology enables precise control through logic, replacing inefficient manual controls. PLCs manage automation by controlling inputs and outputs while enabling real-time system monitoring. Effective use of manufacturing systems employing PLCs relies on skilled professionals proficient in operating and programming these systems.

Vocational education can produce graduates ready to work in the industry. Learning in vocational education focuses on the knowledge, competencies, and practical skills required by students in specific fields [3]. In the field of electrical engineering vocational education, one of the required competencies is PLC. PLC technology is the heart of the process control industry, making PLC competency crucial for implementation [4]. Mastery of programming and operating analog input PLCs is essential for students to become professional workers. Vocational education must provide students with knowledge and skills in programming analog input PLCs to meet industrial needs.

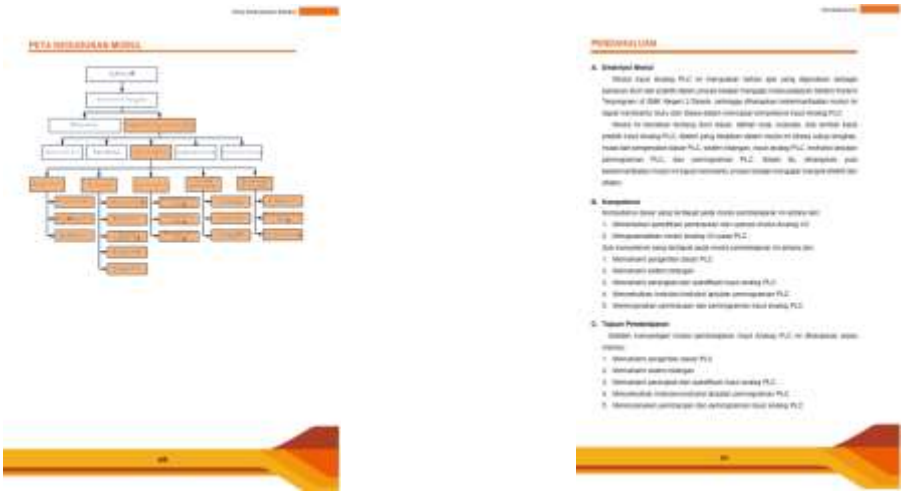
Various factors contribute to improving students' competency in analog input during the learning process. Success in improving PLC programming competency depends on factors such as instructor’s competence, the availability of learning materials or media, available infrastructure, and students' motivation to learn [5]. Learning media can help students study independently anytime and anywhere [6]. Learning modules serve as effective tools in providing practical understanding to students about the concepts and applications of industrial control systems based on PLCs. Moreover, the implementation of learning modules can improve student learning outcomes [7]. An educational course on analog input Students can practice programming and managing continuous sensor data, such as flow, pressure, and temperature, which are frequently utilized in industrial processes, with PLCs.

Developed learning modules need expert evaluation. Expert-based evaluations help identify strengths and weaknesses and provide recommendations for improvements [8]. Expert assessments evaluate two aspects, aspects content and aspects media [9][10]. Content evaluation assesses the material included in the module, while media evaluation assesses the appearance of the printed learning module for analog input PLCs. This research aims to evaluate and test the feasibility of the analog input PLC learning module from content and media aspects by experts.

a. Analog Input PLC Learning Module

The PLC analog input learning module that has been developed is used as an object of evaluation by experts. The PLC analog input module is used in learning PLC practices in vocational education, especially in improving student learning outcomes.

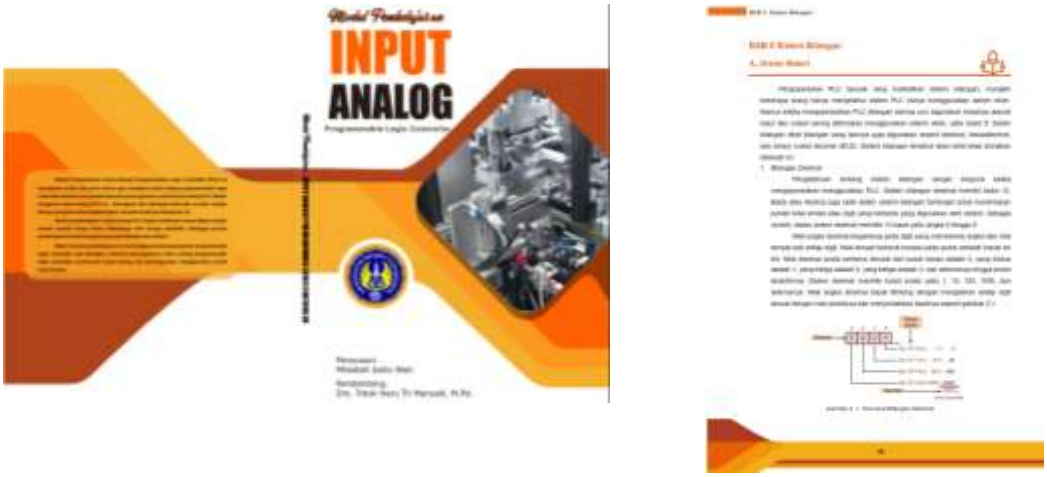
This learning module consists of a cover page, front page, preface, table of contents, list of figures, list of tables, instructions for using the module, module position map, introduction, material description, final evaluation, practical worksheet, answer key, and references. The cover page and front cover aim to provide information about the title and author of the learning module. Figure 1(a) shows the module position map which serves to provide information about the position of the analog input learning module in PLC learning activities. The introduction to the module provides information about the module description, competencies learned, and learning objectives, the introduction display is shown in Figure 1(b). The PLC analog input module's learning objectives include teaching students the fundamentals of PLC, the number system, PLC analog input devices and specifications, advanced PLC programming instructions, and how to read and program PLC analog input.



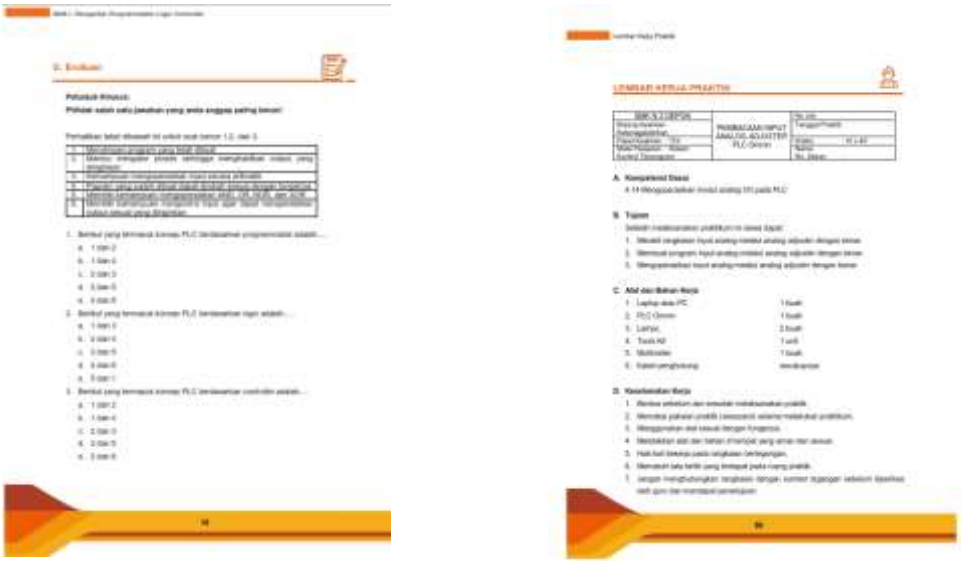
(a) (b)

Figure 1. (a) Module Position Map and (b) Introduction

The material description consists of five chapters: Chapter 1 covers PLC introduction, Chapter 2 covers number systems, Chapter 3 covers analog input PLCs, Chapter 4 covers PLC programming instructions, and Chapter 5 covers analog input reading and programming.



(a) (b)



(c) (d)

Figure 2. (a) Cover Page (b) Material Description (c) Evaluation (d) Practice Worksheet

Figure 2 shows parts of the analog input PLC learning module. Figure 2(a) is the cover page of the learning module. Figure 2(b) is the presentation of the number system material description in the learning module. Figure 2(c) shows the evaluation sheet for measuring student learning outcomes, while Figure 2(d) shows the analog input PLC practice worksheet for students. Each chapter begins with learning objectives and a brief introductory description of the material to be presented. Chapter 1 material includes the understanding and basic concepts of PLCs, PLC components, and PLC input/output. Chapter 2 material includes decimal, binary, hexadecimal, octal, binary coded decimal (BCD) numbers, and number conversion. Chapter 3 material includes the understanding and basic concepts of analog input PLCs, specifications of analog input PLCs, and analog input devices. Chapter 4 material includes the operation of scaling, move, and compare instructions. Chapter 5 material includes reading using analog adjusters, addressing and programming analog inputs, wiring analog input PLCs, and analog input application examples. The final evaluation includes assessment questions from Chapters 1 to 5, with answer keys. The practice worksheets available include reading analog adjuster inputs, OMRON CP1H PLC mixers with temperature sensors, and label machines with temperature sensors.

For PLC learning, the use of learning modules is highly advantageous. The creation of modules with a thorough structure and specific content guarantees that the learning module for analog input PLCs is made to give students a thorough and hands-on educational experience. Through this learning module, students are expected to develop the necessary competencies to work in increasingly automated industries and be ready to face challenges in the workforce.

Method

This research aims to validate the analog input PLC learning module. To make sure that the creation of educational materials satisfies the requirements for both media and content, validation is carried out. Evaluation of the content component pertains to the content and structure of the learning program in vocational education. The evaluation of

content experts involves several industrial automation experts, particularly in PLC programming. Media aspect evaluation refers to the text-based appearance of the module, such as image quality, layout, typography, color composition, and font size. The evaluation process begins with the development of evaluation instruments by industrial automation material experts and print media experts. The instrument grids are developed based on theoretical reviews related to PLC material, particularly programming and operating analog inputs, and theoretical reviews related to learning module quality criteria. Instrument items are developed based on the grid and indicators, forming a 4-point Likert scale evaluation questionnaire. The developed instrument is then validated by educational evaluation experts according to the indicator development instrument.

a. Developing The Instruments for Evaluation

The questionnaire instrument uses a Likert scale with four options. Evaluation is used to obtain qualitative and quantitative data. Qualitative data includes comments, suggestions, and feedback from learning module experts, while quantitative data is used to determine the feasibility level of the learning module. Feasibility criteria for learning modules are based on Daryanto [11], Daryono & Rochmandi [10], Prihandono, et al. [12], and Hamid, et al. [13] have been analyzed. As a result, the feasibility test of the learning module is assessed based on two parts such as content and media.

Media aspect evaluation has six aspects, namely format, attractiveness, organization, font form and size, empty space, and consistency. The format aspect has two indicators, including paper and column format and typing format and layout. The attractiveness aspect has three indicators, including use of images, compatibility of colors, images, and font styles, and evaluating packaging. The organizational aspect has indicators of Sequence of learning materials, placement of tables, images, illustrations, and text, flow arrangement between chapters, units, and paragraphs, and use of material coverage maps. The font form and size aspect have two indicators, namely ease of reading fonts and sizes and proportional font sizes between titles, subtitles, and content. The empty space aspect has two indicators, including empty space and space between texts. The consistency aspect has four indicators, including font style and size consistency, design consistency, typing layout consistency, and text spacing consistency.

Table 1 Shows the Grids and Indicators of The Media Evaluation Instrument.

Table 1. Media Expert Instrument Grids and Indicators

No	Aspect	Indicator	Description	Item Number
1	Format	Paper and column format	The paper and column format used are proportional.	1,2
		Typing format and layout	The typing format and layout of the module are good.	3,4
2	Attractive-ness	Use of images	The use of illustrative images on the cover matches the module's content, and the images within the module are clear.	5,6

No	Aspect	Indicator	Description	Item Number
		Compatibility of colors, images, and font styles	The use of illustrative images on the cover matches the module's content, with attractive color combinations, and appealing font styles and sizes.	7,8,9
		Evaluation packaging	The presented evaluation is attractive and the evaluation pages are easy to find.	10,11
3	Organization	Sequence of learning materials	The presented learning materials are sequential and align with the basic competencies.	12,13
		Placement of tables, images, illustrations, and text	The tables, images, or illustrations presented match the module's needs.	14,15
		Flow arrangement between chapters, units, and paragraphs	The structure between chapters, units, and paragraphs is well-organized. The structure between titles, subtitles, and content is also well-organized.	16,17
		Use of material coverage maps	The presentation of concept maps aligns with the explanations in the module and is easily found by users.	18,19
4	Font and Size	Ease of reading fonts and sizes	The fonts and sizes used are easy to read.	20,21
		Proportional font sizes between titles, subtitles, and content	The font sizes between titles, subtitles, and content are proportional. The font style and size of the content are proportional.	22,23
5	Empty Space	Empty Space	The empty spaces are used effectively.	24,25
		Space between texts	The spacing between paragraphs and lines is consistent.	26, 27
6	Consistency	Font style and size consistency	The font style and size in each chapter are consistent. The use of font variations (bold, underline, and italic) is consistent.	28,29
		Design consistency	The design format in each chapter is consistent. The cover design and module content are harmonious.	30,31
		Typing layout consistency	The paragraph layout in each chapter and between chapters is consistent.	32,33
		Text spacing consistency	The spacing size between paragraphs and lines is consistent.	34,35

The assessment from the perspective of material experts involves five aspects, namely self-instruction, self-contained, stand-alone, adaptive, and user-friendly. The self-

instruction aspect includes seven indicators, namely clarity of learning objectives, packaging of learning materials, availability of material summaries for each chapter, use of language in the module, learning materials supported with examples, images, and illustrations, availability of practice questions, and availability of assessment instruments. The self-contained aspect has two indicators, namely includes all learning materials for a complete competency standard and material relevance to the context of activities. The stand-alone aspect has indicators that it does not depend on other teaching materials. The adaptive aspect has indicator namely the learning module can adapt to the advancements in science and technology and is flexible for use across various hardware devices. Lastly, the user-friendly aspect has two indicators, namely easily understandable information and easily understandable instructions.

Table 2. Content Expert Instrument Grid and Indicators

No	Aspect	Indicator	Description	Item Number
1	Self-Instruction	Clarity of learning objectives	The learning objectives align with the basic competencies of the subject and the material learned meets the learning objectives.	1,2
		Packaging of learning materials	The learning module is packaged according to the learning activities, facilitating students in understanding the material and helping them to study independently.	3,4,5
		Availability of material summaries for each chapter	Summaries of the material make it easier for students to understand the material and reinforce their memory of what they have learned.	6,7
		Use of language in the module	The language used in the module is easy for students to understand and is appropriate for the readers' age.	8,9
		Learning materials supported with examples, images, and illustrations	The images presented align with the material; the illustrations clarify the understanding of the material; examples of applications are provided.	10,11,12
		Availability of practice questions to measure material mastery	Formative test questions train and guide students to study independently, and assignments train students to develop skills.	13,14,15
		Availability of assessment instruments	The assessment instruments inform the level of students' material mastery and are easy for students to understand.	16,17

No	Aspect	Indicator	Description	Item Number
2	Self-Contained	Includes all learning materials for a complete Competency standard	The module is structured and aligned with the basic competencies outlined in the syllabus.	18,19
		Material relevance to the context of activities	The presented material aligns with the needs and learning activities in the field of control systems.	20,21
3	Stand Alone	Learning module does not depend on other teaching materials	The module can be used independently without assistance from other modules and can be understood without requiring an educator's help.	22,23
4	Adaptive	The learning module can adapt to the advancements in science and technology	The learning module can be used in accordance with technological and informational advancements and can be utilized both inside and outside the classroom.	24,25
5	User-Friendly	Easily understandable information.	The presented images are easy to understand, and the presentation of tables provides clear information.	26,27
		Easily understandable instructions.	Instructions and terms are easily understood by participants.	28,29

b. The Validity of Instruments

The validity of the instrument uses content validity. Content validity measures the relevance of assessment instrument components and represents constructs appropriate to the assessment goals [14]. Instrument experts will evaluate the content of the prepared instrument items. Instrument validity is necessary to ensure that the instrument is feasible and can be used to evaluate research products. Instrument validity involves two vocational education experts. With a few recommendations for enhancements, the two instrument specialists declared that the instrument is viable for use in research. These recommendations include adopting communicative language, standardized language, balancing the number of things in each indicator, and sequentially ordering the information. The experts agreed to balance the number of items per indicator by adding or removing items. Suggestions and inputs from the experts were used to improve the instrument, ensuring that the final instrument could be used for data collection during the research.

c. The Feasibility Procedure

The assessment uses two instruments: one for content evaluation by experts and another for media evaluation by media experts. The evaluators include a vocational education lecturer and a vocational high school teacher specializing in industrial

automation and PLC subjects. The experts were selected to ensure objective assessments and gain feedback from experienced PLC educators. Media experts include two vocational education lecturers specializing in instructional modules and teaching media courses, chosen for their relevant expertise.

The evaluation begins with a brief presentation of the developed learning module. The presentation explains its sections, sequence of material, and assessments contained in the learning module to all experts. Subsequently, the experts explore the learning module independently. Question and answer sessions and discussions are conducted to analyze parts that may lack detail. Questionnaires related to the assessment aspects of content and media are provided to gather quantitative and qualitative data. All experts involved in the research must adhere to ethical standards to prevent potential conflicts of interest. Honesty, fairness, objectivity, confidentiality, and independence are crucial points that experts must apply throughout the research. To ascertain the module's level of applicability, quantitative data is gathered and examined following completion of the given instruments. For additional product improvement, qualitative data—such as expert opinions and suggestions—is also examined.

d. Product Eligibility Criteria

The data obtained from the questionnaire is quantitative, using a four-point Likert scale, are highly feasible, feasible, moderately feasible, and less feasible. Feasibility categories are determined based on the number of questionnaire items, maximum score, minimum score, average score, and standard deviation [15]. Quantitative data is analyzed to determine the level of feasibility of the product. The feasibility level of the learning module is determined based on the assessment scores from the experts. Table 3 shows how to determine the feasibility according to media and content experts in the learning module using ideal score conversion.

Table 3. Feasibility Categories of Media and Material Experts [15]

No	Interval	Category
1	(Mn + 1.5 SBn) – (Mn _ 3.0 SBn)	Highly Feasible
2	(Mn) – (Mn + 1.5 SBn)	Feasible
3	(Mn – 1.5 SBn) – (Mn)	Moderately Feasible
4	(Mn – 3.0 SBn) – (Mn – 1.5 SBn)	Less Feasible

Notes: Mn is the ideal mean and SBn is the standard deviation

Result and Discussion

This section describes the research results in the form of analysis data obtained during the study. Discussions and analysis are also presented in this section. The feasibility of the learning module was validated by media learning experts and material experts in PLC programming.

a. The Evaluation of Learning Module Qualifications by Media Experts

The feasibility assessment of the learning module by media experts aims to determine the module's feasibility from a media aspect. The feasibility testing by media experts used a questionnaire with 35 items consisting of format aspects, attractiveness aspects, organization aspects, font and size aspects, empty space aspects, and consistency aspects. Each aspect of the assessment obtained average scores of 14.5, 22.0, 27.5, 13.0,

12.5, and 29.5, respectively. Table 4 shows the results of media experts' assessments, where four aspects were categorized as "Highly Feasible" and two aspects as "Feasible".

Table 4. The Assessment Results of the Learning Module on the Media by Experts

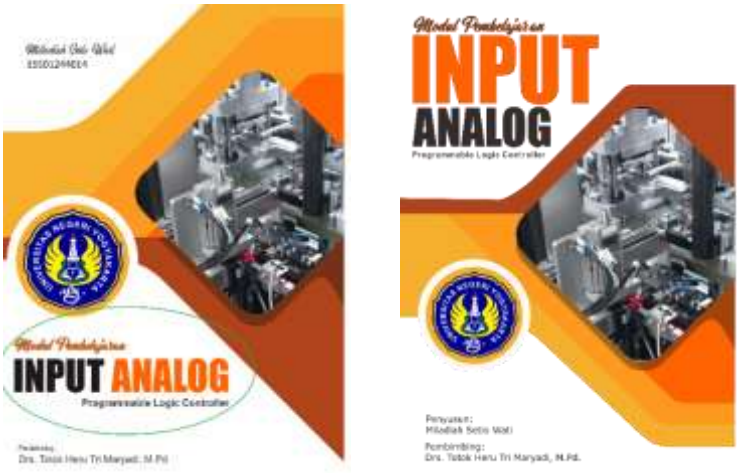
No	Aspect	Evaluation Score		Average	Category
		Expert 1	Expert 2		
1	Format	15	14	14.5	Highly Feasible
2	Attractiveness	20	24	22.0	Feasible
3	Organization	26	29	27.5	Highly Feasible
4	Font and Size	12	14	13.0	Highly Feasible
5	Empty space	12	13	12.5	Feasible
6	Consistency	29	30	29.5	Highly Feasible

The assessment from media experts also produces qualitative data in the form of comments, suggestions, and feedback. Table 5 presents the qualitative data obtained from media experts. The qualitative data obtained is then analyzed to make improvements to the learning module.

Table 5. Comments, Suggestions, and Feedback from Media Experts

Respondent	Comment, Suggestions, and Feedback
Expert 1	• The cover section needs to highlight the module title to make it attractive and easy to read. • The module usage instructions need revision. • Brief explanations should be added to the module layout map to differentiate the meaning of white and orange blocks.
Expert 2	• Reduce white space in the learning module. • Include images of sensors in Chapter 1. • Move the initial chapter writing position from the right to the left. • Change the title "Daftar Pustaka" to "Referensi" in the bibliography.

Based on the comments, suggestions, and feedback from media experts in Table 5, the next steps involve improving the learning module. The improvements include enhancing the cover title of the learning module, adding brief explanations to the module position map, including sensor images in Chapter 1, and relocating chapter writing. The improvement to the title on the cover of the learning module involves revising its position from below to the top. This revision is made to ensure that the module title stands out more prominently and attracts the reader's attention. Figure 3(a) shows the cover before revision, where the title is located below and lacks prominence, making it difficult to find. The revised module title is depicted in Figure 3(b).



(a) (b)

Figure 3. (a) Before Revision, (b) After Revision by Moving the Position of the Learning Module Title

The suggestion for improvement includes adding brief explanations to the module layout map. This addition aims to assist readers in distinguishing between the meaning of white-colored blocks and orange-colored blocks. Figure 4 illustrates the revised module layout map, where the red boxes indicate the added color explanations on the diagram blocks.

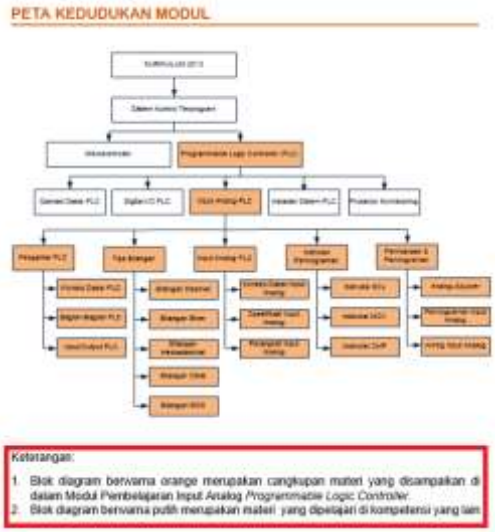


Figure 4. Module Position Map after Revision

The media experts suggested adding sensor images in Chapter 1. This addition aims to help readers better understand examples of analog inputs or outputs used in PLCs. Illustrative images are crucial in learning modules to engage and motivate readers effectively. The final improvement involves relocating the position of chapter titles. Initially, the chapter opening design placed them on the right side as shown in Figure 5(a). After revision, the redesigned chapter opening is depicted in Figure 5(b), with the chapter numbering positioned on the left side, similar to the text layout. This adjustment was made to maintain consistency and readability throughout the module.

(a) Before Revision (b) After Revision

Figure 5. Chapter Start Page Improvements

b. The Evaluation of Learning Module Qualifications by Material Experts

The feasibility assessment of the learning module by material experts aimed to evaluate its content on analog input PLCs. This assessment used a 29-item questionnaire covering aspects such as self-instruction, self-contained, stand alone, adaptive, and user friendly. The scoring range used a Likert scale with four points. According to Table 6 each aspect has average scores of 57.0, 13.5, 5.0, 6.5, and 14.0. Three aspects were categorized as "Highly Feasible" and two as "Feasible".

Table 6. The Assessment Results of the Learning Module Material by Experts

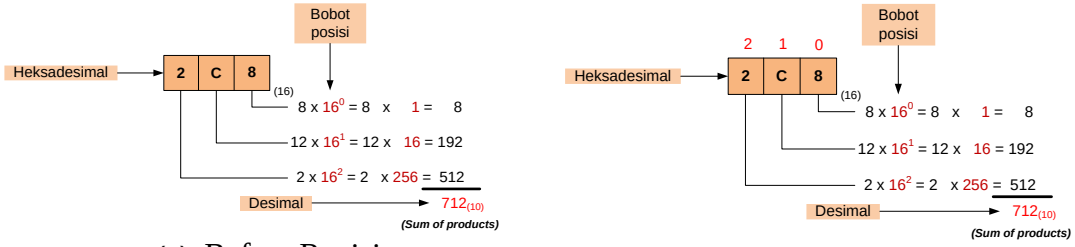
No	Aspect	Evaluation Score		Average	Category
		Expert 1	Expert 2		
1	Self-Instruction	59	55	57.0	Highly Feasible
2	Self-Contained	14	13	13.5	Feasible
3	Stand Alone	4	6	5.0	Feasible
4	Adaptive	6	7	6.5	Highly Feasible
5	User Friendly	13	15	14.0	Highly Feasible

The developed product was validated by content experts. The content experts provided assessments using a questionnaire and qualitative data in the form of suggestions and comments for improving the product in terms of PLC material. The qualitative data from the validation by content experts is shown in Table 7.

Table 7. Comments, Suggestions, and Feedback from Material Experts

Respondent	Comments, Suggestions, and Feedback
Expert 1	• Add position weights for binary numbers. • Add a place to put the remainder of the division results in converting decimal numbers to binary. • Image for question on page 53, number 1, is not yet available. • Add explanation for ladder diagram program process per rung.
Expert 2	• Provide examples of implementation in programming instructions. • Add addressing and programming procedure diagram for analog inputs.

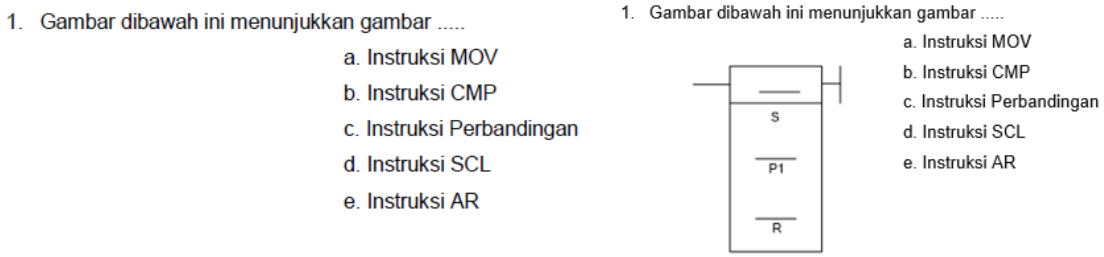
Based on the comments and suggestions from content experts, not all suggestions could be implemented by the researcher. However, several improvements were made, including adding position weights, adding images to evaluation questions, and including a diagram of addressing procedures for analog inputs. The first improvement involved adding position weight explanations to the number conversion material. Figure 6(a) shows the number conversion method without position weight explanations, while Figure 6(b) illustrates the number conversion method with position weight explanations at the top of the number system. This enhancement was made to help readers understand the function of position weights in number conversion.



(a) Before Revision (b) After Revisions

Figure 6. Improvements to Addition of Position Weights

The second improvement involved adding an image to evaluation question number one on page 53. This revision was necessary because the printed module lacked the question image, as shown in Figure 7. Adding the image aimed to facilitate readers in understanding the question, as depicted in Figure 7.



(a) Before Revision (b) After Revisions

Figure 7. Improvements to Adding Images to Questions

The final improvement is adding a diagram illustrating the procedure for addressing analog input in PLC, as shown in Figure 8. This enhancement aims to facilitate students in understanding the steps involved in using analog inputs in PLCs.

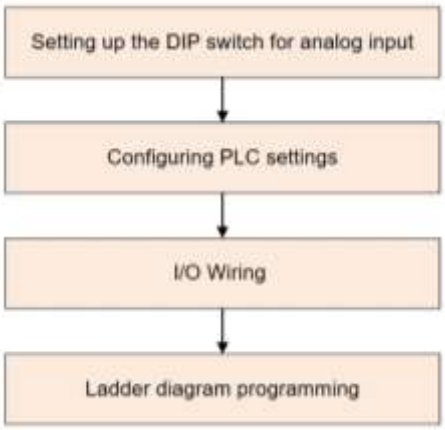


Figure 8. Improvements to Adding Diagrams

The evaluation of the PLC analog input learning module is conducted through a combined approach involving content and media experts. The evaluation utilizes a Likert scale questionnaire to obtain structured and measurable feedback from these experts. This evaluation was conducted by Badarudin, et al. [16], categorizing the Likert scale into four levels of feasibility based on media and content experts: very good, good, good enough, and not good. Consistent with Hariyanto & Köhler [17], a four-point Likert scale is used to evaluate the viability of the media and content, and the average of the ratings is transformed to a "0-100 score" scale. The module is regularly improved by using input from media and content specialists, which raises the standard of vocational education. Students can better prepare for the difficulties of the fast-paced industrial environment by evaluating the learning module.

Conclusion

This study focuses on evaluating the learning module based on media and content aspects. Media assessment aims to evaluate the layout that is attractive and easy to follow for students. Meanwhile, content assessment aims to evaluate the feasibility of the material for PLC analog input competencies. Each aspect of media and content is evaluated by two experts. The results of the media assessment categorize four aspects as “Highly Feasible" and two aspects as "Feasible". Similarly, the content assessment results categorize three aspects as "Highly Feasible" and two aspects as "Feasible". Limitations of this study include the assessment of PLC analog input material and printed learning modules. Future research could involve user-based evaluations, including feedback from vocational education students and instructors specializing in PLC analog input.

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