The Development of Programmable logic controller tutorial in the form of industrial-based learning material in vocational high schools

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ABSTRACT - *This research and development aims to (1) produce teaching material of industrial-based of PLC tutorial which could improve the quality of learning at SMK, (2) examine students and teachers' response toward teaching material of developed PLC tutorial, and (3) examine the effectiveness of developed teaching material. This research and development employed Four-D model. The samples of the study were 17 students at SMKN 1 Makale South Sulawesi Indonesia.*

In order to obtain the product of qualified teaching material, there were four steps were conducted, namely 1) define, 2) design, 3) development, and 4) disseminate. To examine students and teachers' response toward teaching material, questionnaire was used. The effectiveness of developed teaching material could be shown through the result of observation on students and teachers' activities which obtained through pre-test and post-test. The results of the study revealed that (1) the result of data analysis on product validity was in high valid category, 2) the result of data analysis on practicality which obtained through data analysis of students and teachers' response was in excellent category, and 3) the result of data analysis on effectiveness which obtained through the result of analysis of pre-test and post-test showed improvement of students' score. Meanwhile, the result of data analysis of observation on students and teachers' activities during the teaching and learning process was in very active category. Based on those data, it can be concluded that the developed industrial-based teaching material in the form of PLC tutorial has met the category of valid, practical and effective so that it will be feasible to be developed.

Keywords - *Industry, PLC, SMK, tutorial teaching material*

I. INTRODUCTION

The changes and developments in science and technology have grown more rapidly in recent years. One of the industry's technological developments that may affect the increase in the quantity and quality of production is the use of automation systems in production machines. Industrial world requires a production process that can be operated in sequence from one process to another process without having to use many human labors. Therefore, it will be necessary to have automation system. Automation system is a series of some of the production process that are interconnected and controlled from a single center (control room). The application of technology in the industry requires skilled workers that have qualification to be involved directly in the production process, and has competencies to master and apply these technologies.

Vocational High School (SMK) is part of a national education system that aims to prepare workers who have the skills and appropriate knowledge that match the needs of employment requirement and be able to develop his or her potential in adopting and adapting to technological developments. This means that vocational education graduates are going to produce skilled manpower at the secondary level who are ready to be used in the business and industrial world.

Charles Prosser in Djojonegoro (1998) suggested [1]:

a) Vocational education will be effective when it can provide the minimum provision of required abilities in world of work (as a minimum standard of the profession), make it more easy and adaptive to its development; b) vocational education will be effective when the job training in the execution of a task is already accustomed to the real conditions in the future; c) Vocational education will be effective if it notice the labor market conditions; d) Vocational education will be effective if the used source data to determine the educational program based on the real experience in the work field ". The development of the industrial world is dynamic and changing rapidly following the development of science and technology. This suggests that the existing school curriculum needs to be reviewed to see whether there is a match between the competencies taught in

schools and the competence needs in industry. Vocational education curriculum should be designed according to the required competencies in the industrial world. The relevance of vocational education with industry is closely related to the suitability of learning materials' contents in the preparation of labor. It is expected that vocational graduates can apply the knowledge, abilities and skills in the world of business and industry.

Programmable Logic Controller (PLC) is one of the control systems that is used to automatically control the production process where in the condition of the modern era, the use of PLC control technology become more widespread.

PLC is one of the subjects in vocational productive. Based on researcher's observations in several vocational high schools, it was found that PLC learning in schools was much lack behind with the development of PLC in the industrial world. The used practice equipment is lacking and very different with the existing equipment in the industry today.

The aim of this study are: 1) to generate a PLC tutorial that is industrial-based teaching materials that can improve the quality of learning in vocational high school, 2) To know the response of students and educators to the developed PLC tutorial that is industrial based teaching materials, 3) to assess the effectiveness of the developed teaching materials.

Teaching materials that were developed in this study are: 1) PLC CD Tutorial Learning (TP-PLC), 2) Handbook Media, 3) Instructional Materials, 4) Learning Implementation Plan (RPP) and 5) Test Results.

II. LITERATURE REVIEW

2.1. Vocational Education Concept

According to the Law on National Education System (UUSPN) no. 20 2003 [2], vocational education is an education that prepares students especially to be able to work in a particular field and ready also proceed to a higher level of education. The purpose of vocational education is to prepare students as candidates for employment and develop the existing students, for the benefit of students, community, nation and state [1].

The characteristics of vocational education according Djojonegoro (1998) are as follows [1]: a) vocational education are arranged to prepare students to enter the labor market; b) vocational education are made based on the "demand-driven" (needs of the workforce); c) the content focus of vocational education emphasize on the mastery of knowledge, skills, and values needed by the world of work; d) the actual assessment on the success of students should be on vocational education; f) the "hands-on" education or performance in the world of work; e) a close relationship with the world of work is the key to a good vocational success which is responsive and adaptable to technological advances; g) vocational education is more emphasis on "learning by doing" and "hands-on experience"; h) vocational education requires cutting-edge facilities for practice; i) vocational education requires greater investment and operating costs than the general education.

Charles Prosser in Djojonegoro suggested that there are 16 principles of vocational education. Based on this 16 principles, there are four principles that relate to the conducted research, namely: 1) Vocational education will be effective when it can provide the minimum provision of required abilities in world of work (as a minimum standard of the profession), make it more easy and adaptive to its development; 2) vocational education will be effective when the job training in the execution of a task is already accustomed to the real conditions in the future; 3) Vocational education will be effective if it notice the labor market conditions; 4) Vocational education will be effective if the used source data to determine the educational program based on the real experience in the work field [1].

2.2. Teaching Materials

According Yaumi [3], teaching material is a set of materials that arranged in a systematic way for the learning needs which are obtained from printed materials, visual aids, audio, video, multimedia, and animation, as well as computer and network. The objective of teaching materials according to the Ministry of Education[4] are: a) providing instructional materials in accordance with the needs of the students; the teaching materials that are suitable with the characteristics and social or environmental setting of students; b) assisting students in obtaining alternative teaching materials as an addition to textbooks that are sometimes difficult to obtain; and c) allows teachers in implementing the learning. The importance of the preparation of teaching materials according to Yaumi [3] includes three essential elements, namely: a) as a representation of teachers, lecturers or instructors presentation; b) as a mean of achieving the standard of competence, basic competence, or learning objectives; and c) as the optimization of service to learners. Forms of teaching materials are as follows [4]: a) printed materials such as handouts, books, modules, worksheets learners, brochures, leaflets, and wallchart; b) audio-visual such as: video / film and Video Compact Disk; c) audio such as: radio, cassette, CD audio and Power Head; d) visual: images, drawings and models / prototype; e) Multimedia: an interactive CD, computer-based and Internet.

According Aunurrahman [5] in the selection of teaching materials, there are some principles that need to be considered, which are: a) the principle of relevance meaning, learning materials should be relevant or nothing to do with the achievement of standards of competence and basic competences ; b) the principle of consistency means constancy. If the basic competencies that must be mastered by students are four kinds, the teaching materials that should be taught also have to include them; and c) the principle of sufficiency means that the material being taught should be sufficient to help learners master the basic competencies that are taught.

2.3. Tutorial

According Hamalik [6] tutorial is learning guidance in the form of guidance, assistance, guidance, direction, and motivation for the students to learn efficiently and effectively. Tutorial program is a learning program that is used in the learning process by using software such as computer programs that contain subject matter and practice questions. The purpose of learning tutorials ([6] & [7]) are as follows: 1) to improve the mastery of the knowledge of the students in accordance with that the content in the learning modules: make efforts to enrich relevant material; 2) to improve the capabilities and skills of students on how to solve problems, overcome difficulties or obstacles to be able to guide themselves; and 3) to enhance the ability of learners on how to learn independently and apply them to each module being studied. The stages or steps of tutorial that use computer-based learning models [7]are as follows: 1) the presentation of information which in the form the learning material to be studied by students; 2) questions and responses (question of responses), in the form of practical questions that must be done by students; 3) assessment of response (judging of responses), the computer will respond to the performance and response of students; 4) provision of feedback responses (providing feedback about responses), which once completed, the program will provide feedback what has been successful / unsuccessful or have to repeat; 5) repetition (remediation); and 6) the segment of lesson setting (sequencing lesson segment).

2.4. Programmable Logic Controller (PLC)

National Electrical Manufacturers Association (NEMA) defines PLC as digital electronics equipment that uses programmable memory for storing instructions and implement specific functions such as logic, sequential, timers, counters and arithmetic to control machines and processes [8].

PLC function according to [9] are as follows:
a. Sequential Control
PLC process the binary signal inputs into outputs that are used for the processing techniques in sequential order. Here, PLC keep all the steps in a sequential process takes place in a proper order. For example: a conveyor in a series of automated production. PLC task is to control all the motors (eg conveyor belt speed), controls the hydraulic or pneumatic components.
b. Monitoring
PLC continuously monitors the status of a system such as: temperature, pressure, altitude level, flow and take the necessary action in connection with the controlled process (eg, the value has exceeded the limit) or display the message to the operator.

c. PLC as an Interface Control (control interface) on CNC machines
Currently, most of the control machine tools equipped with CNC (Computer Numerically Controller), where PLC as an interface are needed between machines and CNC controls.
Meanwhile, the advantages of using PLC by Ackermann et al [9] are: a) it is flexible, meaning that it can control multiple machines with a PLC; b) it can be detected / monitored during operation (running); c) it can be documented, which means the program in the PLC memory may be downloaded for printing; d) it can be operated very fastly; and e) it is easily modified without changing the wiring cables.

2.5. The Basic Component of PLC
The basic components of a PLC are [10]:
a. Module Input/Output (I/O Module)
I / O modules are physically connected to equipment in the field. There are different types of input and output devices.

2.5.1. Processor
The processor is the brain of the PLC. It is similar to the microprocessors used in personal computers. The work of the processor are: signal is sent to input module by the input elements machine / process. Input module then generates a logic signal which is then sent to the CPU. When receiving instructions from memory and feedback on the satus of I / O, CPU generates word to be sent to equipment output. This command controls the equipment on the machine or process.

2.5.2. Resources (Power Supply)

PLC and its modules are equipped with power generated from the power supply. Power supply voltage power line change as required by the components.

2.5.3. Memory Unit

Memory unit of a PLC is a register in which the programs are stored.

The memory can be erased or not erased. Memory is erased, the latter is causing the loss of data when power is removed. Battery backup (battery backup) is usually mounted so that the memory of the system will not be erased. There are three types of memory are: Read Only Memory (ROM), Read/Write Memory (R/W) and Random-Access Memory (RAM). Other memory types are electrically erasable programmable read only memory (EEPROM).

2.5.4. Network interface (Network Interface)

PLC is able to communicate with other equipment such as a computer program, the operator panel or an I / O that is placed in a location remote from the PLC. This communication takes place through a network interface.

2.5.5. Unit Programmers (Programming Units)

Programming unit established a relationship between the programmer (user) and PLC. Program equipment used to create or insert instructions into memory.

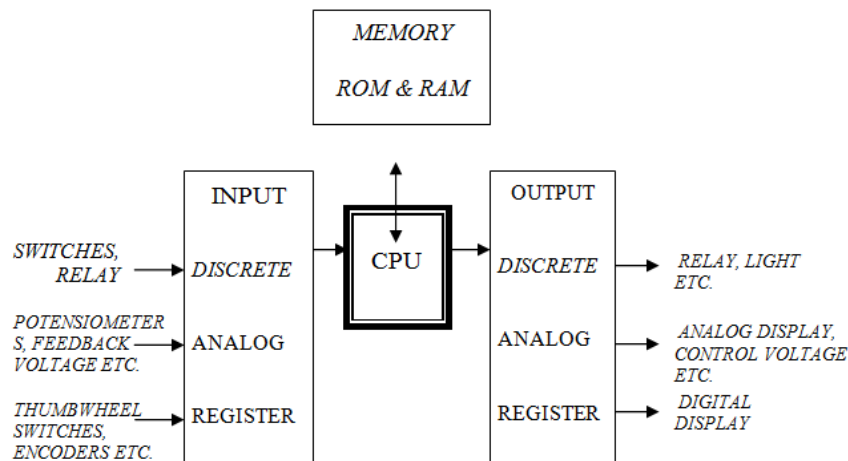Block diagram of a PLC is shown in the following figure:

Figure 1. Blok Diagram of PLC

2.6. PLC program (Software)

PLC program has a very specific structure, determined by the electronic-electronics in the central control unit (CCU). Program is created by the programmer from the source program. In principle, the programmer is able to create a program with three different methods [11] namely: a) Program Statement List (STL); b) Ladder Diagram (LAD); and c) Function Block Diagram (FBD).

Ladder Diagram is a graphical representation of the problem, using a common symbol relay logic in the USA. This symbol represents the status of "1" and "0". This screen is arranged in a horizontal rung. This arrangement provides a schematic view of Ladder diagram method of the control circuit wiring. Function Block Diagram is a graphical representation of the control task, using the symbols defined by DIN 40700 and DIN 40719. Each function is represented by the symbol. Input will be displayed on the left symbol and outputs on the right. Meanwhile, Statement List using mnemonic abbreviation to formulate the control task. All functions can be programmed in STL and is also featured in the STL by programmers. Basically, any format can be converted to each other format, using a programmer.

2.7. Industry-Based Learning

Industry-based learning is the learning that is designed so that students have competency that matched with the needs of industry [12]. Industry-based education requires the design and implementation of learning that involve various external parties such as business / industry, industry experts / business, or professional associations.

The development of the industrial world is dynamic and changing rapidly following the development of science and technology. Rapid changes in the industry suggests that the curriculum needs to be reviewed to see if there is a match between what is taught in schools with the needs of industry. Vocational education curriculum should be designed according to the needs of industry. The relevance of vocational education with industry closely related to the suitability of the content of learning materials in the preparation of labor so hopefully vocational graduates can apply the knowledge, abilities and skills based on what is required by the world of work. The importance of the content of vocational learning materials relevant to the world of work is used as measures to anticipate developments.

III. RESEARCH METHODS
3.1. Model and Procedure Development

The design of research to develop teaching materials is conducted by referring to
Four-D model development (4D) proposed by Thiagarajan and Semmel. For research purposes, we used flow development of teaching materials adapted from the 4D model as follows:
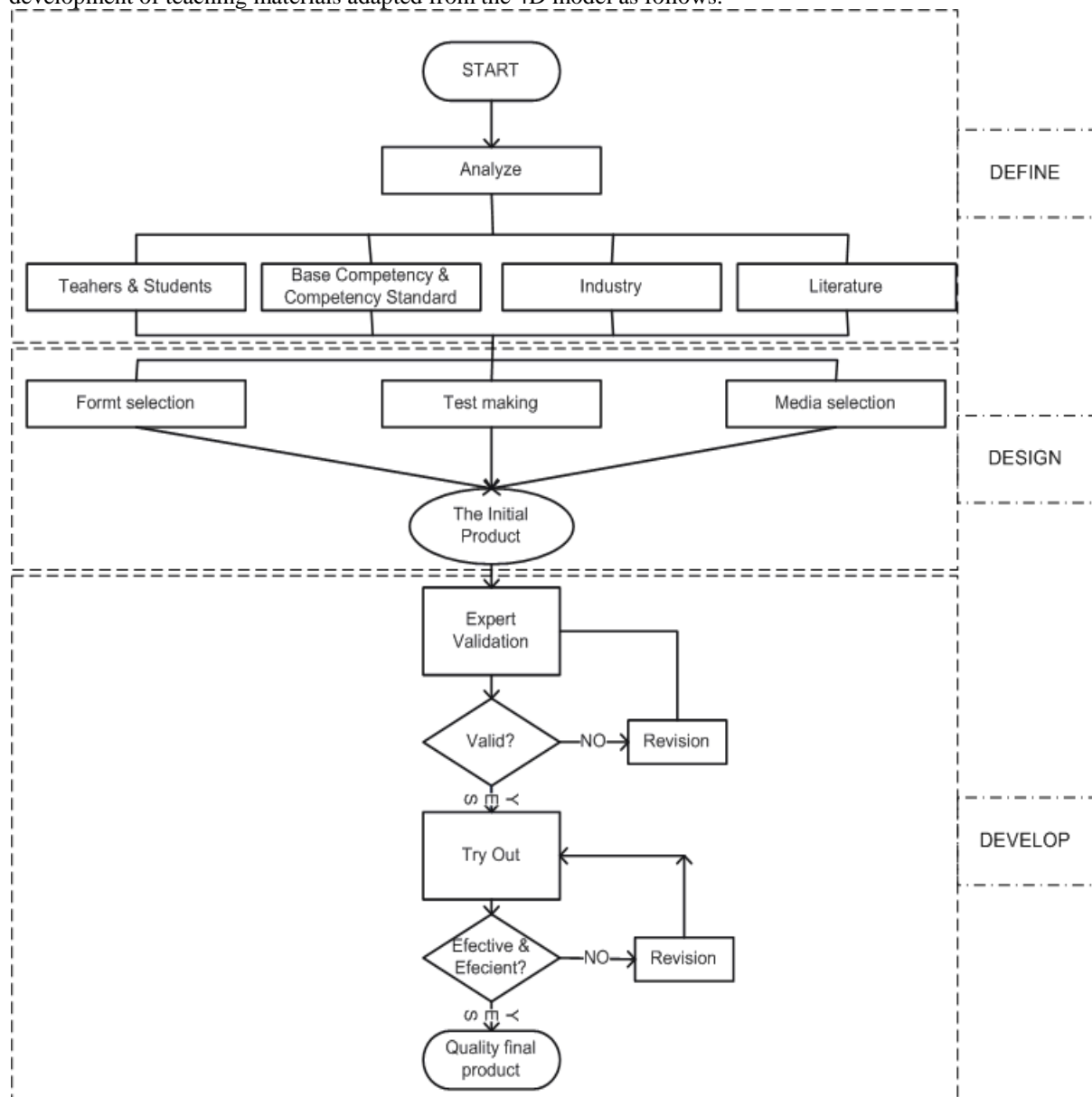

Figure 2. The Design and Teaching Material Development adapted to 4-D Model

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The stages of R & D are described as follows:

3.1.1. The definition phase (define)

In the definition phase, need analysis is conducted in schools and industry. In school, needs analysis is the analysis of the teachers, students and SK-KD (competency standard - basic competency). This is done to determine the problems and appropriate solutions and to determine the competence of learners.

Based on the analysis of the above requirements, then in this activity indicators formulated learning outcomes with reference to the basic competencies and learning outcomes to be achieved. Details specification of learning outcomes indicators aims to formulate specific learning goals, which in turn became the basis for the preparation of test and designing teaching materials based Industry in *SMK* (*Sekolah Menengah Kejuruan* – Vocational High School).

3.1.2. Design Stage

3.1.2.1. Format Selection

Format selection is intended for designing instructional materials or the learning content, the selection of strategies, approaches teaching methods and developed learning resources.

3.1.2.2. Initial design of teaching materials

Activity in the initial design includes writing the initial draft of teaching materials. The results of the preliminary design of teaching materials consist of: 1) lesson plans, and 2) teaching materials, and 3) achievement test.

3.1.2.3. The selection of instructional media

The selection of instructional media is done with the goal to determine the appropriate media to present learning materials which is ,in this study, the tutorial. Through this design phase, the initial product of industrial based PLC obtained which is called PLC Learning Tutorial (TP-PLC).

3.1.3. The development phase

3.1.3.1. Expert Validation

Validation is the assessment process of teaching materials conducted by experts namely: teaching materials and instructional media expert. This validation generally includes the substance of truth, conformity with the level of student thinking and conformity with the principles and characteristics of students. Validation of the design of teaching materials involves validators who have competence in the development of teaching materials. Based on their advice, teaching materials will be improved so that they become more precise, effective, useful, and have high quality.

3.1.3.2. Testing

After going through the validation by expert, teaching materials and instruments that exist subsequently revised in accordance with comments and suggestions from validator. Furthermore, they will be tested in the test class.

1) The individual test

Individual testing is done to test the readability of products involving three students (respondents) of the three categories of achievement (high, medium, and low).

Individual testing is done with the following procedure: (a) Sharing files TP-PLC to the students; (b) Explaining the purpose and objective of the pilot activities that carried out; (c) Operating the TP-PLC program to observe students; (d) Distributing the questionnaire sheet for students to be filled in accordance with the criteria that have been made; (e) allowing the students to evaluate the presentation in the TP-PLC media and fill their evaluations on the instrument that has been given; (F) to analyzing the collected data. The results of the data analysis are used as a benchmark for revising the TP-PLC. Result of improvements in the testing phase of this individual into the products tested on a small group with more trial subjects.

2) Testing in a small group

Small group trial is the same as in the individual trials. Small group trial conducted to test the readability of products involving seven students (respondents) of the three categories of achievement (high, medium, and low). Small group trial also evaluated the teaching materials and media tutorials from several aspects. The procedures similar with the experiments performed with individual testing. After the implementation of the trial, further analysis of the data obtained. The revised result at this stage is a product that will be tested in field trials with more trial subjects.

3) In-Field Testing

In-Field testing involves 17 people as trial subjects. The procedures which were performed in this activity are: (a) to carry out pre-test to distribute material about the PLC to the students. Pre-test was performed prior to the implementation of the teaching learning process by using TP-PLC; (B) Educators implement the teaching learning process by using the media TP-PLC; (C) Students as trial subjects try to follow the learning process with the help of a computer equipped with CD TP-PLC as a medium of learning; (D) Observers observe the learning process and record observations on the observation sheet according aspects and criteria that have been established; (E) to implement the achievement test (post-test) and the provision of questionnaire responses of students and educators who filled in at the end of the learning activity. The data were obtained from field trial activities through observation, questionnaire administration and subsequent tests were analyzed to determine whether the TP-PLC PLC used in the study have met the required quality criteria which are criteria of validity, practicality and effectiveness.

3.1.4. Deployment Phase (Disseminate)
This stage is the stage of dissemination according 4D-model. In this research, the dissemination phase is only done in the form of socialization product because time and high expense were considered.

3.1.5. Research Instrument
Data collection was performed using research instruments in the form of: (a) The needs analysis interview for activities conducted in schools and industry; (b) The questionnaire in the form of: 1) the validation sheets which are RPP (learning plan) validation sheet, learning material validation sheet, media validation sheet and test validation of learning outcomes; and 2) copies of the responses questionnaire of students and educators about devices that have been developed; (c) The observation of students' activities and learning management observation sheet; (d) The pre-test and post-test in the form of questions that should be done by the students to know their understanding of the development of teaching materials before and after development.

3.2. Data Analysis Techniques
The types of data in this development research are qualitative and quantitative data. Data analysis technique used a descriptive analysis which was done to assess the quality of teaching materials in terms of validity, practicability and effectiveness of its use. Qualitative data present in the form of comments and suggestions from experts, educators and learners for improvement of product which will describe in qualitative descriptive to revise the developed products. Moreover, the analysis of quantitative data is in the form of assessment scores from experts, educators and students.

3.2.1. Analysis of data validity
Data validation results from experts for each instrument were analyzed by descriptive qualitative form of the general assessment that includes: a very valid, invalid, quite valid, and invalid. Product teaching materials can be used by category: without revisions, minor revisions, major revisions, and cannot be used still require further consultation. Data validation results from experts for each learning formats analyzed by considering the assessment, feedback, comments and suggestions from the validator. The results of this analysis serve as guidelines for revising learning format in accordance with the grain of the assessment if it is still received less votes before the test.
The category of validity cited and modified from Hobri are as follows [13]:

Table 1. Criteria Analysis validity

No.	Interval	Category
1	$1,0 \leq \bar{X} < 1,5$	Invalid
2	$1,5 \leq \bar{X} < 2,5$	Less valid
3	$2,5 \leq \bar{X} < 3,5$	Valid
4	$3,5 \leq \bar{X} \leq 4$	Very valid

3.2.2. The analysis of data practicality.
Analysis of data practicality obtained through the data analysis of students and educators response to PLC tutorial teaching materials developed. Evaluation data using a questionnaire based on the 4-scale opinion by Sudjana is processed on the following criteria [14]: 1 = Disagree; 2 = Less Agree; 3 = Agree and 4 = Strongly Agree
Data were further analyzed descriptively in the form of percentage by using the formula:

$$score = \frac{\sum(answer \ x \ weight)}{n \ x \ highest \ weight}$$

n = total number of subject

to give meaning and help in decision making, the used criteria were cited and modified from Arikunto [15] as follows:

Table 2. Level of Achievement and Qualification

Level of Achivement	Qualification
1% - 100%	Very Good
61% - 80%	Good
41% - 60%	Less Good
< 41%	Not Good

3.2.3. Analysis of the data effectiveness

3.2.3.1. Data analysis activities of students and educators

Data observation of learners and educators activity was analyzed by comparing the average total activity of whole grains such liveliness assessment criteria. PLC tutorial teaching materials which were developed would meet the criteria of effective if the activity of learners and educators reached an average score of greater than 2.5. The categories of activity are cited and modified from Hobri are as follows [13]:

Table 3. Criteria Analysis Activeness

No.	Interval	Category
1	$1,0 \leq \bar{X} < 1,5$	Not active
2	$1,5 \leq \bar{X} < 2,5$	Less active
3	$2,5 \leq \bar{X} < 3,5$	Active
4	$3,5 \leq \bar{X} \leq 4$	Very active

3.2.3.2. Data Analysis THB (pre-test and post-test)

Score results of field trials using objective tests are analyzed by looking at the difference between the scores of pre-test and post-test.

IV. RESULTS AND DISCUSSION

The stages of development of industrial-based teaching materials PLC tutorial have been carried out based on the stages of the research. They are:

4.1. Initial Investigation Stage (define)

The observations in the field through field observations and interviews with teachers of subjects PLC, Vocational Industrial Automation showed that: a) the competencies taught in the field of PLC have not relevant to the vocational competencies required in the industrial world, b) learning resources for PLC in vocational learning is still lacking, c) lack of understanding of students on PLC, and d) students are less motivated to learn subjects PLC.

While the results of the need analysis of the industry in the form of competencies required in PLC field for vocational graduates are: 1) understand the automation system, 2) Know and understand the basic components of a PLC, 3) Know and be able to distinguish the use of symbols in the PLC, 4) Knowing the PLC communication with other equipment, 5) Knowing PLC signals, 6) understand the functions and advantages of using PLC, 7) to know and understand the installation of modules PLC, PLC maintenance and PLC troubleshooting.

4.1.2. Design Stage

The results form of the initial product design, consist of: 1) teaching materials, 2) lesson plans, 3) Learning Test Results (pre-test and post-test, 3) media tutorials, and 4) the use of the media guide (attached). Teaching materials and media generated tutorials are called as PLC learning tutorials (TP-PLC).

4.1.3. The development phase
4.1.3.1. The results of expert evaluation
The results of the validity analysis of the initial products and instruments of research shows that the initial product presents in the form of lesson plans, teaching materials, test results of learning, media tutorials, guidebooks and research instruments that have been developed in the form of observation sheet of educator activity, observation sheet of students activity, response questionnaire sheet of students and educators, that meet the criteria of validity with very valid categories based on validator assessment. The results of the common assessment of the validator indicates that the initial products and instruments developed well and can be used to perform minor revisions.

Qualitative data such as criticism, suggestions and feedback from the validator are then used as a consideration in revising the initial products and instruments. Feedback, critiques and suggestions from the experts on product development of instructional materials, can be seen in Table 4 below:

Table 4. Input, critiques and suggestions from content and media experts for
development of teaching materials (tutorial) based industry product

No.	Evaluation Component	Input, critiques and suggestions
1.	All aspects in students' response	Match the indicator of each aspects in the instrument with the one that has been observed.
2.	Typing	There are several typing that are need to be corrected
3.	Language	- Make sure that the sentence is not too long. - The capital letter should not be in the middle of a sentence
4.	Learning Material	Add preface and figure list.
5.	Tutorial Media	In order to be more attractive, it should be added with more color combination in tutorial media.

4.1.3.2 The trial results
The test result of individual and small group
The results of individual testing in several aspects such as appearance, language, programming and quality of the content, show that the product TP PLC developed very well. Likewise, the results of testing in a small group in the same aspects show that the TP-PLC products are developed very well.

Based on the record of the results of the qualitative evaluation in the form of comments, criticisms and suggestions of individual respondents in both trials suggest that there is nothing to be revised.

The results of limited field trials
Field trials involve 17 people as trial subjects. Field trial was conducted to obtain data on the practicality and effectiveness of the products developed [16] & [17].

The practicality of developed teaching materials viewed through the response of students and educators to development result product. The results of the data analysis of students' response to TP-PLC on a limited field test reached an average score of 3.8 with a percentage of 94.9% in very good category. The results of the data analysis of the response of educators to TP-PLC teaching materials received an average score of 3.7 with a percentage of 89.8% in very good category. Based on the results of the analysis of response data for both students and educators on TP-PLC teaching materials products showed that TP-PLC teaching materials are practical in use and deserves to be developed.

The effectiveness of teaching materials developed viewed through the activities of students and educators during the learning process and the scores of pre-test and post-test. The results of the analysis of observational data on the activities of students and educators in the TP PLC learning process, obtained an average value of 3.6 and 3.7 with a very active category.

To test the effectiveness of the developed products in addition to the observation activities of students and educators, learning achievement test also conducted in the form of pre-test and post-test .. The results of the data analysis of pre-test and post-test shows the average results of the pretest was 60.8 and posttest results amounted to 82.3, by a margin of 21.5. This means that the use of the products of the development of teaching materials can improve students' score by 21.5%.

Based on the analysis of observational data of students and educators activity as well as the results of the data analysis of the pre-test and post-test, it can be concluded that the developed PLC tutorial teaching materials meets the criteria of effectiveness and deserves to be developed.

V. CONCLUSIONS AND SUGGESTIONS

Based on the results of research and product development of PLC-based tutorial teaching materials industry, as noted earlier, it can be concluded:

1. The process of development of industrial -based teaching materials PLC tutorial refers to the development of the Four-D models that include four phases namely: 1) the stage of defining the form of the need analysis in schools and industry, 2) design phase to produce the initial product of teaching materials, 3) the development stage consisting of: product validation and testing of products. Initial product design results validated and tested to produce a quality product that meets the category of valid, practical and effective. The results of development process is in the form of industrial -based teaching materials PLC tutorial that has high quality and referred as PLC Tutorial Learning (TP-PLC), and 4) the stage of dissemination is done in the form of a product of socialization.

2. The practicality of developed products viewed through the response of students and educators to development result product. The results of the data analysis on field trials is limited to responses of students to TP-PLC showed very good category. While educators response to TP-PLC also showed very good category. From the analysis of the response data of students and educators on the TP-PLC, suggesting that the developed industrial -based teaching materials PLC tutorial is practical and feasible.

3. The effectiveness of the developed products from the aspects of: a) the achievement of learning outcomes in the form of pre-test and post-test, and b) the implementation of the activities of students and educators based on appropriate indicators set. The results of the data analysis and the results of pre-test post-test data analysis showed increased scores. This means that the use of the products of the development of teaching materials can improve the scores of students. Meanwhile, the results of observational data analysis activities of students during the learning process of TP-PLC is in the category are very active and the results of the analysis of observational data educators activity during the learning process TP-PLC also very active in the category. Based on these data, it was concluded that the PLC tutorial teaching materials developed for use in vocational is effective, especially at SMK Negeri 1 Makale.

Based on the results of research and development, it is suggested the following:

1.   In research product and development in the form of industrial -based teaching materials PLC tutorial, it is necessary to do operational field trials on a larger subject, before it is used for the entire vocational industrial automation systems. It is expected that the greater subjects, the more increase in learning outcomes.

2.   Media tutorial development results can be used as an alternative for the development of teaching materials for other subjects in vocational, especially at SMK Negeri 1 Makale.

3.   Based on the trials that have been conducted, it turns out that TP-PLC product is effectively used in SMK. Therefore, it is recommended to other SMK that the developed products can also be applied in their schools.

VI. ACKNOWLEDGEMENT

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