Design of mechatronic simulators to improve the quality of students learning outcomes in mechatronics subject

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Abstract. Today condition in learning mechatronics subject, especially at Universitas Pendidikan Indonesia Departemen Pendidikan Teknik Elektro still uses learning object and software simulations. This still has not maximized student’s competency in the mechatronics subject, which is required to be skilled in real engineering that will be applied both in the industry and in educational institutions. According to the Universitas Pendidikan Indonesia research master plan which establish its vision to be a Pioneer and Superior University in the field of education, then research on learning innovation is directed to aspects of learning, that is research on learning models, learning media, organizing learning implementation plans, organizing learning materials, and evaluation systems. Learning innovation products generated from this research are expected to be a reference and become the main pillar for all academic units in the UPI environment in implementing learning. Based on the above idea, the researcher proposes to develop a learning media that is corresponding with the requirement of mechatronics subject in the competency based on applicative design mechatronics simulator. The method used in this research is quantitative method with research and development approach. The excellent research of the college with the title "Design Mechatronics Simulators to Improve the Quality of Student Learning On Mechatronics Subject" is a research needed to implement a design that serves as a learning media to improve learning outcomes and student’s competency in mechatronics subjects.

1. Introduction
Learning is skill development process that is owned by every single student. Students are required to be active in constructing knowledge and competency that owned by students with the lecturers as facilitators. With this method student can get knowledge and increase competency well. The effectiveness of the teaching and learning process (learning) is very much influenced by the methods and learning media used. They both are interrelated, where the selection of certain methods will affect the type of media that will be used in the learning process, therefore there must be a match between the both to realize the learning objectives. The use of media in learning can arouse new interests and talents and stimulate student learning motivation in the learning process.

In increasing the interest in learning and student understanding, it needed a learning media that can be used as an alternative in carrying out the learning process in the classroom as a media. This mechatronic simulator learning media is an important tool for improving student learning outcomes in the mechatronics course, because this media is a form of student competence development.
In the mechatronic engineering competency standard taught to students at the Departemen Pendidikan Teknik Elektro, learning is done using simulation learning media. The obstacle faced when learning engineering is that students can only engineer visuals rather than their original objects, so students only learn to analyze through visuals.

The design of mechatronic simulators which will be tested can be used by various electronic engineering systems, including pure pneumatic systems, electropometric systems and programmed pneumatic systems.

This research aims to determine the improvement of student learning outcomes in the mechatronics course with media learning simulators and electronic simulator work systems.

2. Literature review

2.1. State of art
Some of the development of mechatronic learning models using simulators have been carried out by media development researchers. The learning device model developed is feasible for use in mechatronic lectures. The implementation of computer-based mechatronic learning devices is the subject of PLC can improve the quality of teaching and learning processes, because students show a positive response, the implementation of learning includes good categories and learning outcomes of students cognitive and psychomotor aspects have achieved completeness individually and classically [1].

Other researchers did this by utilizing mechatronic controls with the Raphson PLC simulator. The next researcher uses another approach, namely conducting a Mechatronic system design process using modern interdisciplinary design procedures, it is the simultaneous selection of evaluations, integration and optimization of the system and all sub-systems and components as a whole and integrated [2]. The next research is about the design of Mechatronics designing that is integrated in view of their specific nature and can be applied in the education process is very necessary, these guidelines for structural design methodologies proposed in learning [2-4].

2.2. Mechatronics
Mechatronics is technology or engineering that combines technology about machinery, electronics, and informatics that aims to design, produce, operate, and maintain systems to achieve desired goals. Based on these definitions, it can be concluded that mechatronics is a combination of science and technology disciplines in mechanical engineering, electrical engineering, informatics engineering, and control techniques.

The definition of mechatronics is more directed at numerical control technology, namely controlling the mechanism of using actuators to achieve certain goals by monitoring information on the condition of the motion of the engine using sensors, and entering that information into a microcontroller / microprocessor. Figure 1 is simple diagram mechatronics formation.

Figure 1. Simple diagram mechatronics formation.
There are several benefits of mechatronics application:

- Increasing flexibility
- Increasing reliability
- Increasing precision and speed

The application of digital control and electronic technology, the level of precision of the machine and the speed of movement of the engine can be raised even higher to a certain extent, along with mechatronic elements, that is:

2.2.1. **Engine mechanism.** Engine mechanism is control object that usually forms like robotic arms, automotive drive mechanism, power plant generator, etc. Engine driving piston mechanism can show on figure 2.

![Figure 2. The engine driving piston mechanism.](image)

2.2.2. **Sensor.** Sensor is an instrument to detect or measure something that used for changing mechanical variation, magnetics, thermal, rays, and chemistry become electrical voltage or current. Some examples of sensors which are effect-hall sensors that come from mechanical pressure are potential differences.

2.2.3. **Controller.** The controller is an element that functions as a decision maker when the state of the control object is in accordance with the desired reference value and then processes the information to set the command value to reflect the state of the control object, the block diagram of the controller.

2.2.4. **Drive circuits.** The drive circuit is an element that functions to receive command signals from the controller and convert them into energy that is able to move the actuator to carry out commands from the controller.

2.2.5. **Actuator.** Actuator is part of output for changing supply energy to power energy that used. The actuator includes a single acting cylinder and double acting actuator.

2.2.6. **Energy source.** One concrete form of an energy source is a battery for a displaced system or AC-DC adapter for stationary systems (still in place).
3. Method

3.1. Research flow
Research flow that done can be seen on figure 3

![Research Procedure Diagram](image)

**Figure 3.** Research procedure.

Research Procedure do in two years. First year is to do literature studies and observation, in this step it is learned subject content that will make its media and also learned the way of media fabrication. Next step is to design and make product to be tested limited and get input from product users to be product improvement. In the second year, it is perfecting the product and applying the product as a learning medium and then studying the influence of the media on learning outcomes.

3.1.1. Preliminary studies. The purpose of the preliminary study is to identify and formulate problems that will be used as research material. Preliminary studies were conducted at Departemen Pendidikan Teknik Elektro Universitas Pendidikan Indonesia.

3.1.2. Conducting program planning. As a first step we make a program plan based on the analysis of the problems that have been made in essays on the development of mechatronic technology, then discuss groups plan the concepts to be used, design tools, create timelines of activities, make technical instructions for activities, and make work steps for making tools. Regarding the tools that will be made, we use the literature study method by looking for data from various sources such as; books, internet, and data from field surveys.

3.1.3. Planning and designing tool. The process of making tools based on program planning data in the form of technical instructions and work steps as in figure 4.

![Planning and Designing Instruments](image)

**Figure 4.** Planning and designing instruments.
3.1.4. Research roadmap. Referring to the Indonesian Education University research master plan which set its vision to become a Pioneer and Superior University in the field of education, the research on learning innovation is directed to aspects of learning namely research on learning models, learning media, organizing learning implementation plans, organizing learning materials, and evaluation system. Development of a research road map on the electric power transmission system on the basis of Kelompok Bidang Keilmuan (KBK) road map for each study program. This research was developed on the KBK Electric Power System in Teknik Elektro Program.

This research refers to the Kelompok Bidang Keilmuan (KBK) Electric Power System roadmap 2015 by Kelompok Bidang Keilmuan Electric Power System Departemen Pendidikan Teknik Elektro FPTK UPI. The ultimate goal of this research plan is the creation of a comprehensive study of mechatronic-based learning media models.

Preliminary research on the network system of electric power transmission systems began to be initiated by conducting a study of the widely used standard methods. The method that has been done by KBK Electric Power System DPTE FPTK UPI among others in the form of a model. The results of the research that have been and will be carried out will then be implemented in the lecture on Electric Power Mechatronics in Departemen Pendidikan Teknik Elektro FPTK UPI

3.2. Research schedule
The research is planned during 8 months, starting from the preparation stage of formatting and mapping of field data needs, data collection, data processing, comprehensive discussion and presentation in the dissemination of research results. For the complete as follows:

| No | Type of activity                  | Month |
|----|----------------------------------|-------|
| 1  | Step I Data Preparation           |       |
| 1.1| Literature Study and journal      |       |
| 1.2| Preliminary Studies              |       |
| 1.3| Taking Data to CV Pudak          |       |
| 1.4| Dokumentation I                  |       |
| 2  | Step II Analysis Exploration and Modelling |       |
| 2.1| Selection and Data Analysis      |       |
| 2.2| Compilation Equation Models      |       |
| 2.3| Modelling Calculation Results    |       |
| 2.4| Dokumentation II                 |       |
| 3  | Step III Validation, Simulation dan Optimization |       |
| 3.1| Validation and Model Verification|       |
| 3.2| Simulation of model application in the case study area |       |
| 3.3| Analysis of the specified model  |       |
| 3.4| Dokumentation III                |       |
| 4  | Step IV (Final Report)           |       |
| 4.1| Report Compilation               |       |
| 4.2| Presentation and Publication      |       |

4. Results and discussion

4.1. Design and fabrication of learning modules for electropneumatic control systems
Design and fabrication of electropneumatic control system consists steps as follows:

4.1.1. Modules requirement analysis. The learning module of the Electropneumatic Control System is designed based on observations and the results of interviews with teachers of these subjects at the SMK Negeri 4 Bandung Industrial Automation Engineering expertise program. The learning module of the Electropneumatic Control System is expected to be a complement in meeting the requirement of students and teachers as educators who are not yet available for these subjects.
4.1.2. **Designing learning modules.** At this stage, the design of the Electropneumatic Control System learning module is designed based on the analysis of the results obtained. The choice of material in this module is based on the syllabus of the Electropneumatic Control System subject used at SMK Negeri 4 Bandung. In this module material is provided in appropriate with the syllabus, practice questions, tasks and student job sheets. Practice is structured as a step in students' cognitive evaluation of the material presented, while the student job sheets as a practical learning step in these subjects and as an affective and psychomotor evaluation instrument.

4.1.3. **Learning modules development.** Validation done aims to determine the level of feasibility of the learning module that has been made. Learning media validation was carried out by media experts who were lecturers of Departemen Pendidikan Teknik Elektro and material experts by lecturers of Departemen Pendidikan Teknik Elektro and Electropneumatic Control System subject teachers at SMK Negeri 4 Bandung, Industrial Automation Engineering expertise program. Validation is done by filling out questionnaires related to the feasibility of learning media that refers to the provision of assessment of learning media sourced from Badan Standar Nasional Pendidikan (BNSP),

4.1.4. **Learning modules implementation.** The learning module of the Electropneumatic Control System that created was then implemented in teaching and learning activities in the subject of electropneumatic control systems in class XI of SMK Negeri 4 Bandung. Teaching and learning activities are carried out based on the RPP that has been made. The implementation process of the Electropneumatic Control System module was conducted in three meetings. The stages of teaching and learning activities during the research are shown in table 2.

| Meeting | Learning Activity | Results |
|---------|------------------|---------|
| 1       | a) Providing pre-test | a) The pre-test was attended by 30 students. The time given for the test is 40 minutes. |
|         | b) Introducing electropneumatic control systems learning module and how to use it | b) The teacher introduces the contents of the learning module of the Electropneumatic Control System and how to use it in the KBM process |
|         | c) Introducing module | |
|         | d) Presenting learning subjects | |
| 2       | a) Presenting learning subjects | a) Teaching and learning activities use the Electropneumatic Control System learning module that has been created and implemented according to the RPP. |
|         | b) Practice according to job sheet. | |
|         | c) Providing post-test | |
|         | c) Fill the questionnaire out | a) Students are directed to form practice groups and practice according to the job sheets provided in the learning module of the Electropneumatic Control System. Post-test was attended by 30 students, 40 minutes of processing time. |
|         | b) Fill in the questionnaire regarding the feasibility of the Electropneumatic Control System learning module that has been used | |

4.1.5. **Learning module evaluation.** Evaluation is carried out to process the data that has been obtained and review each step carried out is correct, then the final revision is carried out in accordance with the evaluation results or needs that have not been found in the learning module of the Electropneumatic Control System.

4.2. **Feasibility of learning media**
4.2.1. **Assessments of media experts.** The results of the media expert’s assessment indicate that the learning module of the Electropneumatic Control System made is very feasible with an average percentage of feasibility about 98%. There are recommendations to improve the results of this assessment, that is to add a conversion table for the unit of measurement and add an observation table for students.

The results of the content feasibility assessment of 95%, indicate that the contents of the learning module of the Electropneumatic Control System that has been made are very suitable to use.

The assessment of media experts in the feasibility of graphics shows results of 100% and in the very feasible category. Assessment criteria in the feasibility of graphics include book size, book cover design, use of letters and layout of the contents of the book. Recommendation for this learning media include the addition of color variations to make it better, the illustrations contained in the book cover design are not sufficient to reveal the character of the object.

4.2.2. **Assessment of material experts.** The assessment of the Electropneumatic Control System learning module was carried out by two material experts, one lecturer of Departemen Pendidikan Teknik and one from the teacher of the Electropneumatic Control System subject. The results of the assessment of material experts obtained a percentage of 91.7% and included in the category of very feasible. Recommendation given for the Electropneumatic Control System learning module is aspects for affective assessment, giving color differences in the image for components with air and without air and independent tasks addition.

The feasibility of the content in the Electropneumatic Control System learning module is in the very feasible category with an average score of 92.97%. The assessment of material experts for the feasibility criteria for this presentation reached 95% with a very feasible category. Furthermore, the speech assessment found in this learning media in decent category with an average score of 85%. The assessment indicators contained in the feasibility of this speech include communicative speech, grammar, spelling and terms, the accuracy of spelling and the correctness of terms.

The feasibility of graphics found in the Electropneumatic Control System learning module is 94.12% with a very feasible category. There is no recommendation in evaluating the feasibility of this graphic.

4.3. **Research results**

4.3.1. **Data normality testing results.** Author uses the chi square test to determine the normality of the data that has been obtained. In the cognitive aspects of learning outcomes, authors did normality tests on the pre-test and post-test values. This data normality testing is done using Microsoft Excel 2013 Software, Table 4.2 shows the results of the normality test for students' pre-test scores.

| No | Interval Class | fo | fe | (fo - fe) | (fo-fe)^2 | (fo-fe)^2/fe |
|----|----------------|----|----|-----------|-----------|-------------|
| 1  | 17 – 21        | 5  | -3 | 8         | 64        | -21.33      |
| 2  | 22 – 26        | 7  | 5  | 12        | 144       | -28.80      |
| 3  | 27 – 31        | 4  | 7  | 11        | 121       | -17.29      |
| 4  | 32 – 36        | 7  | 5  | 13        | 169       | -24.14      |
| 5  | 37 – 41        | 7  | 2  | 5         | 25        | -6.5        |
| 6  | 42 - 46        | 7  | 2  | 9         | 81        | -40.50      |
|    | Measure        | 30 | -28| 58        | 604       | -138.31     |

\[ x^2 \text{table} = 11.07 \]

Table 3 shows that the data value \( x^2 \text{calculated} \) for pre-test assessment about 138.31, because \( x^2 \text{calculated} \) is smaller than \( x^2 \text{table} \) that is 11.07, then it can be concluded that data of pre-test has normal distribution.

Similar with testing normality for the pre-test value, testing of the post-test value uses chi squared. Table 4 shows the results of the normality test for the post-test value.
Table 4. Data normality testing results of post-test.

| No | Interval Class | fo | fe | (fo - fe) | (fo-fe)^2 | (fo-fe)^2/fe |
|----|----------------|----|----|-----------|-----------|-------------|
| 1  | 63 – 68        | 5  | -3 | 8         | 64        | -21.33      |
| 2  | 69 – 74        | 2  | -5 | 7         | 49        | -9.80       |
| 3  | 75 – 80        | 10 | -6 | 16        | 256       | -42.67      |
| 4  | 81 – 86        | 1  | -6 | 7         | 49        | -8.17       |
| 5  | 87 – 92        | 8  | -4 | 12        | 144       | -36.00      |
| 6  | 93 - 98        | 4  | -2 | 6         | 36        | -18.00      |
|    | Measure        | 30 | -26| 56        | 598       | -135.97     |

Table 4.3 shows that value data of $x^2_{count}$ for post-test score is about -135.97. Because $x^2_{calculated}$ is smaller than $x^2_{table}$ that is about 11.07, then it can be concluded that post-test data has normal distribution. As a comparison, author also did data normality testing on SPSS. The results of the normality of the pre-test and post-test data obtained significant values of 0.51 and 0.051, to know the data has normal distribution or not, here are normality testing category of Shapiro-Wilk:

- If value were Sig. > 0.05, then data has normal distribution.
- If value were Sig. < 0.05, then data does not have normal distribution.

Then, based on that category, pre-test and post-test data have normal distribution.

4.3.2. Data homogeneity test results. Based homogeneity testing results about learning outcomes of students between pre-test and post-test results are obtained the value of $F_{calculated} = 1.80$ and $F_{table} = 4.20$, then the data of student learning outcomes are homogeneous. As a comparison, author did homogeneity testing using SPSS Software. The result is obtained significant value from students learning outcomes about 0.085. Because significant value is larger than 0.05, then students learning outcomes include in the homogeneous category.

4.4. Result of hypothesis

Hypothesis testing is done to find out whether the hypothesis proposed in this study was accepted or rejected. This hypothesis test is done by comparing the $t_{calculated}$ value with the value of $t_{calculated}$ with $t_{table}$. It is to see the price of $t_{table}$, it is based on the value of the degree of freedom $(df) = 30 -2 = 28$, with a significant level 5% ($\alpha = 0.05$). After testing using Microsoft Excel Software, the results are obtained that $t_{calculated} > t_{table}$, it can be concluded that the alternative hypothesis (Ha) is accepted, while the null hypothesis (Ho) is rejected. The alternative hypothesis accepted shows that student learning outcomes were more than before using the learning module.

4.5. Research results discussion

Based on the results of the study found several things related to the implementation of the learning module of the Electropneumatic Control System. These findings explain the learning outcomes in the cognitive, affective and psychomotor domains in students who use the learning module of the Electropneumatic Control System with those without the learning module of the Eletropical Control System, and the students’ responses to the learning module.

These findings are evidenced by the results of the N-gain test and hypothesis testing. The results of the hypothesis test manually using Microsoft Excel 2013 found that $t_{calculated}$ is greater than $t_{table}$, then Ha which reads "Student learning outcomes after using the learning module is greater than before using the learning module" is accepted.

The authors also found that there was little influence on the learning module of the Electropneumatic Control System to learning outcomes in the affective and psychomotor domains. In the psychomotor
domain, students are easier to practice using learning modules because the stages in practice have been explained in the learning module.

Students also assess that the learning module of the Electropneumatic Control System applied when learning is corresponding for use in teaching and learning activities. This is based on the questionnaire authors have spread to students who have used the Electropneumatic System learning module in the learning process.

After the implementation process, there were also some obstacles found among them, some students had less interest in reading, so they only read the parts that were considered interesting and important. The results of this research are also more or less influenced by the condition of the students, because when the research process takes place there are some students who arrive late, so that students miss some parts of the learning process.

5. Conclusion
Based on the research that done, it can be concluded that:

- The design of the mechatronic learning module with the subject of the Electropneumatic Control System has been designed by carrying out several stages, that is starting with the module needs analysis process, designing the learning module, developing the learning module, and then evaluating implementation.
- The mechatronic learning module with the subject of the Electropneumatic Control System designed, has gone through feasibility tests conducted by material experts and media experts by testing the feasibility of content, speech feasibility, presentation feasibility and graphic feasibility. The results of the feasibility test by material experts and media experts are learning module that designed is feasible.
- Use of modules The mechatronic learning module with the subject of the Electropneumatic Control System can improve student learning outcomes in the cognitive realm. The increase can be seen from the average value of the pre-test and post-test which was then tested by the N-gain test and entered into the high criteria. In the affective and psychomotor domains, the average student gets good grades.

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