Development of trainer sensor as media learning control systems for engine cadets at Merchant Marine Polytechnic Surabaya

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Abstract
The purpose of this research designed to: (1) develop sensor trainers that fit the needs of control system subjects (2) develop sensor trainer with good performance, and (3) test the feasibility of sensor miner as media learning for control system learning at Surabaya Merchant Marine Polytechnic. This study was a Research and Development (R&D) in the field of education. The development research model used was ADDIE: Analysis, Design, Development, Implementation, and Evaluation. The instrument used in this study was questionnaire with four options answer of Likert scale.

The validity test of instrument carried out by consultation section with material experts and media experts. Instrument reliability calculated using alpha formula and produced a reliability value of 0.87 (very reliable). There are three aspects measured at this implementation stage, aspects of material quality, media operations, and learning aspects. The results obtained for quality of material got a percentage of 78.76%, for media operations got 68.77%, and for learning got a percentage of 76.35%. Of the three percentages, a total percentage of 76.62% was obtained, so that the media trainer sensor was declared feasible to be used as a learning media for the control system course after the feasibility test was conducted by the user.

Keywords: development; learning media; trainer; control system preliminary.

INTRODUCTION

Technology has significant impact for students’ learning. In this era of technologies such as virtual reality, environments allowed us to create and validate the representative environment (Miller, Wang, Jeong, & Gillig, 2019). The development of automation technology in the era of globalization is rapidly growth. The development of automation technology is useful and helpful for the community. An automation technology product nowadays is the existence of a smart home, where a person can monitor room conditions and control electronic equipment in the house using computer or smart phone. Improving the quality of human resources can be started from the field of education (Kustandi, Situmorang, & Lestari, 2019). Education need to follow
the development of technology including have a good trainer sensor as media learning as what all the components of education need technology and it will help to develop good performance of students learning achievement.

Education is an appropriate and effective implementation for technology and its development to students. Increasing Student’s motivation, involving them within the educational process allows educators to improve the quality of learning (Gorbatuc & Dudka, 2019). In every formal education, learning has several basic competencies that must be achieved. Basic competencies written in syllabus included inside each subject. These basic competencies must be achieved in every learning activity. From the results of observations that have been made, researchers get a syllabus subject of control system in Surabaya Merchant Marine Polytechnic. Sensor trainer is one of learning media interactive, because students required interacting with the use of sensor trainers. Therefore sensor trainer needs to be developed according to standard.

The researchers gained information that Surabaya Merchant Marine Polytechnic does not have the tools for trainer learning practice control system courses yet. Feasibility and necessity of creating system help to develop sensor trainer obtain a good performance. Based on the explanation above, the problem can be found that are how to design a sensor trainer for control system course at Surabaya Merchant Marine Polytechnic and what is the performance of the sensor trainer for the control system course at Surabaya Merchant Marine Polytechnic, and what is the eligibility level of the sensor trainer for the control system course at Surabaya Merchant Marine Polytechnic.

CONCEPTUAL FRAMEWORK

1) Research and Development

There are many development research models; one of a type on development research models that often used in education is ADDIE research model. According to Mulyatiningsih inside (Julianda, 2018) ADDIE development research model is an abbreviation of Analysis, Design, Development or Production, Implementation or Delivery, and Evaluation developed by Dick and Carry inside (Donmez & Cagiltay, 2016). ADDIE development research model is often used for development of teaching materials such as modules and learning media

a) Analysis

At this stage, analyzing the need for development of new learning models/methods and analyze the feasibility and development requirements new learning models/methods as the main of analysis process. The following process conducted at analysis stage such as:

1) Thinking about new products to be developed.

2) Identifying products that suitable with the target audience students, learning objectives, identifying content / learning material identify learning environments and delivery strategies in learning.
b) **Design**
1) Designing new product concepts.
2) Designing new product development devices.
3) The design is written for each learning unit.
4) Instructions for applying the design or manufacturing of products should be written in detail.

**c) Development**
1) Developing the product tools needed in development. Based on product design results and the structure of the model.
2) Making instruments to measure product performance.

**d) Implementation**
1) Start using real and new products in learning
2) Evaluate the goals of product development, interaction between students and ask for early feedback in evaluation process.

**e) Evaluation**
1) Evaluate the impact of learning in critical way
2) Measuring the achievement of product development goals.
3) Looking for any information that can make students achieve a good result.

2) **Learning Media**
According to Kemp and Dayton in (Daryanto & Karim, 2017) learning media contributed as the following below:

-a) Delivery of learning messages can be more standardized.
-b) Learning becomes more interesting.
-c) Learning becomes more interactive by applying theory on study.
-d) Learning time can be shortened.
-e) Quality of learning can be improved.
-f) Learning process can take place anytime and anywhere.
-g) Positive attitude of students towards learning materials and processes learning can be improved.
-h) The teacher’s role changes in positive direction.

3) **Sensor Trainer**
Sensor trainer is one of learning media interactive, because students required interacting with the use of sensor trainers. Students will interact with the trainer uses the help of job sheet that has been provided before. Sensor trainer consists of three parts, the sensor section, controller, and output. The sensors used in this sensor trainer, is LM35 temperature sensor, the controller used microcontroller Arduino Uno. Whereas for the output section is an LCD, LED, buzzer, and DC motor.

-a) **Sensor**
Sensor is a component used to detect the changes nature of an object or environment. LM 35 temperature sensor is a sensor used to measure the temperature of object or environment. LM 35 works by changing the heat energy into energy electricity. This sensor has been packaged in form of IC (Integrated Circuit) which has 3 legs, which is VCC, output, and GND. The
output of LM35 is linear with temperature changes around, where if the temperature rises then the voltage at the foot of LM 35 output will increase. This LM35 sensor has scale factor of 10mV/˚C, thus will happen to increase in output voltage by 10 mV each there temperature increases of 1˚C.

b) **ATmega328**

ATmega328 is Atmel’s micro controller output a member of the 8-bit AVR family. This microcontroller has a flash capacity (program memory) of 32 Kb (32,768 bytes), memory (static RAM) 2 Kb (2,048 bytes), and EEPROM (non-volatile memory) of 1024 bytes. The maximum speed that can be achieved is 20 MHz. The special design of this processor family allows achievement execution speed up to cycle per instruction for most instructions, therefore speeds can be reached close to 20 million instructions per second. ATmega328 is a feature-rich processor. In a packaged chip in the form of DIP-28 there are 20 Input/Output pins (21 pins if the reset pin is it use, 23 pins when not using an external oscillator), with 6 in among them can function as an ADC (analog-to-digital converter) pin, and 6 others have PWM (pulse width modulation) functions (see **Figure 1**).

![Figure 1. Configuration pin ATmega 325](image)

Arduino Uno R3 is a development board microcontroller based on ATmega 328P chip. Arduino Uno has 14 digital input / output pins (or commonly written I / O, where 14 of them can be used as intermediate PWM outputs others pins 0 to 13), 6 pins of analog input, using crystal 16MHz include pins A0 to A5, USB connections, power jacks, headers ICSP and reset button. That is all that is
need to support a microcontroller circuit. Specifications Arduino Uno R3 can be seen in Table 1 and Arduino Uno R3 can be seen in Figure 2.

### Table 1. Specifications Arduino Uno R3

| Characteristics       | Values       |
|-----------------------|--------------|
| Microcontroller       | Atmega 328   |
| operating voltage     | 5 volt       |
| Input voltage         | 7 - 12 volt  |
| Pin I/O Digital       | 14           |
| Pin Analog            | 6            |
| Current DC each pin I/O | 50 mA     |
| Current DC when 3.3V  | 50 mA        |
| Memory Flash          | 32 KB        |
| SRAM                  | 2 KB         |

Figure 2. Arduino Uno R3  
Source: based on figure 2

### c) The Output

1) LED (see Figure 3)

LED (Light Emitting Diode) is a diode that can emit light. LEDs are formed from materials semiconductors, namely doping gallium, arsenic, and phosphorus. The nature of LED resembles a diode that only works on one course direction that is happen when LED given a forward bias. Although the nature of LED resembles a diode but the current maximum that can be passed by LED is only 20mA, if the current passing through of LED exceeds maximum value, LED will be damaged. Within the ability to skip small current, LED needs to be given any resistance in form of resistors mounted in series that has function as current divider.

2) LCD

According to Andrianto (Andrianto, 2016) LCD is a display of crystalline liquid material which can be operated using dot matrix system. LCD widely used as display of electronic devices such as calculators, digital multi-tester, and digital clock and others.
RESEARCH METHODS

Development Model

Research and development of this sensor media trainer included in research and development methods (Research and Development) in field of education. This research aims to develop a feasible product to help cadets practice control systems. Research steps and the development used is the ADDIE model according to Mulyatiningsih in (Julianda, 2018). The development that carried out is the development of media sensor trainer learning for control system course at Surabaya Merchant Marine Polytechnic.

Development procedure

The development research procedure broadly adopted ADDIE steps explained by Mulyatiningsih (Julianda, 2018). The steps implemented include:

1) Analysis
   - think about the product to be developed;
   - identify learning content / material, this stage the researcher made observations on the syllabus of control system;
   - identifying learning conditions;
   - identifying delivery strategies in learning.

2) Design
   - designing product concepts at this stage designed the work diagram of the trainer sensor. Sensor trainers must be able to help students to achieve basic competencies of analog and digital input-output;
   - designing product manuals and job sheets in accordance with learning objectives. The manual contains the procedures for using the trainer sensor.

3) Development
   Make products in accordance with the product concept design. This step is the development of a media sensor trainer to support the learning process that has been prepared. Following an electronic trainer sensor design:
   a) Minimum system circuit
      The minimum system circuit consists of supply chain minimum power and circuit Arduino Uno. The power supply for this circuit will be distributed later
to the entire series used. All ports on the Arduino Uno are connected to the pin housing female to provide full access to trainer users as sensor.

b) LM35 Circuit

The LM35 series consists of female pins for LM35 and pins female for LM35 and Arduino Uno connections. LM35 is sensors that are read in analog, so to access it uses Arduino Uno, which has features ADC (Analog to Digital Convener). To access it VCC, GN D, and data pins are required. Figure 4 is image circuit of the LM35 sensor.

![LM35 Circuit](image)

Figure 4. Configuration LM 35
Source: data sheet LM 35

c) 16 x 2 LCD circuit

It takes nine pins to access the circuit 16x2 LCD, these pins are VCC, GND, RS, RW, E, D4, D5, D6 and D7. In this series there is one variable resistor to adjust the contrast on the 16x2 LCD. 16x2 LCD including digital output, so all ports on ATmega328 can be used to access this series. Figure 5 below is a 16x2 LCD image series on the sensor trainer.

![16x2 LCD Circuit](image)

Figure 5. LCD 16x2 circuit
Source: data sheet

d) DC Motor Circuit

The DC motor output circuit can be accessed digitally or analog. Digitally, all PORT ATmega16 can be used to access the circuit. Analogically, the port can be used to access a DC motor circuit which has PWM facilities. By accessing the
circuit DC motor analog we can adjust the motor speed. In this DC motor circuit there is a transistor BD 139 which has functions as a switch. Figure 6 is Pictures of DC motor circuits on the sensor trainer:

![DC Motor Circuit](image)

Figure 6. **DC Motor circuit**  
*Source: data sheet*

e) LED Circuit  
There are eight LEDs on the sensor trainer. LED can be accessed using all existing I/O portion ATmega 16. In this LED circuit, the method used active high where if the data pin is given logic high, the LED will lights up (on). Figure 7 below is a series of eight images LED pieces on the sensor trainer:

![LED Circuit](image)

Figure 7. **LED circuit**  
*Source: data sheet*

f) Buzzer Circuit  
There is one transistor 9014 in circuit buzzer. Transistor was used as a switch to activated buzzer. To access the buzzer circuit, it needs three pins, such as VCC, GND, and data. All ports I/O on ATmega16 could be used to access this series. Buzzer will be active (on) if data pin is given logic 1(high) and will die (off) if the data pin given low logic 0 (low). Figure 8 below is a buzzer sequence on sensor trainer:
4) Implementation

After learning resources were made and declared by material experts and media experts, then the application phase carried out as learning process. The implementation phase was carried out for engine cadets at Surabaya Merchant Marine Polytechnic. Implementation phase conducted to determine the feasibility of the sensor trainer in the process learning. At this stage cadets were given the user questionnaire to measure eligibility of sensor trainer.

5) Evaluation

There are two stages of evaluation conducted in this study. The first evaluation was done after the researchers got the results of test validation which done by material experts and media experts. Them, result of test validation used as reference for conducting improvements to sensor trainer. Second evaluation phase carried out after researchers obtain data at the implementation stage. Data from questionnaire was processed and used to measure the trainer’s eligibility sensor.

Research subjects

Subject of this research is cadets of engine department of Surabaya Merchant Marine Polytechnic.

Data collection methods and tools

1) Data collection method

There are two methods used to obtain the data, observation method the questionnaire method. Observation conducted to collect the needed data of manufacturing instructional Media. Questionnaire method carried out to collect data on feasibility of instructional media.

a) Observation method

Data collection method done by observed the process of learning activities and media used. Data observations before research are used in manufacturing background and problem identification. Design of sensor trainer also refers to data obtained at the time of observation.
b) Questionnaire method

Questionnaire method was conducted by giving questionnaire contains of items of statement to respondents to assess media learning that has been made. In this study, respondents are material experts, media experts, and users. Questionnaire to assess the feasibility of sensor trainer arranged using Likert scale four choices. The use of four choice Likert scale will be more maximum compared to five choices, this because four choice of Likert scale stimulated respondents to make an assertive answer more because there is no neutral choice.

2) Data collection tools

According to Sugiyono (Sugiyono, 2016b) research instruments are tools which can be used in measuring social phenomena and nature. The preparation of research instruments according to Widoyoko (Widoyoko, 2017) can be passed through several stages: (l) determine the variables which need to be examined, (2) formulate a conceptual definition, (3) construct conceptual definitions, (4) arrange the lattice instrument, (5) arrange the instrument points. Based on the steps from relevant research readings, a grid obtained some instrument as below:

a) Instrument for material experts

Instruments for material experts used to assess the feasibility of sensor trainer in material terms.

b) Instrument for media experts

Instruments for media experts used to judge the feasibility of sensor trainer in terms of learning media. The experts’ media are lecturers or teachers who are experts in field of media learning.

c) Instrument for users

Instruments for users used to judge feasibility of sensor trainer can be seen from the user, Surabaya Merchant Marine Polytechnic cadets.

Data analysis technique

1) Validity test

Instrument declared as valid if instrument can be used to measure what should be measured (Sugiyono, 2016b). Points of statement in material expert questionnaire should be leads to material content of sensor trainer which is also carried out together with statement items on media expert questionnaire and user. Validity test was done by holding consultations with the expert judgments.

2) Instrument reliability test

Reliability Tests carried out to determine the level of reliability instruments used for data collection. Instrument could be declared as reliable if instrument that used to measure an object at the same time or many times it will still produce the same (Sugiyono, 2016a). Instrument reliability test can be done using Cronbach’s alpha formula.
3) **Feasibility test**

Learning media products have been implemented in form of finished product then will be tested by the suitability products. Questionnaire used has four choices: Strongly Agree, Agree, Disagree, and Strongly Disagree. These choices include qualitative data, to transform into quantitative data used grading 4 gradations that 4,3,2,1.

**RESEARCH RESULTS**

**Description of data test**

1) **Sensor Trainer Performance**

Testing product trials conducted in order to find out whether media learning can work according to product design or not. Testing is done by making a program for each series of inputs and outputs on sensor trainer. Here are descriptions of tests that have been carried out:

a) Testing the Buzzer Output done by creating program which makes sounds from the buzzer for 3 seconds then silenced for the next 3 seconds.

b) LED Output Testing is done by creating a sequential LEDs program. In this program, LED will light one after another within an interval of one second.

c) Testing DC Motor Output

Testing DC motor output done by making DC motor speed control program. The program created motor speed will increase by 50 PWM each interval per three seconds, after the speed reaches 250 PWM, then DC motor will stop for another three seconds.

d) 16x2 LCD Output Testing

Testing LCD output done by making program which displays letters, numbers and symbols on 16x2 LCD. In program of writing cursor on LCD, it placed on 5th column and 0th row of 16x2 LCD with the command "Ledgotoxy(5.0);"

e) Testing the LM35 Sensor

Input LM35 Sensor testing done by making a program that displays ADC data generated from temperature reading by the LM35 sensor. To display ADC data 16x2 LCD is used to increase the temperature of LM35 sensor, and then LM35 sensor is put close to the heater. On this LM35 test temperature sensor has temperature change linear when it put close to the heater.

2) **Description of material validation data**

Result of data calculation for material quality aspect was 82.03% and aspects of expediency of 90.63%. From those aspects, it also obtained a total percentage of 86.33%. Based on the calculations above, total average score is obtained as 3.45 and percentage of total score was 86.33%. Based on the results, it was concluded that the sensor trainer was declared "VERY WORTH" indicated by the material validation test.
3) **Media validation data description**

Media validation test was done to assess sensor trainer seen from the point of view of learning media. Media validation is done by giving questionnaires to lecturers who are experts in the field of media learning and teaching subjects. Assessment results by Media experts are 82.64%, aspects of operation are 82.81%, and aspects the benefit of the media are 86.98%. From these aspects, it obtained total percentage of 84.14%. From the calculations that have been made, the average total score is obtained to 3.37 and the percentage of total score was 84.14%. From the results, it was concluded that the sensor trainer was declared "VERY WORTH" based on the media validation test.

4) **Limited test data description**

Limited test was conducted by 20 cadets engine department. This test was done to get advice from users. In this section, only calculation results are presented feasibility analysis of limited test, more detailed calculations regarding the feasibility of sensor trainer. Based on the limited test, it obtained the total average score of 3.12 with percentage of 78.02%. Due to these results, the sensor trainer declared as "WORTH".

5) **Instrument reliability test**

The instrument reliability test was done by questionnaire for users who used to measure the level of eligibility of sensor trainers by cadets. Previously, the questionnaire had been consulted with experts to get valid results. Testing was done using alpha formula. The data tested for reliability are data taken from the limited test. Based on calculations that have been done, it obtained result of 0.89 included as "VERY RELIABLE".

**Analysis of implementation data**

The implementation took place at Surabaya Merchant Marine Polytechnic and the following below were the result which obtained 77.87% in aspects material quality, 69.12% for media operations, and 78.73% for learning. It also obtained an average total score of 3.01 with a percentage of 75.24%. Within these results, the sensor trainer was declared "DECENT" as learning media for control system course at Surabaya Merchant Machine Polytechnic.

**Product review**

1) **Electronic sensor trainer**

The following below was an explanation of obtained electronic circuits on the sensor trainer:

a) **Minimum system**

The minimum system was main controller of trainer sensor. The minimum system used Arduino Uno. At this minimum system the power supply produced from an adapter of 5V was channeled through DC jack connector. There was also a minimum system port for delivering power to input and output circuit.
b) Buzzer output circuit

To turn on the buzzer use one transistor NPN 9014 is the type that has functions as a switch. There were three pins in buzzer output circuit, pin +, data, and pin -. The data pin was taken from the Arduino Uno I/O port which was used as the output.

c) LED output circuit

The LED output circuit has 8 LEDs that can function as output. In this series there was 8 data pins and 1 pin-. Eight data pins were connected by I/O ports ATmega328 was used as an output.

d) DC Motor output circuit

The DC motor output circuit used is BD 139 transistor which has functions as a switch. There were three pins on DC motor output circuit, which is pin+, data, and -. to regulate DC motor speed, then the data pin must be connected with ATmega 16 I/O port which has functions as output and the port was programmed to produce a PWM signal (pulse with modulation).

e) l6x2 LCD output circuit l6x2

LCD output circuit used to display the data in form of writing and numbers. In this series there was one variable resistor used to adjust the intensity light on LCD background.

f) LM35 Sensor input circuit

LM35 sensor circuit was very simple because it only consists of a sensor that could be read with facility ADC on ATmega328. Arduino Uno port that could be used for ADC facility was PORT A. Here is an example of how cadets used the sensor trainer (see Figure 9).

Figure 9. Cadets used the sensor trainer
Source: own study

2) Manual Book

The manual used to simplify the operation sensor trainer by user. In the Sensor trainer’s manual there is also an initial explanation about Arduino Uno microcontroller.

3) Job sheet

Job sheets were used by cadets to help the process sensor trainer operation. Job sheet creation was sorted based on basic competencies to be achieved. The
order starting from digital output programming, analog output, digital input, and the last is analog input.

**DISCUSSION OF RESEARCH RESULTS**

This discussion describes the answers of problems that have been formulated in formulation of problem. The formulation of problem will be answered in the process and data carried out during the study.

1) How was the sensor trainer design in accordance with basic competency needs in control system subject at engine department of Surabaya Merchant Marine Polytechnic?

The sensor trainer designed based on competence at control system subject at engine department of Surabaya Merchant Marine Polytechnic. The sensor trainer able to assist students in making programs analog input, digital input, analog output, and digital output.

2) How is the performance of sensor trainer for control system course at Surabaya Merchant Marine Polytechnic?

Performance test was done by doing programming on each input and output of the sensor trainer. The following below is description of tests:

a) Buzzer output testing

Testing the buzzer output was done by creating a program which sounds the buzzer for 3 seconds then silenced for other 3 seconds. Programs that are made repeatedly implemented. This testing buzzer can function based on the program that was made.

b) LED output testing

LED output testing was done by creating a sequential LEDs program. In this program the LED will light one after another with an interval of one second. In this test all LEDs can function properly.

c) Testing the DC Motor output testing the DC motor output is done by making DC motor speed control program.

In this program created the speed of the motor will increase every three seconds, after the speed reaches maximum, the DC motor will stop for three seconds. The DC motor testing program is running repeatedly. In this test a DC motor can work well.

d) 16x2 LCD output

LCD output testing is done by making program which displays letters, numbers and symbols on the 16x2 LCD. In this test 16x2 LCD can function related to the created program.

e) LM35 testing

LM35 Sensor input testing is done by making a program that displays ADC data generated from temperature reading by the LM35 sensor. To display ADC data 16x2 LCD is used. In this test, LM35 temperature sensor can function related to its working principle.
3) What is the eligibility level of sensor trainer as media learning at control system subject at engine department of Surabaya Merchant Marine Polytechnic?

The level of eligibility was measured using instruments has been consulted by experts. There were three types of questionnaires that used as instruments to test the feasibility of the media trainer sensor. The questionnaire was in the form of a questionnaire for material validation, media validation, and questionnaires for users.

a) Material validation

Material validation was carried out by two material experts competent in the field of control system subject. There were two aspects measured in this validation, namely the quality of the material, and expediency. Media trainer sensors on the aspect of material quality get a percentage of 82.03% and 90.65% in the aspect of expediency. From these two aspects, a total percentage was obtained 86.33%, thus the media sensor trainer included as "VERY WORTH" was used in control system subject at engine department of Surabaya Merchant Marine Polytechnic.

b) Media validation

Media validation was done by lecturers and teachers who competent in the field of learning media. There were three aspects measured in this validation, i.e. media design, operation and expediency of the media. Media trainer sensor on aspects of media design got a percentage of 82.64%, in aspects operation gained 82.81%, and in the aspect of expediency the media got 90.63%. From the three aspects obtained a total percentage of 84.14%, thus the media trainer sensor declared "VERY WORTH" was used on control system subject at engine department of Surabaya Merchant Marine Polytechnic. In revision testing, it was not found and the media sensor trainer and declared as "WORTH IT". There were three aspects measured at this stage of implementation aspects of material quality, media operations, and aspects learning. The results obtained for material quality is 77.87%, for media operations got 69.12%, and for learning got 75.24%. Based on the three percentages, it obtained a total percentage of 75.24%, thus, media trainer sensors declared as "DECENT" used as learning media.

CONCLUSIONS

After doing research and development of learning media sensor trainer, the following conclusions can be drawn as below:

Research and development of sensor trainers was carried out using ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) which requires researchers to analyze aspects that exist in the object of research. The results of the analysis served as the basis of making instructor learning media the sensor. The selection of inputs in the form of sensors and various outputs the sensor trainer must be based on basic competencies that
were contained in the syllabus of subjects. Performance testing was carried out to determine whether the trainer the sensor could work well or not. The performance of the trainer the sensor was done by programming each input and output there is a sensor trainer.

Thus, the feasibility of the sensor trainer learning media was tested from 3 aspects, i.e. material validation test, media validation test, and user test. Sensor true learning media include as the category "Very Worth". In validation of media trainer the sensor got include to the category of "Very Worth". On eligibility at the implementation stage, the trainer sensors declared as "Decent" were used as learning media. Furthermore, for further research can use different development model to develop sensor trainer in the next learning control system. and the expert from other studies can be involved to make a validation.

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