Teaching Microcontrollers using Arduino Nano Based Quadcopter

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Abstract. Learning to use the Arduino Nano based quadcopter is an innovation that can improve students’ motivation in learning. Microcontroller learning is one of the subjects in vocational high school, especially in electronics engineering. This study aims to motivate students in learning and knowing students’ responses about the use of Arduino Nano based quadcopter learning media. The first stage of this learning is students learn about components that exist in the quadcopter and remote control. The second stage of students integrates between components to form a quadcopter and remote-control system. The last stage is students learn to program using Arduino. Data is obtained by using a questionnaire to determine students’ responses to learning by using these media. Data are obtained from students’ motivational quesitioner in 1 Magelang public vocational high school in Indonesia with a total of thirty-two students. The result showed that motivation students increased after participating in learning using Arduino Nano based quadcopter.

1. Introduction
The microcontroller has been used as a digital system that has been widely applied in household and industrial electronics. Microcontrollers are a choice because of the affordable prices. Microcontrollers are usually used as control systems, signal processing, instrumentation, and others [1]. In vocational high school, the microcontroller is a productive subject that must be mastered by students. Microcontroller learning is very important because it is related to practical skills and programming [2]. Microcontroller learning is a basic knowledge of today’s digital technology and knowledge [3]. Therefore, the expertise of the microcontroller is very important in response to technological challenges [4].

Students at vocational high school must learn through practice in real life from only limited theoretical learning [5]. Simple microcontroller learning usually uses computer simulations but this has become less effective because it does not show the real application of the microcontroller [2][6]. Students will be bored and less interested. Several learning methods that can support more innovative learning. One of them is problem-based learning (PBL). The PBL is a learning model that emphasizes in real conditions to solve real problems [7]. PBL is one learning model that can increase student motivation [8][9]. Implementation of the PBL model in microcontroller learning will motivate students more when carried out with interesting media, one of which is using Arduino Nano based quadcopter. Arduino is a prototype and a platform that is a combination of hardware and software [3]. Arduino uses an open-source library available on the Internet.
The use of Arduino is very diverse from very simple to complex. One of its uses in learning is quadcopter. Arduino becomes popular because it is simple and easy to use. Learning by using Arduino includes of electronic design, block diagram, programming, etc. Arduino Nano based quadcopter has a variety of devices and sensors: Arduino Nano, accelerometer sensor, gyroscope sensor, electronic control speed (ESC), brushless motor, liquid crystal display (LCD), transceiver, and joystick. Each devices and sensors are arranged together to form a quadcopter system. Each circuit has its own characteristics based on its settings. Data was obtained through research in 1 Magelang public vocational high school. Syllabus in microcontroller subjects are as follows: (1) concepts of the basics of designing hardware and software microcontrollers, (2) supporting components of microcontrollers, (3) input/output programming of microcontrollers, (4) liquid crystal display (LCD) programming, (5) DC Motor programming, (6) internal pulse width modulation (PWM), (7) microcontroller interruptions, (8) timer/counter, and (9) internal analog-digital converter (ADC).

1.1. Problem-Based Learning
Problem-based learning models are based on the learning process that helps students to solve real-world issues, communication, and teamwork skills [10][11]. PBL is one of the learning strategies that focuses on students learning. PBL is widely applied in learning methods because it includes a problem-solving process and high-level thinking [12]. PBL positions the teachers as the facilitator in charge of supervising and the students’ instruction in learning. Students use existing knowledge to learn to solve problems and to participate actively in the teaching process [13][14]. Through the problem-based learning model, students learn each part as a whole. Here are some things to be achieved in problem-based learning.

- Students will be motivated in learning, understanding the Arduino Nano architecture, describing the central processing unit, addressing input-output, and programming.
- Students will get used to Arduino Nano through practical practice on a quadcopter.
- Students can combine all parts of the quadcopter and programming between parts so that the parts can be connected properly.

1.2. Arduino Nano Based Quadcopter and Programming
Arduino is an open-source platform arranged in a simple microcontroller board [15]. The Arduino is designed to be easy to use unit has its programming language called as the Arduino programming language [16]. Arduino has the advantages of being able to connect with a computer easily through the USB port. Arduino can also combine with other components such as the transceiver NRF24L01, liquid crystal display, and others very easily. Along with the growing popularity of Arduino at this time so Arduino began to be used to facilitate the learning of embedded microcontroller systems. One of themicrocontroller systems that can be developed in learning using the Arduino is learning by utilizing the Arduino for Arduino based quadcopter. The quadcopter is a type of vehicle that enters the category of flying and landing in a vertical [17]. The quadcopter has the advantage of a helicopter which can fly and move in a small space. Tools and materials used in the learning are Arduino based quadcopters and personal computers for Arduino based programming. The quadcopter component consisted of: Arduino Nano, electronic speed control (ESC), accelerometer gyroscope sensor, NRF24L01 transceiver, 2x16 LCD, analog joystick, brushless motor, and propeller. Programming using Arduino language.

2. Research Method
This study applied a quantitative research method. Data was obtained using questioner which includes the student’s motivation and interest in the use of Arduino Nano based quadcopter in learning. The questioner consisted of four alternative answers: strongly disagree, disagree, agree, and strongly agree. Instrument validation is done by the lecturer. The study conducted in the Electronics Engineering Department of 1 Magelang public vocational high school. The number of the subjects in the study was thirty-two grade XI students.
3. Topic Learning Materials

The topic plan was used by the teacher as a reference in microcontroller material topic. The stages of learning activities consist of ten topics to facilitate students in learning microcontroller. Each topic was delivered in sixty minutes.

Table 1. Learning Materials

| Lesson | Topic |
|--------|-------|
| 1      | Introduction to electronic digital and embedded systems |
| 2      | Arduino embedded system |
| 3      | Arduino language programming |
| 4      | Internal timer |
| 5      | Internal analog digital converter (ADC) |
| 6      | Electronic speed control (ESC) and internal pulse width modulation (PWM) |
| 7      | Serial communication |
| 8      | Sensor accelerometer and gyroscope |
| 9      | Liquid crystal display (LCD) |
| 10     | Transceiver NRF24L01 |

The following is a description of each topic.

3.1. *Introduction to electronic digital and embedded systems*

In this topic, the teacher provided an overview of electronic digital and its application in the real world. The teacher also gave motivation to the students regarding to the goal to be achieved after learning activities. After that, the student was introduced to the embedded systems. The students were given with an overview of the kinds of embedded systems and its application in the real world. Then the teacher explained the advantages and disadvantages of the embedded systems.

3.2. *Arduino embedded system*

The students listened to the teacher's explanation of Arduino Nano architecture, block diagrams, memory addressing, and input/output ports.

3.3. *Arduino programming language*

The teacher explained to students about Arduino programming with the C language includes its structure, syntax, variables, mathematical operators, comparison operators, and structuring structures. The teacher presented the problems related to Arduino programming with C language then students tried to solve the problem with the guidance of the teacher.

3.4. *Internal Timers*

Students tried to learn the material by reading from microcontrollers book and articles from the internet. The material learned includes how to the timers’ work, the type of the timers, and the timer applications on the system. In the final stage, students tried to write a program in Arduino using a timer and then they need to observe the output using the oscilloscope.

3.5. *ADC*

In this material students were challenged to read data from the output of a joystick and potentiometer. The students tried to write a program to read the ADC input which is in an analog joystick form and then they tried to display it to the LCD.

3.6. *ESC and PWM*

The teacher explained the ESC function in a system includes: how ESC works, how program the ESC and how to control ESC with PWM. The students learned about ESC by reading books and article from internet. The teacher delivered a little description of the PWM and its application to a system. The students were also challenged with a case: how to regulate the speed of a brushless and ESC motorbike using PWM that supplied with DC voltage through the converter in the form of ESC [18].
3.7. **Serial Communication**

The teacher explained about serial communication in Arduino, how to program, and its application to the system. Students were also challenged by a case: how to program the accelerometer sensor and gyroscope to adjust the balance in a system.

3.8. **Accelerometer and gyroscope sensor**

The teacher explained about the accelerometer and gyroscope function of a system, then the students learned it more by reading books and articles from internet.

3.9. **LCD**

Students listened to the teacher's explanation of the 16x2 LCD port, how to install the system, and how to program. After that student challenged to write a program that can create the menu of a system and displayed on the LCD.

3.10. **Transceiver NRF24L01**

Students tried to write a program to the transmitter at the remote so they can send signals according to the pattern of changes in the joystick.

4. **Task Discussion**

The focus of task discussion was the assembly and the programming of the quadcopter. This section included remote and quadcopter systems. For the remote system, it was consisting of analog joystick reader, LCD, and a transceiver with NRF24L01. Meanwhile, for the quadcopter it was consisting of accelerometer/gyroscope sensor, reception with NRF24L01, and PWM on a brushless ESC motor.

![Figure 1. Remote control based Arduino Nano](image1)

![Figure 2. Quadcopter based Arduino Nano](image2)

4.1. **Remote Control System**

In this project, students were challenged to assemble and write a program for an analog joystick so that it can be read by Arduino Nano through the ADC port and displayed on the LCD. The programming activities included of four ADC inputs which are used for up and down, back and forth, left and right controls, and turn left and right rotate. For make sure the ADC output is good, the calibration conducted to the ADC input. The programming activities started by making a simple LCD menu first. After that, the students proceed with the ADC program and displayed the result on the LCD. After all ADC inputs can be read properly, then the data transmitted to the quadcopter with NRF24L01.
4.2. Quadcopter system
In this project, students tried to write a program for the Arduino so it able to read the data received by NRF24L01. After the data can be received by the NRF24L01 receiver, the students continued it by trying to use the data to control the brushless motor movement through ESC. The students also wrote a program to control one BLDC motor. After it worked properly, then they challenged to write a program to control two BLDC motors, and finally the students need to wrote the program to control all four BLDC motors. Motor speed adjusted by ESC program that written using PWM. After the BLDC motors can be programmed and the speed can be adjusted, then the students need to wrote a program to control the quadcopter according to the remote control's commands such as the up and down movements, back and forth, left and right, turn left and right rotate. Finally, a program also needs to write to control the balance and stability the quadcopter by utilizing the accelerometer and gyroscope.

Figure 3. Remote Control Diagram

Figure 4. Quadcopter Diagram Based on Arduino Nano
5. Result of Methodology
In this section, an evaluation is carried out to determine students’ responses to the learning process that has been carried out. The evaluation carried out was about students’ motivation after following the learning. The following are the results of student scores.

Table 2. Survey Result

| Question                                                                 | Strongly Disagree | Disagree | Agree | Strongly Agree |
|-------------------------------------------------------------------------|-------------------|----------|-------|---------------|
| My knowledge increased after studying with Arduino Nano based quadcopter | 6%                | 14%      | 55%   | 25%           |
| The ability to program with my Arduino increased after learning with Arduino based quadcopter | 2%                | 16%      | 48%   | 34%           |
| The use of Arduino Nano based quadcopter makes it easier for me to learn microcontroller material | 5%                | 18%      | 38%   | 39%           |
| The use of Arduino Nano based quadcopter supports in microcontroller learning | 9%                | 19%      | 40%   | 32%           |
| My motivation increased after learning to develop programs with Arduino based quadcopter | 0%                | 21%      | 53%   | 26%           |
| The Arduino Nano based quadcopter gives me an attraction                | 4%                | 22%      | 55%   | 19%           |
| Learning with Arduino Nano based quadcopter is interesting because it fits the application in real life | 3%                | 15%      | 24%   | 58%           |
| My activity increases when learning with Arduino Nano based quadcopter   | 6%                | 11%      | 56%   | 27%           |
| My creativity increases when learning with Arduino Nano based quadcopter | 9%                | 16%      | 46%   | 29%           |

Based on the results of the study in table 2 the calculated data is the choice of agreeing and strongly agree. The results showed that most students felt the knowledge of microcontroller increased by 80%. A total of 82% of students felt the perfection of programming with the Arduino increased. As many as 77% of students find it easier to learn microcontrollers. 72% of students feel Arduino Nano based quadcopter supports in learning microcontroller. 79% of students answered that motivation increased in microcontroller learning. Most students view Arduino Nano based quadcopter as having a good attraction of 74%. A total of 82% of students are interested in learning microcontroller by using Arduino Nano based quadcopter. 83% of students felt that activeness in learning increased when participating in microcontroller learning. As many as 78% of students answered their creativity increased when microcontroller learning. Based on these data, the use of quadcopter based Arduino Nano is very supportive of student learning activities.

6. Conclusion
The use of Arduino Nano based quadcopter in microcontroller learning helps students in learning, increased their knowledge, and the skills in system development. Arduino Nano based quadcopter application also increased the motivation and activeness based on the results of survey responses from
students in learning. The application of the problem-based learning model in the learning of microcontrollers using Arduino based quadcopter increased students' motivation and creativity because the students tried apply the concept they received in the class to real life.

7. References

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