

# Embedded system training based on Arduino to improve software programming knowledge for vocational students

Pelatihan embedded system berbasis Arduino untuk meningkatkan pengetahuan pemrograman software untuk siswa SMK

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## ABSTRACT

Vocational high school students majoring in engineering, who are the successors to technology developers in society, need hard skills to enter the workforce. However, the students of SMK Negeri 2 Bangkalan have not received knowledge about embedded systems. In supporting this need, Master in Applied Informatics and Computer Engineering Program at Politeknik Elektronika Negeri Surabaya held a community service program by holding practice-based training on Arduino Uno-based embedded systems. This program is aimed at vocational high school students so that they can improve their abilities and skills in hardware programming and embedded. The method used in this activity is workshop-based training. The workshop includes a basic explanation of recognizing Arduino and embedded systems, a simple Arduino circuit practicum, and questions and answers between tutors and trainees. The results achieved from this activity are indicated by the results of the training evaluation questionnaire. In general, the training material is considered to be in accordance with the need to add insight, knowledge, skills, and expertise. In addition, the practice-based training on Arduino Uno-based embedded systems has provided benefits for students to use technology in their daily lives.

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## 1. INTRODUCTION

An embedded system is a combination of software and computer hardware designed for a specific purpose. The three components in an embedded system are hardware, software and firmware, as well as a real-time operating system called Realtime Operating System (RTOS) which is used to monitor the software while it is running. Small scale embedded systems may not have an RTOS. Embedded systems can be defined as microcontroller-based, software-based, reliable, real-time control systems. The most

popular embedded system is the Arduino UNO. Arduino can control what the user wants by using a program (Khan et al., 2019). Arduino is an embedded system device that can be used to connect with sensors or actuators or can control electronic devices (Arafat et al., 2021). Arduino is a microcontroller system that is free to use its license (open source). Arduino can be divided into two systems, namely hardware and software. With this open-source license, Arduino is growing fast and is widely used in the design of electronic systems. Microcontrollers from the ATMEL family are the core of Arduino processors, such as the ATmega8, ATmega2560, and so on (Arisandi, 2016).

Various types of man-made equipment are used to fulfill the wants and needs in carrying out various activities (Zanofa, 2020). Along with the development of technology, the demand for embedded systems is getting bigger, for example in everyday life which cannot be separated from digital clocks, mp3 players, and traffic lights. Implementation of other embedded systems such as designing an IoT (Internet of Things) system, for example in a home security system based on the Arduino Mega 2560 (Ramadhan, 2016). The security system was developed using a fingerprint sensor based on the Arduino UNO R3 microcontroller (Dita et al., 2021). In this regard, vocational high school graduates are required to be ready to participate in the development of technological products. However, currently knowledge about embedded systems and their relation to technology products has never been conveyed to students of SMK Negeri 2 Bangkalan.

Universities in Indonesia have an obligation to carry out the *Tri Dharma* of Higher Education (*Tri Dharma Perguruan Tinggi*), namely to provide education, research, and community service. These three are the responsibility of all elements of higher education, namely students, lecturers, and the academic community involved (Jurningsih, 2021). Community service is one form of applying science and technology that can be done by universities so that they can contribute to the welfare of society. In this regard, the Computer and Informatics Engineering Master's Degree Study Program (*Program Studi S2 TIK*) from Politeknik Elektronika Negeri Surabaya (PENS) carry out the community service activity program annually.

Community service programs can be done through several fields and forms of activities that are tailored to the conditions and needs of the community as well as the scientific background of the organizers (Yuniarti et al., 2022). Computer and Informatics Engineering Master's Degree Study Programs one of the study programs based on electronic engineering and information technology, in the realization of community service programs, various technology-based activities have been carried out to improve people's quality of life. In this regard, community service is carried out on training for Arduino-based embedded systems. By using Arduino, SMK students can increase their creativity to implement embedded systems. This activity is titled Arduino-based Embedded System Training for Vocational Students at SMK Negeri 2 Bangkalan. In this year's activity, where the COVID-19 pandemic period has subsided enough, making community service carried out offline taking into account health protocols.

This community service program aims to increase the knowledge and skills of SMK Negeri 2 Bangkalan students in hardware programming and embedded systems. This activity also aims to develop the interest of vocational students in developing Arduino-based embedded fields. This is an effort to prepare students for further education and readiness to participating the working field.

## **2. METHODS**

Community service activities by Department of Computer and Informatics Engineering Master's Degree from Politeknik Elektronika Negeri Surabaya are implemented by holding embedded systems

training for students at SMK Negeri 2 Bangkalan as the partner. This activity is carried out offline and takes place in partner computer laboratories. There are 4 methods used.

### **Presentation and Q&A Session**

The presentation method describes a series of activities that will be held, introduction to the implementing team, and materials to be delivered to students of SMK Negeri 2 Bangkalan. This method aims to visualize and help illustrate the message that the presenter wants to convey. In addition to using the presentation method, this activity uses a question and answer session. The question and answer method serves to provide a form of interaction between the implementing team and students. Questions and answers can spark the motivation and curiosity of the training participants, as well as increase the absorption and memory of the material for participants. The material presented includes an introduction to Arduino, the benefits of Arduino, types of Arduinos, and examples of using Arduino in a project. This material develops from theory to practice.

### **Practicing**

The practical method is used so that students of SMK Negeri 2 Bangkalan can directly apply the knowledge gained from delivering material using the previous method. The practical method is a learning method to train students in order to improve their ability to implement the knowledge and skills that have been learned. Practice is one way to help students deepen their knowledge with the implementation team helping the process of this practical method. The implementation team will be divided to deliver material on the project and help students follow the practical process presented. The question and answer method is still used because students are required to give questions to the implementing team if there is material that has not been understood, this is done so that the material obtained by students can be useful in the future. The process of implementing the practice requires modules as well as several supporting components based on the material presented.

### **Modules**

The module used in the process of delivering material is intended to be a reference for students of SMK Negeri 2 Bangkalan. This module contains lots of examples and discussions about the application of Arduino. Modules used with the title "19 Jam Cepat Belajar Arduino" (Quickly Learn Arduino in 19 Hours).

### **Components**

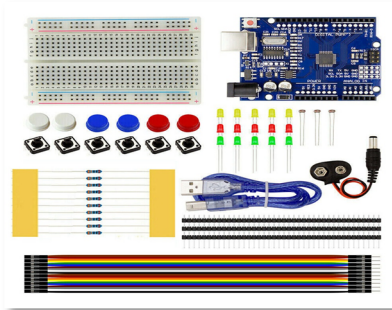
Components are used to support the delivery of project material so that students can directly apply the material that has been delivered. The components used are hardware and software from Arduino. The hardware in the project is an Arduino kit, LCD (Liquid Crystal Display), buzzer, and PIR (Passive InfraRed) sensor.

The Arduino kit contains supporting components for the project, such as Arduino UNO as a microcontroller, BreadBoard, Arduino USB cable, colorful LED lights, on-off button, resistors, 9V battery, and headers. BreadBoard serves as the basis of electronic circuits so that the applied circuit scheme can be changed (Faudin, 2017). Arduino USB cable serves as a medium for uploading programs from the Arduino software.

LCD (Liquid Crystal Display) is one type of electronic display made with CMOS logic technology that works by not producing light but reflecting the light around it to the front-lit or transmitting light from the back-lit. LCD has several pins or pins such as data pins, RS pins, R/W pins, E pins, and VLCD pins. LCD functions as a display of data, letters, graphics and characters according to the desired results.



**Figure 1.** "19 Jam Cepat Belajar Arduino" (Quickly Learn Arduino in 19 Hours)



**Figure 2.** Arduino kit

(Source: <https://randomnerdtutorials.com/esp32-esp8266-i2c-lcd-arduino-ide/>)



**Figure 3.** Liquid Crystal Display (LCD)

(Source: <https://randomnerdtutorials.com/esp32-esp8266-i2c-lcd-arduino-ide/>)



**Figure 4.** Buzzer

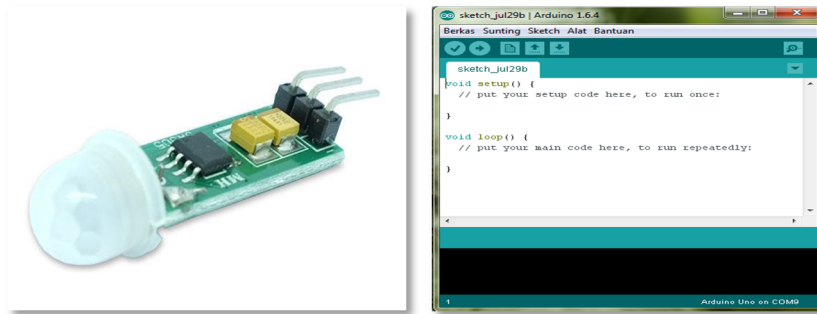
(Source: <https://www.walmart.com/c/kp/arduino-circuit-board?page=25&affinityOverride=default>)

Buzzer is an electronic component that can produce sound vibrations in the form of sound waves. Buzzers will produce sound vibrations when given a certain amount of electrical voltage according to the specifications of the shape and size of the buzzer. Basically, every electronic buzzer requires an input in the form of an electrical voltage which is then converted into sound vibrations or sound waves that have a frequency ranging from 1 - 5 KHz. (Hidayatullah, 2020).

The PIR (Passive InfraRed) sensor is used to detect the presence of infrared rays from an object. The PIR sensor is passive so that this sensor does not emit infrared light but can only receive infrared radiation from outside (Saefullah et al., 2015). PIR sensors can detect radiation from various objects, because all objects emit radiant energy. For example, when a motion is detected from an infrared source with a certain temperature, humans try to pass through another infrared source such as a wall. Then the sensor will compare the infrared radiation received per unit of time, so that if there is movement there will be a change in the reading on the sensor.

Arduino IDE is a software used to create programming sketches or as a medium for programming boards. Arduino IDE is useful for editing, creating, uploading to a specified board, and coding certain programs. The use of the Arduino IDE software is carried out to provide instructions using the C programming language which aims to run the system so that it can work according to the program code that has been loaded into an Arduino (Widodo et al., 2020). Arduino IDE is made from the JAVA programming language, which is equipped with a C/C++ (wiring) library to make input/output

operations easier. Meanwhile, Sketch Arduino is an application to compile and upload programs to the Arduino microcontroller (Anantama et al., 2020). Microcontroller is a computer on a chip that is used to control electronic equipment, which regulates efficiency and cost effectiveness (Hafidhin, 2020). In control electronics, a chip can store and execute programmed data, namely the electrical component in the form of a microcontroller. Microcontroller can be used to control a device so that it can work automatically (Riski et al., 2021).



**Figure 5.** PIR (Passive Infrared) Sensor  
(Source: <https://ecadio.com/jual-sensor-pir-mini-hc-sr505>)  
**Figure 6.** Arduino Software

### 3. RESULTS AND DISCUSSION

#### Results

The community service activity entitled “Arduino-based Embedded System Training for Vocational Students at SMK Negeri 2 Bangkalan” was held on May 25, 2022. The training took place at SMK Negeri 2 Bangkalan and took place offline. The implementation team consists of lecturers, laboratory technicians, and several students of Computer and Informatics Engineering Master’s Degree Study Program students from Politeknik Elektronika Negeri Surabaya.

#### Implementation

The implementation of activities is carried out in several stages, namely: (1) Opening; (2) Material delivery; (3) Arduino module practicum; (4) Filling out the training evaluation questionnaire by the training participants. Table 1 is the arrangement of activities during the training along with the objectives of each activity, which is used as an indicator of the impact of the training for students.

**Table 1.** Activities arrangement

Activities	Goals	Duration
Opening	Opening the event and handing over souvenirs and Arduino kits for SMK Negeri 2 Bangkalan	10 minutes
Material delivery	Provide knowledge about Arduino and embedded systems to trainees	15 minutes
Arduino module practicum	Provide examples and hands-on practice of Arduino modules	60 minutes
Filling out the training evaluation questionnaire	The evaluation of activities for improvement and input on further activities.	10 minutes

## Opening

Community service activities by the Computer and Informatics Engineering Master's Degree Study Program students from PENS started with a speech and continued with the delivery of souvenirs. This agenda was represented by the Head of the PENS Graduate School to the SMK Negeri 2 Bangkalan and the Head of the SMK Negeri 2 Bangkalan. The handover of the Arduino kit was carried out symbolically from the PENS to the SMK Negeri 2 Bangkalan.



**Figure 7.** Handing over souvenirs and symbolic handover of the Arduino kit

## Compiling materials

In this community service program, the materials used in this implementation are compiled by the implementing team in the form of modules that have been adapted to the abilities of participants. The material is sourced from the book "19 Jam Cepat Belajar Arduino" (Quickly Learn Arduino in 19 Hours). Apart from the modules distributed by the presenters, the complete Arduino materials and programs from this training module can also be accessed by training participants by accessing the link <http://pens.id/pkmArduino>.

## Delivering materials

At this stage, the material is presented in the form of presentations by students and lecturers of the Computer and Informatics Engineering Master's Degree Study Program from PENS. The first material is an introduction to Arduino which is an electronic device that will be used during the training. The second material is the installation of Arduino and Arduino IDE on the PC used by each participant, then continued with the third material in the form of an explanation of the modules that will be practiced during the training. A laptop or PC is used to create programs which are then uploaded using the Arduino IDE software to the Arduino microcontroller (Samsugi et al., 2020). The material presentation is shown in Figures 8.



**Figure 8.** Presentation of material by PENS' students and presentation of material by PENS' lecturer

### **Arduino module practicum**

At this stage, participants can directly implement the material that has been presented. After installing the Arduino on their respective PCs, as many as 20 participants who had received the Arduino kit formed a group of two and practiced the Arduino module described previously. The modules that are worked on are sourced from the book "19 Jam Cepat Belajar Arduino" (Quickly Learn Arduino in 19 Hours). The materials practiced by the training participants include LED Light Programming, LED Light Animation, Traffic Light Simulation, and Digital Input Data, LCD Programming, Speaker/Buzzer Programming, and Motion Detection Programming. During the practicum, participants were assisted by students and lecturers as instructors. Participants were very enthusiastic during the practicum. This 60-minute practicum got the participants excited to learn more about Arduino. A number of participants took the initiative to modify the modules described, so that the results of the practicum varied. Figure 9 shows the participants and presenters who are carrying out the practicum.



**Figure 9.** Arduino module practicum

### **Filling out the training evaluation questionnaire**

This stage is the closing stage of a series of Arduino-based Embedded System Training activities for Vocational Students at SMK Negeri 2 Bangkalan. The students of SMK Negeri 2 Bangkalan as training participants were given a training evaluation questionnaire which was filled out as a form of assessment and evaluation material. This evaluation is aimed at implementing better activities in community service for the following year.

### **Discussion**

This community service program activity is in the form of Arduino-based embedded system training. The activity aimed at Vocational Students at SMK Negeri 2 Bangkalan aims to introduce, add new knowledge and hard skills of participants in the field of embedded systems, especially with Arduino. Arduino kits and modules given to SMK Negeri 2 Bangkalan can be used as Arduino teaching and learning materials at the school.

The implementation of the community service program at SMK Negeri 2 Bangkalan is supported by several factors, namely: (1) The active role of partners, in this case the SMK Negeri 2 Bangkalan which has given permission and cooperation to be able to carry out community service at SMK Negeri 2 Bangkalan; (2) The enthusiasm and curiosity of the training participants towards the Arduino material taught during the training. This is shown by the active role of the participants in question and answer during the training and experiments conducted on the Arduino kit, so that they gain new knowledge and experience apart from the material presented by the previous presenters; (3) Smooth communication between the presenters, participants, and facilitators on duty during the training. The training took

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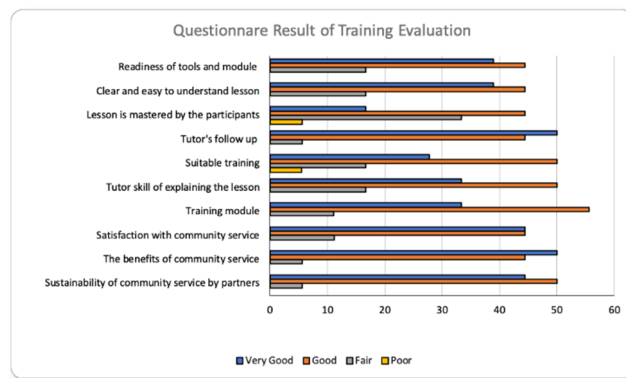
place making a conducive atmosphere and the material could be conveyed well; (4) There were no other activities outside the training, because the training took place in the laboratory of SMK Negeri 2 Bangkalan, where facilities such as computers needed to run the Arduino program were available.



**Figure 10.** Active role of partners and active role of participants as supporting factors in activities

In the implementation of this community service program, there are several inhibiting factors that occur during the program, namely: (1) A more detailed explanation regarding the Arduino module is needed for each participant, because the trainees come from several classes of different majors and are still new. For the first time getting to know Arduino when the training started; (2) Some of the trainees have not managed to complete the training practicum, so they need further assistance and guidance.

At the end of the session, the participants were given a questionnaire sheet. The questionnaire contains 10 questions containing material for evaluating the community service program for Department of Computer and Informatics Engineering Master's Degree from PENS. The questionnaire data were collected as shown in Figure 11.



**Figure 11.** Questionnaires result

From Figure 11, it can be stated that some participants were satisfied with the implementation of service activities that had been carried out by the team. This is also supported by the answers of the trainees who stated that: (1) The material presented was in accordance with the needs in increasing participants' knowledge and expertise; (2) Tutors who explained well the relationship between topics and the context of life; (3) Tutors followed up on questions and participants' problems during the training; (4) Participants stated that the material presented was useful and could be continued by service partners, although there were still participants who felt they had not mastered the material being taught. This



is because the participants are using and implementing Arduino for the first time, so it requires more practice and practice.

This community service activity in the form of short training has an impact that can be felt directly, namely the enthusiasm of the students of SMK Negeri 2 Bangkalan in learning Arduino. In addition, knowledge and skills to recognize Arduino also increase, because previously the participants had never studied one of these embedded systems. The students as trainees can identify the components needed in an embedded system, assemble Arduino circuits according to the modules given properly, and are able to implement simple embedded systems. The implementation of the practicum carried out in groups also has a positive impact in the form of cooperation between groups and increases the creativity and activity of each individual in working together in teams to build simple embedded systems.

#### **4. CONCLUSION AND RECOMMENDATIONS**

Based on the evaluation results, it can be stated that some participants were satisfied with the implementation of service activities that had been carried out by the team. This is also supported by the answers of the trainees who stated that: (1) The material presented was in accordance with the needs in increasing participants' knowledge and expertise; (2) Tutors who explained well the relationship between topics and the context of life; (3) Tutors followed up on questions and participants' problems during the training; (4) Participants stated that the material presented was useful and could be continued by service partners, although there were still participants who felt they had not mastered the material being taught. This is because the participants are using and implementing Arduino for the first time, so it requires more practice and practice. This community service activity by the Department of Computer and Informatics Engineering Master's Degree from PENS aims to improve and empower the abilities and skills of SMK students in the field of hardware programming, increase the understanding and creativity of SMK students in developing embedded system-based products, and develop students' abilities and skills. Vocational High School in the Arduino-based embedded field in an effort to prepare for further education. This activity is carried out in the form of Arduino-based embedded system training for vocational students at SMK Negeri 2 Bangkalan. The active role of partners, supporting facilities and infrastructure, the enthusiasm of the trainees, and good communication between the team as tutors and the training participants and partners involved are the supports in the successful achievement of the objectives of this activity. The results achieved are in the form of students' new knowledge in embedded systems, students' abilities in implementing embedded systems with Arduino, and students' new skills in the hardware field. This is indicated by the results of the training evaluation which stated that the percentage of 16.7% of participants mastered the material very well, 44.4% of participants mastered the material well, and 33.3% of participants had sufficient mastery of the material. With this activity, the training participants can continue the practice and implementation of embedded systems in various fields of life, so that they can be useful in their daily technology needs.

It is necessary to hold pre-test, post-test, and additional training duration. The existence of this pre-test is intended so that the tutor knows the basic abilities of the trainees, so that they can take advantage of the available training time to focus more on the abilities of the trainees. The existence of a post-test aims to determine the results of the training in the form of increasing the abilities and skills of the trainees, as well as evaluation materials for tutors during the training. While the suggestion to increase the duration of the training is because the limited training time of 1.5 hours is not enough, seeing the enthusiasm of the trainees in exploring further related to the material being practiced.

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