A Heart Rate Measuring Trainer Kit as a Medical Electronics Practice Learning Media

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Abstract. This research was aimed to produce the learning media for a heart rate measuring trainer kit that can be used easily at relatively cheap price to support the learning process of Medical Electronics Practice. This research adapted the Alessi and Trollip’s development model which consisted of three stages, namely planning, design, and development. The designs used to test the product was alpha testing and beta testing. The subjects of the trial were limited to four students from the Electronics Engineering Study Program (D3) at Yogyakarta State University. The techniques used to to collect the data were interviews, observation, and questionnaires. The technique used to analyze the data was qualitative descriptive analysis. The result of the research showed that in general the heart rate measuring trainer obtained the average score of 3.49 which was included in the very feasible category. The assessment of trainer kit was seen from four assessment indicators, namely design, operation, usefulness, and suitability. A trainer kit with a very feasible category could be used in learning Medical Electronics Practice. A heart rate measuring trainer kit made the practical learning process more real.

1. Introduction
Health is a very important factor in human life. By a healthy body condition, human can work productively and it can be assured that all of their organs can function properly. Therefore, maintaining health is an effort that must be done by human at all times.

Globally, cardiovascular disease is the number one cause of death every year \(^1\). According to data from the Indonesia Health Ministry in 2008 an estimated 17.3 million deaths were caused by cardiovascular disease. Cardiovascular disease is a disease caused by impaired heart and blood vessel function. The heart organs, therefore, need to be monitored regularly.

Heart as one of the organs of the human body has a very important role in the cardiovascular system. Life and death of human can be known from the pulse of heart or not. Heart rate contains electrical signals originating from within the human body and is one of the health parameters that must be monitored at all times. When the heart rate starts to become irregular, it can be considered as a critical sign.

Measurement of heart rate by medical experts is used to diagnose the patient's condition. There are several methods that can be done to measure heart rate such as Palpation, Photoplethysmography (PPG), and Electrocardiography (ECG). All these three methods are clinical and often used by medical experts to measure heart rate. However, commercially available manufacturing instrumentation for this method is relatively expensive, so it can only be used by people or agencies who can afford it.

Palpation method is done by touching the body parts associated with the blood circulatory system such as the arteries to feel the presence or absence of pulses. In general, there are many arteries in the
human body, but there are only a few arteries that can be sensed. The radial artery and brachial artery are the best arteries to examine because they can provide reliable heart rate information. Method provides an accurate measure of heart rate. Therefore, arterial pulses can represent heart rate because blood flows in one cycle in the body.

Photoplethysmography (PPG) method is a light radiation technique on the skin and measuring the amount of light scattered through the bloodstream that changes dynamically due to changes in heart rate or changes in blood volume. Heart rate measurement by Photoplethysmography (PPG) method uses a light source from LED (Light Emitting Diode) and photodetector to detect the changes in blood volume in blood vessels. The light source from the LED emits light to the tissue and the photodetector measures the light reflected from the tissue. The reflected light is proportional to the variation in blood volume. Broadly speaking, the sensor used in the Photoplethysmography (PPG) method can measure the amount of light absorbed or reflected by blood.

Electrocardiography (ECG) is an instrument used to record the electrical activity of the heart. The electrical activity of the heart can be recorded using electrodes mounted on the surface of the body. The recording of the heart's electrical activity is depicted in a graph called an electrocardiogram. The term "electrocardiogram" is a combination of three words, namely "electro" relating to electrical signals, "cardio" meaning heart, and "gram" which means recording. Based on the meaning of the three words, the electrocardiogram can be interpreted as a recording of heart electrical activity. This Electrocardiography (ECG) serves to monitor the condition of the heart and diagnose cardiovascular disease.

Learning about medical instrumentation is not only studied by the students of medical department, but also studied by the students of engineering department. The difference is in the learning focus, the students of medical department more focus on practical use of medical instrumentation while engineering students more focus on designing medical instrumentation. In Yogyakarta State University, Electronics Engineering students at the D3 program also study medical instrumentation in the Medical Electronics Practice course. The status of this new course was required in the year study of 2016/2017 which was previously an optional course. Given the importance of this course as one of the branches of electronics and many industries require the skilled technicians in the field of medical instrumentation as well, and because of no students who take this course every year, so the status of this course becomes a compulsory course. Change in the status of this course has not been balanced with the availability of learning tools that will be used to teach students. One of the learning devices that have not been ready is a trainer kit for practical activities.

There are two important elements in the learning process, namely learning media and teaching methods. Learning media is needed in the Medical Electronics Practice course as a tool that can support the learning process. While, the trainer kit learning media has not yet been available for Medical Electronics Practice courses. Until now, the learning process still uses laptop as a learning media to find and analyze journals relating to the project to be made. The use of laptop in the Medical Electronics Practice course causes the students' learning activities become less active because they only sit in front of the laptop screen during the learning process. Even, most of them are more likely to explore other things beyond learning content. Whereas, the student learning activities can be a determinant factor in the success of learning if all or at least some students are actively involved either physically, mentally or socially in the learning process.

Each course certainly has a competency standard that must be achieved, and so a Medical Electronics Practice course does. Based on the fact, it shows that there is only one standard competency in the course of Medical Electronics Practice achieved in the learning process, while the other one is not achieved yet. Competency standard that has not been achieved is measuring electrical signal originating in the human body. The learning process in this competency is abstract. Therefore, the students are required to think so logically that the learning process needs to be applied in the real life.

To be able to achieve all the competencies of the Medical Electronics Practice course, it needs a learning media trainer kit for measuring the heart rate with various measurement methods as performed by medical experts, in which the price is relatively cheaper than the manufacturer's medical
instrumentation, and contains educational elements to support the learning process of Medical Electronics Practice. The availability of trainer kit learning media in the Medical Electronics Practice course is expected that the practical learning process will feel more real. This assumption is of course necessary to be proven through a series stages of research activities. Therefore, the author takes the research titled "A Heart Rate Measuring Trainer Kit as a Medical Electronics Practice Learning Media".

This research was aimed to produce a trainer kit which was feasibility tested so that it could be used as a learning media in the Medical Electronics Practice course. Theoretically, the benefit of this research was that it could add insight into the use of Medical Electronics Practice learning media and could also be used as reference material for relevant future research. Practically, the benefit of this research was that it could produce a trainer kit that had been tested for its feasibility so that it could be used as a supporting media in the learning process of Medical Electronics Practice.

2. Research Method
This research belonged to the type of Research and Development. The development model used in this research adapted the Alessi and Trollip’s development model. The development procedure in this research consisted of three stages, namely planning, design, and development as shown in Figure 1.

![Figure 1. Research Procedures Adapted from The Alessi and Trollip’s Development Model](image)

The design of product testing used alpha testing involving two media expert lecturers, two material expert lecturers, and beta testing involving some students. The subject of the trial involved four students from the Electronics Engineering Study Program (D3) of Yogyakarta State University. The techniques used to collect the data were interview, observation, and questionnaire. The technique used to analyze the data was qualitative descriptive analysis.

The trainer kit feasibility data obtained from the questionnaire used a combination of quantitative and qualitative data analysis techniques. Data obtained from media experts, material experts, and students in the form of qualitative values will be converted into quantitative values. The rules for giving scores to convert qualitative values into quantitative values were carried out by Likert scale with assessment ranges 1 to 4 as shown in Table 1.
Table 1. Scoring Rules \[13\]

| Assessment                | Score |
|---------------------------|-------|
| Absolutely Agree (AA)     | 4     |
| Agree (A)                 | 3     |
| Disagree (D)              | 2     |
| Absolutely Disagree (AD)  | 1     |

The quantitative data that had been collected was calculated by the average score using the following formula:

\[
\bar{X} = \frac{\sum X}{n}
\]  

(1)

Description:
\( \bar{X} \) = average score
\( \sum X \) = score amount
\( n \) = assessment amount

This score calculation data was then changed into qualitative values based on 4 categories as shown in Table 2. Rules for converting scores into several categories were used to determine the feasibility level of learning media products being developed.

Table 2. Rules for Conversion of Feasibility Category Scores \[13\]

| Score Interval                              | Category |
|---------------------------------------------|----------|
| \( X \geq \bar{X} + 1.SBx \)               | Very Feasible |
| \( \bar{X} + 1.SBx > X \geq \bar{X} \)    | Feasible |
| \( \bar{X} > X \geq \bar{X} - 1.SBx \)    | Unfeasible |
| \( X < \bar{X} - 1.SBx \)                 | Very Unfeasible |

Description:
\( X \) = obtained score
\( \bar{X} \) = overall score average calculated by the use of formula \( \frac{1}{2} \) (maximal score + minimal score)
\( SBx \) = overall deviation score calculated by the use of formula \( \frac{1}{6} \) (maximal score – minimal score)

3. Results and Analysis

3.1. Planning

Planning was the first stage carried out in this research. At this stage, the researcher determined the scope of the research namely about the learning of Medical Electronics Practice. This course was chosen to be researched because it had several problems in the teaching process. Having been identified, it was found that the problem of its process was an unavailability of trainer kit learning media for Medical Electronics Practice courses.

To support the process of problem identification, so the initial data relating to the learning of Medical Electronics Practice was then collected. Data collection was done by interviewing lecturers in charge of Medical Electronics Practice courses. The results of the interview showed that the competency standard in the Medical Electronics Practice course had not been achieved yet, namely the students’ ability to measure electrical signals originating from the human body. Having conducted observation, it was found that there was no one trainer kit that had been used to teach students to practice the theories about Medical Electronics. During this time, the practicum learning process frequently only used laptops connected to the internet network to find knowledge and train students’ skills in making a project. The practical learning process liked this seemed to be passive because the students merely sit in front of the laptop screen and tended to explore other things outside the learning content.
Based on the initial collected data, a need analysis was then conducted through brainstorming together with the lecturer in charge of Medical Electronics Practice course. The results of brainstorming showed that it was necessary to develop a trainer kit learning media for measuring the heart rate to support the learning process of Medical Electronics Practice. By the availability of trainer kit learning media, it was expected that the practical learning process would be more real.

3.2. Design
Designing was the second stage carried out in this research. At this stage, a design concept for the product of Medical Electronics Practice learning media was made by creating a flowchart about the design of the trainer kit as shown in Figure 2.

![Flowchart of Trainer Kit Design](image)

**Figure 2.** Flowchart of Trainer Kit Design

At this stage, a storyboard was made in the form of a trainer kit block diagram for measuring the heart rate using the Palpation method as shown in Figure 3. The trainer kit hardware design for measuring the heart rate using the Palpation method as shown in Figure 4.

![Trainer kit block diagram](image)

**Figure 3.** Trainer kit block diagram for measuring the heart rate using the Palpation method
**Figure 4.** Trainer Kit Hardware Design for Measuring The Heart Rate using The Palpation Method

Besides, a storyboard was made in the form of a trainer kit block diagram for measuring the heart rate using the Photoplethysmography (PPG) method as shown in Figure 5. The trainer kit hardware design for measuring the heart rate using the Photoplethysmography (PPG) method as shown in Figure 6.

![Block Diagram](image)

**Figure 5.** Trainer Kit Block Diagram for Measuring the Heart Rate using The Photoplethysmography (PPG) Method

**Figure 6.** Trainer Kit Hardware Design for Measuring The Heart Rate using The Photoplethysmography (PPG) Method

Besides, a storyboard was also made in the form of a trainer kit block diagram for measuring heart rate using the Electrocardiography (ECG) method as shown in Figure 7. The trainer kit hardware design for measuring heart rate using the Electrocardiography (ECG) method as shown in Figure 8.

![Block Diagram](image)

**Figure 7.** Trainer Kit Block Diagram for Measuring the Heart Rate using The Electrocardiography (ECG) Method

![Block Diagram](image)
3.3. Development

Development was the last stage carried out in this research. At this stage, the product of a trainer kit of Medical Electronics Practice learning media was made based on the design concept that had been made previously. The process of making this product was begun by making a list of the required components and preparing them for making a heart rate measuring trainer kit using the Palpation method, Photoplethysmography (PPG), and Electrocardiography (ECG). Components needed for a heart rate measuring trainer kit using the Palpation method were push buttons, batteries, resistors, capacitors, ICs, diodes, connectors, seven segments, and other supporting components such as cables. Components needed for a heart rate measuring trainer kit using the Photoplethysmography (PPG) method were light sensors, pulse heart rate sensors, Arduino Uno, laptop, and other supporting components such as cables. Components needed for a heart rate measuring trainer kit using the Electrocardiography (ECG) method were electrodes, the AD8232 heart rate monitor, Arduino Uno, laptop, and other supporting components such as cables.

The available components were then assembled to become a trainer kit. This assembly consists of three parts, namely input devices, signal conditioning devices, and output devices. Measuring heart rate using the Palpation method was conducted manually, its input was obtained from arteries, then controlled using a stopwatch circuit, and its output was obtained through the sense of touch using the fingers. Measuring heart rate using the Photoplethysmography (PPG) method was carried out using a trainer kit, its input was obtained from the LED and photodetector as a light sensor, its signal conditioning was obtained by the use of a filter circuit and amplifier circuit available in the pulse heart rate sensor, and its output was displayed using a laptop through a serial monitor. Measuring heart rate using the Electrocardiography (ECG) method was carried out by using a trainer kit, its input was obtained from three electrodes, its signal conditioning was obtained by using a filter circuit and the amplifier circuit available in the AD8232 heart rate monitor, and its output was displayed using a laptop through a serial plotter.

Assembled trainer kit was then programmed in order that they could be operated well. Measuring heart rate using the Palpation method was done manually, therefore there was no special program made for measuring heart rate. The program for a heart rate measuring trainer kit using the Photoplethysmography (PPG) method and the Electrocardiography (ECG) method was created using the Arduino sketch.

The trainer kit which has been programmed was then calibrated. A heart rate measuring trainer kit using Palpation method was calibrated by using a stopwatch. The calibration results of a heart rate measuring trainer kit using Palpation method showed that the error rate was 0% for the measurement time of 15, 30, and 60 seconds. By an error rate of 0%, a heart rate measuring trainer kit using Palpation method showed a very good level of accuracy because the error rate value could still be tolerated in the range of measurement 0.6745% \[^{[14]}\]. A heart rate measuring trainer kit using Photoplethysmography (PPG) method was calibrated by using Oximeter medical instrumentation. The calibration result of a...
heart rate measuring trainer kit using Photoplethysmography (PPG) method showed that the error rate was 0.40%. By an error rate of 0.40%, so a heart rate measuring trainer kit using Photoplethysmography (PPG) method showed a good level of accuracy because the error rate value could still be tolerated in the range of measurement 0.6745% [14]. A heart rate measuring trainer kit using the Electrocardiography (ECG) method had not been calibrated because it was difficult to get permission to borrow its medical instrumentation for research purpose. Although a heart rate measuring trainer kit using the Electrocardiography (ECG) method had not been calibrated and the level of measurement accuracy had not been known yet, in general the measurement result could be seen quite clearly from the ECG waves displayed on the Arduino software, despite noise on the waves. The ECG waves pattern was shown in Figure 9.

![Figure 9. The ECG Waves Pattern in Arduino Software](image)

The calibrated trainer kit was then used to measure the heart rate. Measuring heart rate using the Palpation method as shown in Figure 10. Measuring heart rate using the Photoplethysmography (PPG) method as shown in Figure 11. Measuring heart rate using the Electrocardiography (ECG) method as shown in Figure 12.

![Figure 10. Measurement of Heart Rate using The Palpation Method](image)
The trainer kit was then tested using alpha testing by two lecturers of media expert and two lecturers of material expert. In general, the test results of alpha testing for a heart rate measuring trainer kit using the Palpation method, Photoplethysmography (PPG), and Electrocardiography (ECG) obtained the average score of 3.75 and were included in the very feasible category. These test results still required revisions on a small scale so that an initial revision needed to be made regarding the supply of voltage inputs to the trainer kit from the PLN power source.

The trainer kit which had been tested by alpha testing and got initial revision was then tested again by beta testing in a limited way to the four students of Electronics Engineering (D3) Yogyakarta State University. In general, the results of beta testing for a heart rate measuring trainer kit using the Palpation, Photoplethysmography (PPG) and Electrocardiography (ECG) methods obtained the average score of 3.16 and were included into the very feasible category. Those testing results still required revisions on a small scale so that the final revision of the soldering on a heart rate measuring trainer kit was needed by the Photoplethysmography (PPG) method.

In general, the results of alpha and beta testings showed that a heart rate measuring trainer kit obtained the average score of 3.49 and were included into the very feasible category. A trainer kit with a very feasible category could be used in the learning of Medical Electronics Practice. The analysis of the trial results in the use of the learning media for a heart rate measuring trainer kit made the practical learning process more real.

A heart rate measuring trainer kit using Palpation method served as a timer for 60 seconds. The trainer kit could be controlled manually so that it was easy to adjust to your needs. The workings of this trainer kit was begun by pressing the on button and ended with pressing the off button. It could also be reset by pressing the reset button. The results of heart rate measurements were displayed on two seven segment. The trainer kit part used to measure the heart rate by the Palpation method was marked with a red line as shown in Figure 13.

A heart rate measuring trainer kit using the Photoplethysmography (PPG) method could be used to count the heart rate through the blood circulatory system in the body. The trainer kit used an LED light
sensor and photodetector to detect blood flow in the digita arteries inside the finger skin. The trainer kit used a reflection mode where the LED and photodetector were put on the same area, while the finger was put on top of it. The LED functions as a light emitter, the photodetector functions as a light receiver, while the finger functions as a reflector that would reflect the light from the LED. The light from the LED would be spread through the skin tissue of the finger, then the light was absorbed by the blood so that it created a change in light intensity caused by the change in the volume of blood flowing in the digita arteries contained in the finger skin. The emitted light was received by the photodetector. The heart rate detected by the sensor circuit was filtered using High Pass Filter (HPF) and Low Pass Filter (LPF). The filtered signal was amplified by non-inverting operational amplifiers in which its data was then processed by Arduino Uno. The heart rate measurement results would be displayed on the laptop using the Arduino software on the monitor serial menu. The trainer kit part used to measure the heart rate using the Photoplethysmography (PPG) method was marked with a yellow line as shown in Figure 13.

A heart rate measuring trainer kit using the Electrocardiography (ECG) method could be used to count the heart rate by taking samples from the ECG waves per unit of time. The trainer kit used an electrode sensor to detect the heart rate and record the heart electrical activity. Three electrodes were attached on the right arm (RA), left arm (LA), and right leg (RL). The heart rate detected by the sensor circuit would be filtered using High Pass Filter (HPF) and Low Pass Filter (LPF). The filtered signal would then be amplified by non-inverting operational amplifiers in which the data would then be processed by Arduino Uno. The heart rate measurement results would be displayed on the laptop using the Arduino software on the serial plotter menu. The trainer kit part that was used to measure the heart rate using the Electrocardiography (ECG) method was marked with a green line as shown in Figure 13.

4. Conclusion and Recommendation
In general, a heart rate measuring trainer kit obtained an average score of 3.49 which was included into the very feasible category. A trainer kit with a very feasible category could be used in learning Medical Electronics Practice. A heart rate measuring trainer kit could make the practical learning process more real.

A heart rate measuring trainer kit that had been considered very feasible needed to be implemented on a large scale practical learning activity. Furthermore, it was necessary to do an analysis of the process and student learning outcomes related to the use of a heart rate measuring trainer kit in practical learning.
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