Development and Testing of Microcontroller-Based Learning Media for the Internet of Things Lab Work

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Abstract. These days, the Internet of things (commonly abbreviated as IoT) has been applied in various industrial sectors such as manufacturing, health, restaurant, electricity generation, transmission, and distribution, etc. Therefore, IoT learning materials need to be included in the learning process both at the college and high school level. The most common obstacle is the lack of learning media about IoT. This paper reports on the process of developing an IoT laboratory work (lab work) learning media based on the Arduino UNO and NodeMCU microcontroller. Furthermore, this paper also discusses the results of the feasibility test on learning media. The stages of the research are need assessment, planning, development and implementation, and also evaluation. Outcomes of this development process are the Arduino and NodeMCU-based IoT lab work modules, short manuals and lab sheets. Product testing with student respondents shows that the Arduino and NodeMCU-based IoT lab work modules, manuals and lab sheets are considered to be very feasible for use in learning. The test results show students considered this module can increase learning interest and make it easier for them to understand IoT learning materials.

1. Introduction
The era of the industrial revolution 4.0 has 4 main characteristics namely cyber physical systems, internet of things, cloud computing and cognitive computing. Cyber physical system can be interpreted as the connection of physical systems in cyberspace. Connections between physical systems will require technology and the concept of the internet of things (abbreviated as IoT), namely the connection of "things" through the internet network [1]. Internet of Things can be interpreted as a connection of everything (things) namely objects or objects around us that can communicate with each other through the internet network [2] [3]. The initial idea of the Internet of Things was first presented by Kevin Ashton in 1999 in one of his presentations. Now many large companies, such as LG and Samsung, are starting to explore the Internet of Things and begin to apply the concept of IoT in its innovative products. Many predict that the influence of the Internet of Things is "the next big thing" in the world of information technology, because IoT offers a lot of potential that can be explored [4] [5].

IoT architecture according to Shivangi Vashi et al. [6], is divided into 5 main layers namely: (1) Perception layer; (2) Network layer; (3) Middleware layer; (4) Application layer; (5) Business layer. Some characteristics of a system that uses the concept of IoT are Intelligence, Connectivity, Sensing, Safety and Energy. To establish connections and communication between things, sensors controlled by the microcontroller will send data to the microcontroller and then the microcontroller will send the data to the internet so that it can be accessed by anyone in anywhere [7] [8] [9]. The basic concept of IoT can be illustrated as in Figure 1. A "thing" can be interconnected with both "person" and other "things" using...
the internet network. Data communication between "things" can occur anywhere, anytime, and under any conditions. More broadly, the connectivity and data communication between these "things" will be able to be used to support services and any business.

Figure 1. Basic Concept of IoT

The concept of IoT has been used in various sectors of life, for example: smart health, energy with smart grids, management and urban planning with smart cities, housing with smart homes, education with smart classes, and so on. Therefore, IoT must start to be included in the curriculum of primary, secondary and higher education. However, due to the wide scope of this IoT, IoT learning needs a strategy and a level of material depth that is appropriate to the level of education. Specifically at the level of higher education, IoT learning can be a variety of ways and strategies including: (1) IoT as part of the course, (2) IoT as a course; (3) IoT can be a scientific concentration; (4) IoT as a study program.

Meanwhile, in the Department of Electrical Engineering Yogyakarta State University, IoT learning is still limited as part of a course. IoT is given in 2 or 3 meetings to complement material such as in Interfacing, Data Control and Acquisition, and Technology Innovation. IoT learning in JPTE has actually been implemented but the learning modules related to IoT, especially on internet connection material via Wi-Fi (hotspot) are still very minimal. Therefore it is necessary to develop and also test the feasibility of two types of learning media for IoT laboratory work (lab work); one developed using an Arduino microcontroller equipped with ESP8266 Wi-Fi module and the other using NodeMCU.

Because this IoT will be part of a course, Lite-IoT is used, i.e. several layers in its implementation are combined into one as in the Blynk application. The Blynk application is actually a middleware application, but Blynk also combines the middleware layer with the application layer (and also some network layers). The use of the Blynk application to support the development of a product / system with an IoT concept will be more efficient in the manufacturing process.

Blynk is a mobile application that can be installed both on Android and IOS. The Blynk application is specifically designed to support the development of IoT technology-based projects. For Android users, the Blynk application can be downloaded via Google play. While for IOS users, Blynk can be downloaded at the App Store. This special application to support IoT simplifies the project development process because it includes applications in the middleware layer. Blynk supports a variety of hardware that can be used for IoT projects. Blynk is a digital dashboard with graphical interface facilities in making its projects. Adding components to Blynk Apps by means of Drag and Drop making it easier to
add Input / output components without the need for Android or iOS programming capabilities. Blynk was created with the aim of remote hardware control and monitoring using internet data communication or intranet (LAN network). The ability to store data and display data visually using numbers, colors or graphics makes it easier to create projects in the field of the Internet of Things.

ThingSpeak is an open source platform Internet of Things (IoT) application that provides API features for storing and retrieving data using HTTP protocol over the Internet or through the Local Area Network. ThingSpeak allows the creation of sensor logging applications, location tracking applications, and social networks with status updates. ThingSpeak was originally launched by ioBridge in 2010 as a service to support the IoT application. ThingSpeak has been integrated with numerical computing support from MATLAB MathWorks. This allows ThingSpeak users to analyze and visualize data uploaded using MATLAB without requiring the purchase of a MATLAB license from MathWorks. The use of ThingSpeak can be free (but there is a delay of about 15 seconds between the read and write data) or even paid.

App Inventor will be used to build an application that will access data on ThingSpeak. App Inventor is a software system for creating applications on android devices online, making applications created with graphical visual interaction instead of using lines of program code. The programmer's interaction with MIT App Inventor is almost completely through a visual interface with drag and drop operations. The programmer only needs to specify the behavior of the application you want to create by arranging the appropriate blocks. One of the advantages of MIT App Inventor is that it can be accessed via the web on an online browser (http://ai2.appinventor.mit.edu), thus there is no need to install the MIT App Inventor software on a computer.

The hardware used for the development of this learning module is Arduino Uno, Wi-Fi module ESP8266-01 (version 1) and NodeMCU. Wi-Fi Module ESP8266-01 is a Wi-Fi module that is commonly used by microcontrollers (usually Arduino) to communicate (make connections) with the internet. Physically, ESP8266 differs from other components, because its power supply needs exactly voltage +3.3V (not more or less). There are many versions of the ESP8266 module from version 01 to version 12. Using the ESP8266-01 Wi-Fi module on the IoT system is quite complex because it requires several wiring techniques and sometimes resetting the firmware and baud rate speed is needed.

NodeMCU is a development board (development board) in which the ESP8266 Wi-Fi device is also integrated to make connections with the internet via Wi-Fi hotspot. NodeMCU is a System on Chip (SoC) hardware system based on ESP-12 modules. This device features a 4MByte flash memory capacity, 80MHz system clock, around 50K for usable RAM and an on-chip Wi-Fi Transceiver. NodeMCU can be analogous to the ESP8266 Arduino board. The NodeMCU programmer only requires the same USB data cable extension as an Android smartphone data cable. Because NodeMCU is Arduino-like, for NodeMCU programming it can be used by Arduino-IDE.

2. Module Development Method
This IoT learning module was developed using the steps of the Analyze, Design, Develop, Implement and Evaluation steps [11] [12]. The philosophy of developing this learning module must be student centered, innovative, authentic and inspiring. Analysis is related to the analysis of the situation and the environment, so that it can be determined what products will be developed. Design is a product design activity in accordance with what is needed. Development is a product manufacturing and testing activity. Implementation is an activity using a product, and Evaluation activity evaluates whether every step that has been made is according to specifications.

3. Results and Discussion
3.1. Results of Analysis Phase
Includes the results of need assessment or needs analysis, literature study, syllabus observation or RPS. Need assessment is done by observing and evaluating the learning process of the Full Practice and Data Acquisition courses. The following are the results of evaluations and observations on the course of the practice of Control and Data Acquisition.
a. In the curriculum of S1 Mechatronics Engineering Education Study Program, this lab work course is a new subject in the Study Program. Mechatronics Engineering (PBM has only been carried out twice).

b. The content of this course is closely related to technological developments in the industrial revolution era 4.0, especially about the Internet of Things (IoT).

c. The enthusiasm of students when attending the introductory course is very enthusiastic, especially when given a brief theory about IoT and its application.

d. There needs to be learning about IoT and simple IoT practices in this course.

e. IoT learning is given not at the beginning of the lecture but after the students have completed their competence in control and data acquisition using a single board microcontroller.

f. Learning media for IoT lab work is still minimal and needs to be adjusted to suit the competency demands of the course.

g. This practical learning media designed as simple and as easy as possible for practice for students.

3.2. Results of the Design Stage

The design stage is divided into hardware design and software design. The hardware design prepares the hardware components that will be utilized such as NodeMCU, Wi-Fi module ESP8266-01, sensors and actuators etc. Software design is in the form of designing programs (codes) for Arduino and designing Android application which are all for developing the learning media in the classroom. Next, design a lab sheet and a brief handbook for supporting the IoT Lab work.

For the hardware module that based on NodeMCU, if using ThingSpeak then the design of the hardware module will realize the circuit with sensors, actuators, microcontroller (included the Wi-Fi module ESP8266), which can be depicted in Figure 2.

![Figure 2. Hardware Module Design Based on NodeMCU with ThingSpeak](image)

Data from the sensor will be acquired by NodeMCU, and then will be sent to the ThingSpeak database in the cloud. Everyone can access and view the data from these sensors, anywhere at any time as long as there is internet access using an Android smartphone. Android users can control actuators by sending a control data to ThingSpeak using their smartphone. Furthermore, the data will be read by NodeMCU via a hotspot Wi-Fi network, which will then be used to control the actuator. The Android application for reading from and writing to ThingSpeak is built using MIT App Inventor. Meanwhile, using the Blynk middleware application, the schema of the NodeMCU-based hardware module can be drawn as shown in Figure 3 below. Blynk will merge the programming in the middleware, application and partly at the network layer.
Meanwhile, for the design of the hardware module based on Arduino and ESP8266-01 with the ThingSpeak is as described in Figure 4. In principle it is same as the hardware module based on NodeMCU (Figure 2), only in this configuration there are a microcontroller and a separated Wi-Fi module.

The scheme for hardware modules based on Arduino and ESP8266 with the Blynk application is the same as the scheme in Figure 4, only for the NodeMCU component is replaced with the Arduino and ESP8266 Wi-Fi modules.

3.3. Results of the Development Stage

The development stage is a process to realize the design of both hardware and software that has been made in the previous stage. Along with the development of hardware modules, lab sheet modules and brief handbook were also compiled and developed.

This stage ends with testing the functionality of the developed product. Functionality testing is done by entering various kinds of input data and treatment variations in the process, and observing the output. For the hardware modules that are tested include: data acquisition testing from sensors by Arduino and
NodeMCU, actuator control test with Arduino and NodeMCU, data communication test between Arduino and Wi-Fi module ESP8266, data communication test between microcontroller and ThingSpeak, test data communication between ThingSpeak and Android, and test data communication between Android and a microcontroller via ThingSpeak, test connection and data communication between NodeMCU and ThingSpeak, test data communication between Android and NodeMCU via ThingSpeak, test the connection between Android and the Arduino using Blynk and test the connection between Android and NodeMCU using Blynk.

3.4. Results of the Implementation Stage
In this stage the results of the previous stage (development) that is the learning media products both hardware modules and the lab sheets and the brief handbook are used as teaching aids for teaching and learning process in an IoT lab work class. For this research we used the Data Control and Acquisition Lab work class in the Mechatronics Engineering Education Study Program, Yogyakarta State University. This class has participant 35 students. Next, there were 2 implementations: first implementing the Arduino and ESP8266-01 module and second implementing the NodeMCU module. Both are using ThingSpeak and Blynk application. For the first implementation (using Arduino and ESP8266-01 module with ThingSpeak), all students need more than 3 hours to accomplish all the jobs in the lab sheet.

For the second implementation, using NodeMCU and Blynk Application, the step by step of implementation is as follow. Beginning with distribute the lab sheets and the brief handbook modules to all students. The students are given 10 minutes to read and study the job sheets and the brief handbooks. During in such 10 minutes, the hardware components are distributed to each student. After all is ready, all the students start immediately to do one-by-one instructions in the lab sheet and the stopwatch starts. Once a student finishes all the instructions in the lab sheet, record the time spent of such student. Repeat recording the time spent for all students.

The result shows that from 35 students who took part in the lab work using this learning media, they had all passed. This means they can understand and practice 2-way communication between Blynk application and NodeMCU (sensor-actuators). Only 7 students out of 35 students took more than 1 hour to complete the lab sheet. So it can be resumed that in general students can complete the lab sheet in less than 1 hour. There are even students who only need 40 minutes to complete the entire lab sheet. When compared with Arduino and ESP8266-01, practicing the IoT using NodeMCU (especially with Blynk app) can be faster than using Arduino and ESP8266-01 with both ThingSpeak and Blynk.

3.5. Results of Evaluation Phase
After carrying out a series of research stages ranging from Analysis to Implementation, there are Evaluation results. For the general evaluation based on the questionnaire sheets written directly by all students, the following is a summary of the evaluation.

The material (meaning the basic theory of IoT) in the lab sheet is still lacking, it needs to be added related material in more detail. The codes in the lab sheet are still too difficult to understand and practice. For this problem, there has been a follow up by reviewing programs for both Arduino and NodeMCU. The code lines in the lab sheet need to be given an explanation in each line. The pictures and text in the handbook are still unclear. It needs to be attractive and more interesting. Explanation related to the MIT App Inventor programming need more detail. The IoT learning media in the form of hardware, software and learning modules, there are still some shortcomings, including the ThingSpeak middleware that is used which is still a free account so that there is around 15 second delay in each writing data to the field. The Blynk application still uses the standard (free) version so the features of the components are very limited. The output of this research, those are the hardware module for IoT lab work with ESP8266 and NodeMCU, a brief handbook and lab sheets still need to be updated and improved.
4. Feasibility Test and Discussion

At the implementation stage, after students finishing on the lab sheets and see the results, then students are given a questionnaire to assess this learning media. From the results of the questionnaire it can be analyzed for the feasibility of learning media in the form of the lab sheets, the brief handbook and the IoT lab work hardware module is as follows.

In this study used quantitative data analysis techniques. The assessment data obtained from students were analyzed descriptive qualitatively and used as a reference for revising the learning media products. Eventually it will produce a learning media that is feasible to use. The instructional media products are assessed by students using an assessment sheet. For the lab sheet module and the brief handbook, aspects of the assessment include: the appropriateness, completeness and suitability of the material in supporting IoT competencies, ease in understanding the module, appropriateness of the lab work questions. Then for the IoT lab work hardware module the evaluation aspects include: suitability, appropriateness and completeness of the material with the competencies required in the syllabus especially those related to IoT, ease of compiling and programming, and its attractiveness.

The results of the assessment of these aspects are measured on a Likert scale. Likert scale is a number of statements both positive and negative about an attitude object. The main principle of the Likert scale is to determine the position of a person's attitude in a continuum of attitudes towards the object of attitudes ranging from very negative to very positive [13].

In this study, the answer items for each instrument statement were classified into 5 choices. Each indicator measured is given a score with a scale range from 1 up to 5. A score of 5 means very agree / very appropriate / very appropriate / very good. A score of 4 means agree / feasible / appropriate / good. A score of 3 means quite agree / quite feasible / Quite appropriate / good enough. A score of 2 means less agree / less suitable / less appropriate / less good, and a score of 1 means disagree / not appropriate / not appropriate / not good.

The next step is to assess or test the feasibility of the learning media. The way to do this is by implementing the learning media in a class attended by 35 students. After implementing the learning media, all students fulfill the questionnaire (instruments of the feasibility test). Next the data is obtained, and to determine the weight of each response and calculate the average score using the following formula:

\[
\overline{x} = \frac{\sum x}{n}
\]

Where:
\( \overline{x} \) : the average score
\( n \) : number of respondents
\( \sum x \) : each total score

The percentages were calculated with the following formula:

\[
Result = \frac{Score}{Maximum\ Score} \times 100\%
\]

According to Arikunto S. [14], as quoted by Ernawati [15], the feasibility category is based on the following criteria:
Tabel 1. Feasibility Criteria of Media

| No. | Score in percent (%) | Eligibility Category    |
|-----|-----------------------|-------------------------|
| 1   | <21%                  | Very Poor (VP)          |
| 2   | 21-40%                | Poor (P)                |
| 3   | 41-60%                | Acceptable (A)          |
| 4   | 61-80%                | Good (G)                |
| 5   | 81-100%               | Very Good (VG)          |

4.1. Feasibility Testing of the IoT Hardware Lab Work Module

From the total of 21 statements in the questionnaire provided for the respondents (students), the statements that were subsequently identified were related to the feasibility test for the lab sheet and the manual book. The following statements are related to this: P6, P8, P9, P10, P11, P12, P13, P14, P18, P19, P20 and P21, there are 12 statements in total. The distribution of the answers from 35 respondents is presented in the following table.

| Table 2. Results Assessment Questionnaire of the Hardware Module |
|---------------------------------------------------------------|
| No   | Statement | VP | P | A | G | VG | Sum |
|------|-----------|----|---|---|---|----|-----|
| 1    | P6        |    | 2 | 22| 11|    | 35  |
| 2    | P8        |    | 1 | 22| 12|    | 35  |
| 3    | P9        |    | 3 | 14| 18|    | 35  |
| 4    | P10       |    | 4 | 16| 15|    | 35  |
| 5    | P11       |    | 1 | 19| 15|    | 35  |
| 6    | P12       |    | 5 | 15| 15|    | 35  |
| 7    | P13       |    | 1 | 19| 15|    | 35  |
| 8    | P14       |    | 4 | 17| 14|    | 35  |
| 9    | P18       |    | 2 | 13| 20|    | 35  |
| 10   | P19       |    | 3 | 18| 14|    | 35  |
| 11   | P20       |    | 1 | 15| 19|    | 35  |
| 12   | P21       |    | 1 | 18| 16|    | 35  |

Sum 0 0 28 208 184 420

Table 1 show that all statement items are dominated by the answers of "Good" and "Very Good". There is not a statement item responded with "Very Poor" or "Poor". Then, if it was analyzed using the statistical formula, the calculation is as follows:

Number of statement items = 12 items
Maximum score = 5 x number of statements x number of respondents
= 5 x 12 x 35
= 2100

Results (percentage of feasibility) = \frac{1836}{2100} x 100\%
= 87.4\%

Based on the criteria table, the results were categorized as very feasible.
From the feasibility testing process, several points can be obtained as follows:

a. The materials in the manual book and the lab sheet are in accordance with the Semester Lesson Plan of the subject of KAD.

b. The manual book and the lab sheet were practical and easy to understand.

c. The module for the IoT hardware lab work was particularly in accordance with the competency demands in the subject of KAD lab works.

d. The module is user friendly because the manual book and the lab sheet are provided.

e. The learning media are generally interesting and highly motivating students' learning.

f. The learning media is appropriate to support learning process, especially in the KAD lab works.

4.2. Feasibility testing of the Lab sheets and the Manual Book

From a total of 21 statements in the questionnaire addressed to the respondents (students), the statements that were subsequently identified were related to the feasibility test of the lab sheet and the manual book. The following statements are related to this matter: P1, P2, P3, P4, P5, P7, P15, P16, P17 and P21. The distribution of the answers from 35 respondents is presented in the table 3.

| No | Statements | Disagree | Not Agree | Quite Agree | Agree | Strongly Agree | Total Number |
|----|------------|----------|-----------|-------------|-------|----------------|--------------|
| 1  | P1         | 2        | 17        | 16          | 35    |                |              |
| 2  | P2         | 1        | 22        | 12          | 35    |                |              |
| 3  | P3         | 1        | 25        | 9           | 35    |                |              |
| 4  | P4         | 2        | 17        | 16          | 35    |                |              |
| 5  | P5         | 2        | 20        | 13          | 35    |                |              |
| 6  | P7         | 1        | 24        | 10          | 35    |                |              |
| 7  | P15        | 2        | 28        | 5           | 35    |                |              |
| 8  | P16        | 2        | 16        | 17          | 35    |                |              |
| 9  | P17        | 1        | 14        | 20          | 35    |                |              |
| 10 | P21        | 1        | 18        | 16          | 35    |                |              |
|    | Total      | 0        | 14        | 201         | 134   | 350            |              |
|    | total score| 0        | 2         | 42          | 804   | 670            | 1518         |

Table 3 indicates that all of statement items were dominated by the answers "Agree" and "Strongly Agree". There is only one statement item that was responded by a student with "Disagrees”, namely in the statement of "Examples of programs in the lab sheets are easy to understand and practical". However, in general students answered agree and strongly agree. Then, if it was analyzed using the statistical formula, the calculation is as follows:

Number of statement items = 10 items

Maximum score = 5 x number of statements x number of respondents
= 5 x 10 x 35
= 1750

Results (percentage of feasibility) = \( \frac{1518}{1750} \times 100\% \)
= 86.7%

Based on the criteria Table 3, the results were categorized as very feasible.
5. References

[1] Somayya M., et al. 2015. *Internet of Things (IoT): A Literature Review*. Journal of Computer and Communications, 3, 164-173

[2] Tutorialspoint. 2016. *Internet of Things, Simple Easy Learning*. Tutorials Point (I) Pvt.Ltd.

[3] Huansheng Ning. 2013. *Unit and Ubiquitous Internet of Things*. CRC Press Taylor & Francis Group

[4] Zeinab Kamal, et al. 2017. *Internet of Things Applications*, Challenges and Related Future Technologies. World Scientific News.

[5] Shivangi Vashi et al. 2017. *Internet of Things: A Vision, Architectural Elements and Security Issues*. International Conference on I-SMAC, 2017.

[6] M. Athar & R. Asnawi. 2017. *Monitoring Kecepatan dan Arah Angin Pada Pembangkit Listrik Tenaga Bayu dengan Konsep Internet of Things*. Seminar Nasional Pendidikan Teknik Elektro X.

[7] M. Athar & R. Asnawi. 2017. *Monitoring Kecepatan dan Arah Angin Pada Pembangkit Listrik Tenaga Bayu dengan Konsep Internet of Things*. Seminar Nasional Pendidikan Teknik Elektro X.

[8] Salsabillan Ulfa Tian & R. Asnawi. 2017. *Prototipe Sistem Monitoring Parameter Pembangkit Listrik Tenaga Surya Berbasis Internet of Things*. Proyek Akhir Program Studi Teknik Elektro, Jurusan Pendidikan Teknik Elektro, FT UNY

[9] Ardis Bany Sutrisno & R. Asnawi, 2017. *Monitoring Parameter Pembangkit Listrik Tenaga Surya Dengan Pendekatan Konsep Internet Of Things*. Proyek Akhir Prodi Teknik Elektro, JPTE FT UNY.

[10] ---------. *What is Arduino?*. Diakses dari https://store.arduino.cc/usa/arduino-uno-rev3 pada 15 Januari 2019

[11] Sugiyono 2010 *Metode Penelitian Kuantitatif, Kualitatif dan R&D*. Bandung: CV. Alfabeta

[12] Wagiran 2013 *Metodologi Penelitian Pendidikan (Teori dan Implementasi)* Deepublish Yogyakarta

[13] Arikunto S, Safrudin AJ 2009 *Evaluasi Program Pendidikan Bumi Aksara Jakarta*

[14] Ernawati I, Sukardiyono T 2017 *Uji Kelayakan Media Pembelajaran Interaktif Pada Mata Pelajaran Administrasi Server* Elinvo (Electronics, Informatics and Vocational Education, Volume 2, Nomor 2, November 2017, Yogyakarta