Comparative Analysis of Learning-by-Doing in the Development of an Internet of Things Intelligent Parking System Between Those Carried out Individually and Collectively

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Abstract **–The Internet of Things (IoT) has become necessary in higher education, so unsurprisingly, IoT learning research has received significant attention from academic researchers. In the meantime, classroom education is essential for facilitating learning by doing things such as engineering lessons. The question remains: what about the learning outcomes of IoT development and the impact on student learning by doing? This research reveals it; therefore, this study aims to compare the effects of students' learning by doing in building an IoT-based automatic intelligent parking system carried out individually and collectively. The research of this study is a combination of experiment and survey methods. The research results show that students who learn collectively by building IoT intelligent parking systems are more successful than students who learn individually. Meanwhile, regarding the level of satisfaction with learning by doing, no differences were found between students who studied individually and collectively.**

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1. Introduction

Rapid technological advances have influenced institutions to follow the flow of change by changing the approach to technology-based teaching and learning methods [1]. As a result, the relationship between education and technological progress has received attention in learning practice and research [1]. In the meantime, IoT technology has demanded the need to make it happen in educational activities properly [2]. IoT technology is increasing in all fields for accurate and real-time control [3], [4]. IoT technology has intelligent systems that are the focus of attention in various areas of science, including education [5], [6], [7].

Another advantage of IoT technology is that it works with other technologies to make effective and efficient systems. So, IoT technology has positioned itself as revolutionary advanced information technology [8]. Furthermore, IoT technology makes it possible to realize access from anywhere [4], [9] and is helpful in the processing management of the system [10]. Besides that, the use of IoT technology allows the availability of real-time information anywhere [11], [4].

In short, IoT currently has a vital position in information technology and societal development [12] and has become a primary ongoing need in higher education [13].

The crux is that the learning revolution follows technological advances known as seamless learning and involves student learning experiences through IoT technology [14].

According to [1], involving students in a group practice (participatory) and involving everyone in the group (inclusion) are more effective methods in the practice of implementing IoT technology. Moreover, according to Aldowah [12],

technology will impact students' learning experiences in many ways. Even though the advancement of IoT technology currently provides a broad research space in learning development, IoT-based research for education is still limited [15]. As a consequence, IoT-related research has received greater attention in academic research [13], [16], and researchers focus on internal experience and its effect on learning outcomes [17]. So that is why this research is related to IoT and focuses on learning by doing experience.

The skilled IoT workforce is currently gaining high job market momentum [18]. Consequently, IoT has become part of education and learning processes [19] and has become the focus of learning attention in various higher education institutions [18]. In the meantime, classroom education is essential for facilitating learning by doing things such as medical practice or engineering lessons [13]. So, it is unsurprising that practical knowledge by learning by doing has dominated in the last year [20].

However, even though previous researchers stated the skills acquired through practical experience as an integral part of the profession [21], [22], learning by doing remains a challenge [23]. Further research is required on the impact of practical education on theoretical knowledge [23]. The remaining question is: how about the learning outcomes of IoT development and the impact on students learning by doing? This research will reveal it; therefore, this study aims to determine the effect of IoT practical education on the development of automatic parking systems.

Vehicle parking has become an increasing problem [24], [25]. It happens, among other things, due to the weakness of the parking control system and the rising number of vehicles daily [24]. So, the problem that occurs is that it is challenging for parking users to find an empty parking space in the parking area where they can park their vehicles. This happens because there is no information on the availability of an open parking space unless the user searches for it manually. The result is increased fuel consumption [26] and waste of time.

The solution is the need for a parking system that can overcome the problem of parking difficulties for drivers [25], [27], [28] and keeping in mind that the traditional parking system has not been able to overcome it because it is a routine matter for drivers to face difficulties finding an empty parking slot [29].

Moreover, the traditional parking system relies more on human intervention in parking lots [29].

According to Zhang *et al.* [25], intelligent automatic parking systems can help solve parking problems. In the meantime, according to [29], using IoT technology helps build intelligent parking systems and solve parking problems [29]. So, it is the reason why this study is learning by doing an IoT technology-based automatic intelligent parking system.

The automated parking system developed in this research can guide the user to parking in empty parking slots and barriers to enter/exit the parking area, which can open and close automatically when the vehicle enters/exits the parking area. The automatic parking system designed in this study uses a microcontroller that works together with several sensors and other auxiliary devices to realize the desired parking system control. Although there have been several previous studies related to automatic parking systems, such as work by [25], [27], [29], and [30], none of which has the aim or object of research to investigate the education outcomes of learning by doing collectively in building an IoT-based automated parking system. Likewise, with previous research related to the use of IoT technology, including research conducted by [1], [13], [19], [31], and [32], none of the previous research was a combination of research development (experiment) and survey researches whose research focus was related to learning by doing.

Apart from that, these earlier studies did not build a prototype of an intelligent parking automation system like the one carried out in this article. It means that research has strengths and novelties that have never been studied before. In short, this research article is novel and unique compared to previous articles. In addition, this research contributes essential knowledge to learning by doing outcomes in building IoT-based systems. Practically, this research has implications for determining whether learning by doing is feasible as an alternative learning model for students, including as a learning model for IoT-based intelligent systems; likewise, in revealing whether collective learning is superior in delivering learning by doing for students.

2. Related Works

The following is a brief review of a few recent scientific works related to the work in this research. L-Qozani and Aleryani [13] examined the future impact of technology IoT in education.

This previous research is a literature review research that is different not only in the object or research objectives but also in research methods with the research in the articles in this study, even though both discuss IoT technology in education. Meanwhile, Barriga *et al.* [31] identified the types of components and technologies likely to be used in intelligent parking systems. This previous research was a literature study and not an experimental research or survey on intelligent parking systems and did also not research into learning IoT technology as the research in this article.

Gupta and Rani [29] proposed an IoT-based parking system to realize parking management. However, this prior research suggests an intelligent parking system, but it is limited to indicating parking statuses, such as end users, use of parking slots, and unauthorized parking users. In contrast, the research in this article proposes a parking system that has intelligence in directing the driver of the vehicle to an empty parking slot in the parking area, in addition to the ability to control the opening (and closing) of the door shutters automatically when the vehicle enters (or exits) from the parking area.

Francisti *et al.* [19] examined the effect of students' concentration or attention level on learning outcomes using IoT technology equipment. This previous research showed the impact of learning outcomes on using IoT technology equipment. In contrast, this research article examined the practical learning outcomes of building intelligent automated systems using IoT technology. So, this previous research is different regarding research objectives and objects compared to the articles in this study, even though both are the same in researching learning outcomes related to IoT technology.

Zhang *et al.* [25] conducted research to produce an algorithm to get the shortest parking path in an automatic parking system. Previous research focused on building experimental algorithms to improve the performance of automated parking systems. In contrast, the research in this article makes hardware and software for IoT-based intelligent parking systems. So, the difference between the previous research and the research in this article lies in the research method, the objective (object), and the research results, even though both studies are related to automatic parking systems.

Fahim *et al.* [32] conducted a study comparing innovative parking systems based on technology, sensors, and user interfaces.

The objectives or objects and research methods of previous research differ from the research in this article.

The earlier study aims to compare various intelligent parking systems, while the research in this article builds an innovative parking system. The last research method was a literature review research, while the research in this article is experimental.

Mago *et al.* [27] proposed a system to increase the accuracy of an empty outdoor parking detection system with a saliency detection method and a segmented image hybrid feature extraction model. The similarities between the previous research and the research in this article are that both are experimental studies but have different objectives, even though the research objects are both related to vehicle parking systems. However, this previous research was not related to IoT. In addition, the research in this article improves the parking system's performance and determines learning outcomes in building an IoT-based intelligent automatic parking system.

In the meantime, Tuan *et al.* [2] conducted questionnaires and interviews with teachers and concluded that IoT technology learning is effective and contributes to building sustainable human resources in the future. The difference between this previous research and the research in this article is in the research object and also in the research method. Previous research was survey research to determine the benefits of teaching IoT technology. In contrast, the research in this article is experimental research to reveal the results of students' practical learning in building an IoT-based intelligent automated parking system. This previous research and the research in this article contribute to making future sustainable human resources.

Ghashim and Arshad [1] discussed in-depth IoT issues and problems from various approaches. This previous study examined the current issues of IoT technology and its use in education. Unlike the research in the article, this research is an experiment and survey research to determine the impact of learning by students applying IoT technology in building a prototype of an intelligent vehicle parking system.

Meanwhile, Jabbar *et al.* [30] introduced an example of an IoT-based intelligent parking management system to enrich the realization of a smart city through efficient parking management. Even though this previous research proposed an intelligent parking system model like the article in this work, the earlier study was unrelated to student learning. This prior research suggested a smart city model or a simulation example of a vehicle parking management system.

It was not related to learning about the application of IoT technology. In contrast, the article in this research focuses on student learning regarding the application of IoT technology by building an intelligent parking system.

A review of related works shows that the research in this article is different or has not been done by previous research, as seen in Table 1. In particular, learning by doing for students to build an IoT-based intelligent parking system is a new research side. Apart from that, there has been no research on individual and collective IoT learning by doing for students.

In addition, no previous study has built an intelligent parking system that automatically opens and closes the parking gate when a vehicle is about to enter or leave the parking area and gives directions to drivers to see which parking spaces are still empty.

Another specialty of this research is experimental research (namely, students' learning by doing in building an IoT-based parking system) and, at the same time, survey research (i.e., knowing the results of students' individual and collective learning-by-doing in building an IoT-based parking system).

Table 1. Comparison between the latest prior related works and this (our) article

Research by	**Research Method**	**Build Control System**			**Using controller or controller type**	**Develop computer applications or algorithm**	**Using the learning-by-doing approach or method**	**IoT Technology for Learning**	**Develop a vehicle parking system**	**Description**
		IoT	**Sensor**							
			Infrared	**Ultrasonic**						
L-Qozani and Aleryani (2018)	Literature Review	No	No	No	None	No	No	No	No	Reviewing the influence of IoT technology on the future of education.
Barriga *et al*., (2019)	Literature Review	No	No	No	None	No	No	No	No	Reviewing electronic hardware and types of sensors used in developing intelligent parking systems
Gupta and Rani (2020)	Experiment	No	Yes	No	Raspberry Pi 3	Yes	No	No	Yes	Proposing IoT-based parking system management for cost and time efficiency.
Francisti *et al*., (2020)	Experiment	No	No	No	None	No	No	Yes	No	Describing the impact of attention on student learning outcomes using IoT technology
Zhang *et al*, (2021)		No	No	No	None	Yes	No	No	No	Provides a strategy to obtain the shortest parking path for an automatic parking system based on a two-way search algorithm and the Bellman-Ford algorithm.
Fahim *et al*, (2021)	Literature Review	No	No	No	None	No	No	No	No	Reviewing the technology, sensors and interfaces used in realizing smart parking systems from existing research
Mago *et al*, (2022)	Experiment	No	No	No	None	No	No	No	No	Proposes using advanced Sanitation detection and efficient feature extraction to detect outdoor empty parking spaces.
Tuan *et al*, (2022)	Questionnaires and Interviews	No	No	No	None	No	No	No	No	Conduct research about the contribution and effectiveness of IoT technology learning in building human resources in the future
Ghashim and Arshad (2023)	Literature Review	No	No	No	None	No	No	No	No	Reviewing issues related to IoT and its application to education
Jabbar, Tiew, and Ali Shah (2024)	Design system	Yes	No	Yes	Arduino UNO	No	No	No	Yes	Proposing a simulation or model of an IoT-based smart parking management system
This (our) research	Experiment and Survey	Yes	Yes	Yes	ESP8266	Yes	Yes	Yes	Yes	Building an IoT-based intelligent parking system and researching the impact of learning by doing collectively by students

3. Research Method

This research is a combination of experimental and survey methods. In this research design, students learn by doing and reflecting on the experience of building an IoT-based innovative parking system under the guidance of a lecturer and two laboratory assistants. Lecturers and students jointly define and decide on an IoT-based intelligent parking system being built. Then, students learn to construct IoT-based innovative parking system hardware and software in their respective groups, for students who learn by doing collectively and for students who learn by doing individually. The students who carried out learning by doing in this research were 60 students from the Bachelor of Information Technology study program at Bumigora University, Indonesia, in semester 5 of the 2022/23 academic year.

The learning process carried out by students, who learn by doing collectively, is divided into six groups of students, each consisting of 5 students. Learning by doing takes place in 8 meetings, both for 30 students who learn while doing collectively and 30 students who learn independently. Each learning-by-doing meeting is worth three semester credits (or 150 minutes per weekly meeting). This study uses the PHP and C programming languages to build an IoT-based intelligent parking system application program. The PHP programming language helps realize Web-based applications [33], [34].

Meanwhile, the C programming language helps control the work of microcontrollers, sensors, servo motors, and other equipment from the system being built. The microcontroller used in this research is ESP8266. The ESP8266 microcontroller facilitates the implementation of IoT-based equipment control and has memory and digital and analog input and output ports [4]. Figure 1 shows the stages of learning research to build an IoT-based intelligent parking system in this study.

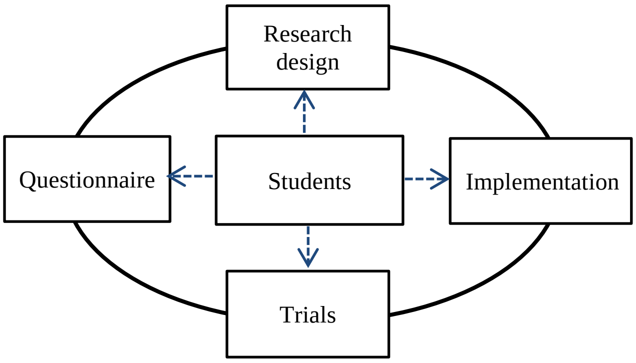


Figure 1. Stages of student learning in building an IoT-based intelligent parking system

4. Result and Discussion

Learning by doing to build an IoT-based intelligent parking system with the ESP8266 microcontroller consists of process stages: research design, implementation, trials, and questionnaires. Hardware and software block diagrams are designed at the research design stage, and all the necessary components or supporting devices are prepared. In contrast, the implementation stage is designing hardware electronic circuits, assembling breadboard circuits, and making control software. Meanwhile, the trial phase is the stage of testing the hardware and software of the developed intelligent parking system. The next stage is the questionnaire stage, which is essentially the stage to determine the achievement level of student learning.

4.1. Research Design

Figure 2 shows the block diagram of the developed intelligent parking system hardware. Meanwhile, Figure 3 depicts a software block diagram for work control of the developed intelligent parking system.

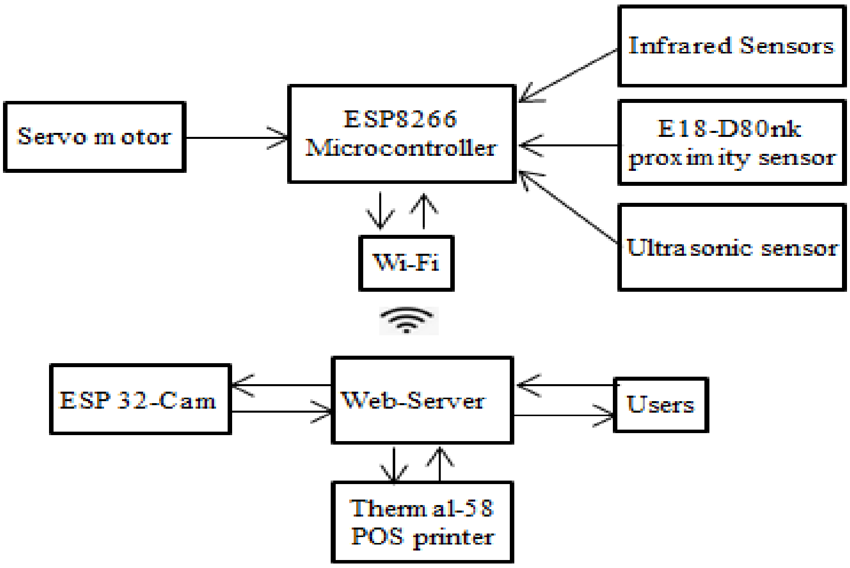


Figure 2. System hardware block diagram

Figure 4 shows a web-based program block diagram when the vehicle exits the parking slot and parking area. The developed intelligent parking system hardware is connected to a web server system (personal computer) that functions as web monitoring when the smart parking system starts working. The designed software ensures the parking hardware system is connected via Wi-Fi to the web server. After that, the E18-D80nk infrared sensor will detect the presence or absence of a car or hand object on the sensor requesting a parking slot. When the E18-D80nk sensor detects an object (at a distance of less than or equal to 80cm), the system will automatically show available parking slots.

Conversely, if the parking slot is unavailable, there will be a notification that the parking lot is full. When a parking slot is available, the ESP32 camera will take an image of the vehicle object and then print the parking receipt. After that, the door shutter will open until the ultrasonic sensor detects that there is no vehicle object. When the vehicle is parked in an empty slot or parking space, the infrared sensor indicates to the web server that the parking slot is used, and the web server updates the status of the available parking slots.

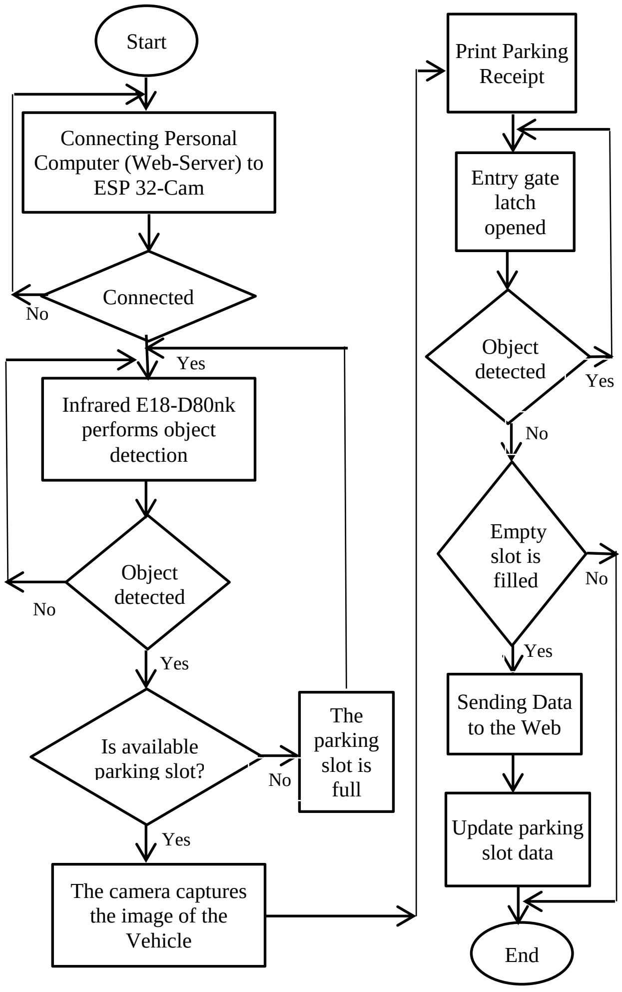


Figure 3. Web-based application program block diagram when the vehicle enters the parking area

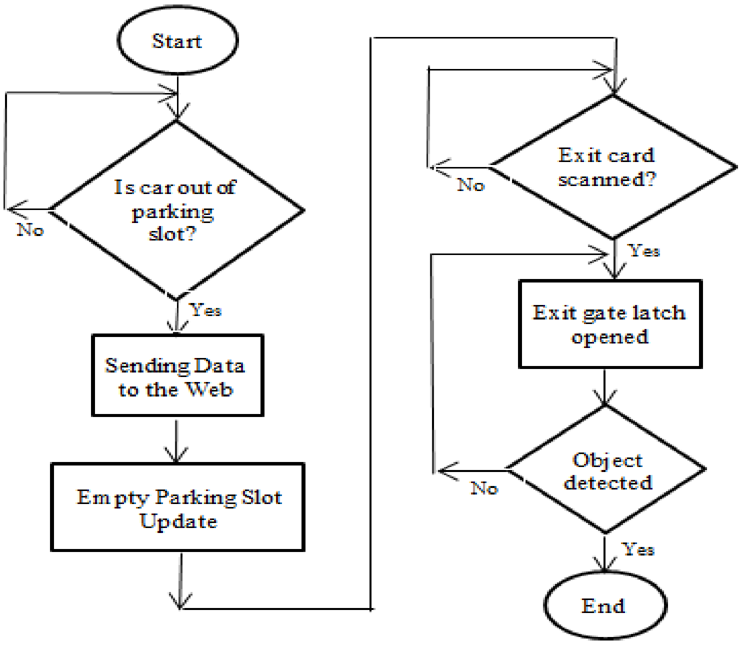
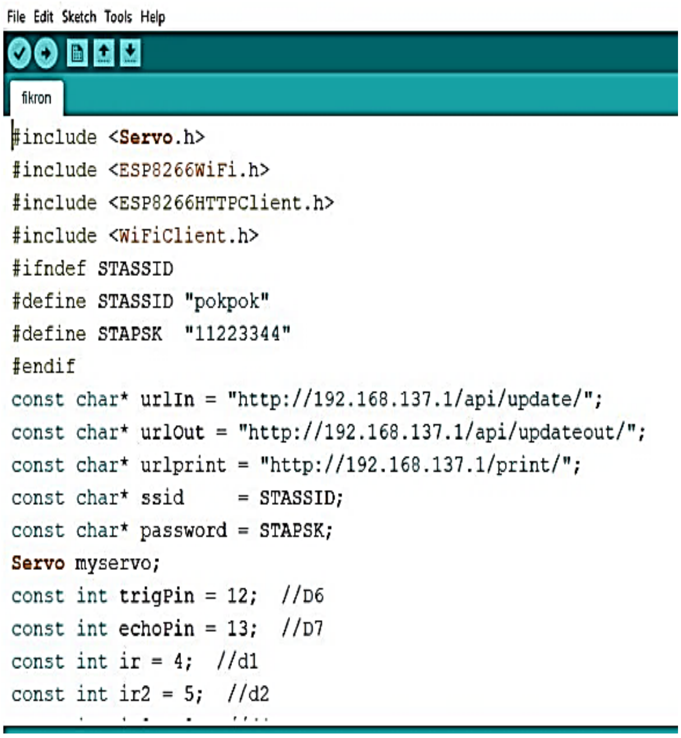


Figure 4. Web-based application block diagram when the vehicle exits the parking slot and parking area

4.2. Research Implementation

This stage determines the system's hardware and software requirements and designs the system hardware circuit diagram. Figure 5 shows part of the clever parking system program coding on the Arduino IDE. Tables 2 and 3 show the software and hardware needed to develop an intelligent parking system.

The overall program coding of the intelligent parking system program is available in the file (Smart Parking Coding.docx) at the link https://shorturl.at/bfHMR. Meanwhile, Figure 6 shows the realization of an intelligent parking system of hardware circuit board scheme and program codes in this study.



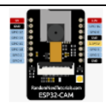

```
#include <Servo.h>
#include <ESP8266WiFi.h>
#include <ESP8266HTTPClient.h>
#include <WiFiClient.h>
#ifndef STASSID
#define STASSID "pokpok"
#define STAPSK  "11223344"
#endif
const char* urlIn = "http://192.168.137.1/api/update/";
const char* urlOut = "http://192.168.137.1/api/updateout/";
const char* urlprint = "http://192.168.137.1/print/";
const char* ssid     = STASSID;
const char* password = STAPSK;
Servo myservo;
const int trigPin = 12;  //D6
const int echoPin = 13;  //D7
const int ir = 4;  //d1
const int ir2 = 5;  //d2
```

Figure 5. Program Coding on Arduino IDE

Table 2. Required software

Software	*Function*
Arduino IDE software	This software acts as a media (auxiliary program) for writing source programs, compiling, and uploading intelligent application programs developed to the microcontroller board.
PHP and C computer languages	This computer language plays a role in developing application programs to manage and control hardware work so that the intelligent parking system works as designed.

Table 3. Hardware requirements

Device	*Amount*	*Specification*	*Function*	*Image*
Microcontroller ESP8266	1	Low-cost Wi-Fi microchip, with built-in TCP/IP networking, Processor: L106 32-bit, 17 GPIO pins, 10-bit ADC, Voltage +3.3 V	This microcontroller device is a supporting hardware work controller that realizes functions according to the developed control application program.	
HC-SR04 ultrasonic sensor	1	Working Voltage: +5V, Measurement Range: 2cm – 400cm; I/O Pins: 4, Operating Current: 15 mA	Serves to detect the object of a vehicle passing/stopping in front of it (as a proximity sensor with a measuring distance of 2cm – 400cm)	
E18D80NK sensor	1	Working Voltage: +5V, Sensing Range: 3cm – 80cm, Current consumption : > 25mA (min) ~ 100mA (max) , I/O pin: 3, Environment temperature: -25 °C ~ 55 °C	Proximity Sensor/Switch E18-D80NK functions as an infrared sensor with a long detection distance and is immune to interference from light bulbs or the sun. This sensor can beset the detection distance according to application needs.	
IR sensor		Working Voltage: 3V – 5V, Sensing Range: 2 – 80 cm	Play a role in wireless remote control and sensing applications with the infrared electromagnetic spectrum.	
Servo motor	1	Micro Servo Sg90, Operating Voltage: 4,8 V – 6 V, Weight: 9gram, Speed: 0.12 S/60 degree	The Servo motor plays a role in opening the gate.	
2-Cam	1	Low-cost ESP32-based development board with low-cost ESP32-based development board, equipped with Wi-Fi 802.11b/g/n/e/i and Bluetooth 4.2 standards	Serves to record/take pictures of vehicles.	
Thermal-58 POS printer	1	Max paper size: 58mm, support barcode printing, operating system: Android, IOS, Windows, Linux, Interface type: USB + wireless, print speed:70mm/s, thermal roll paper	Plays a role in printing parking receipts	

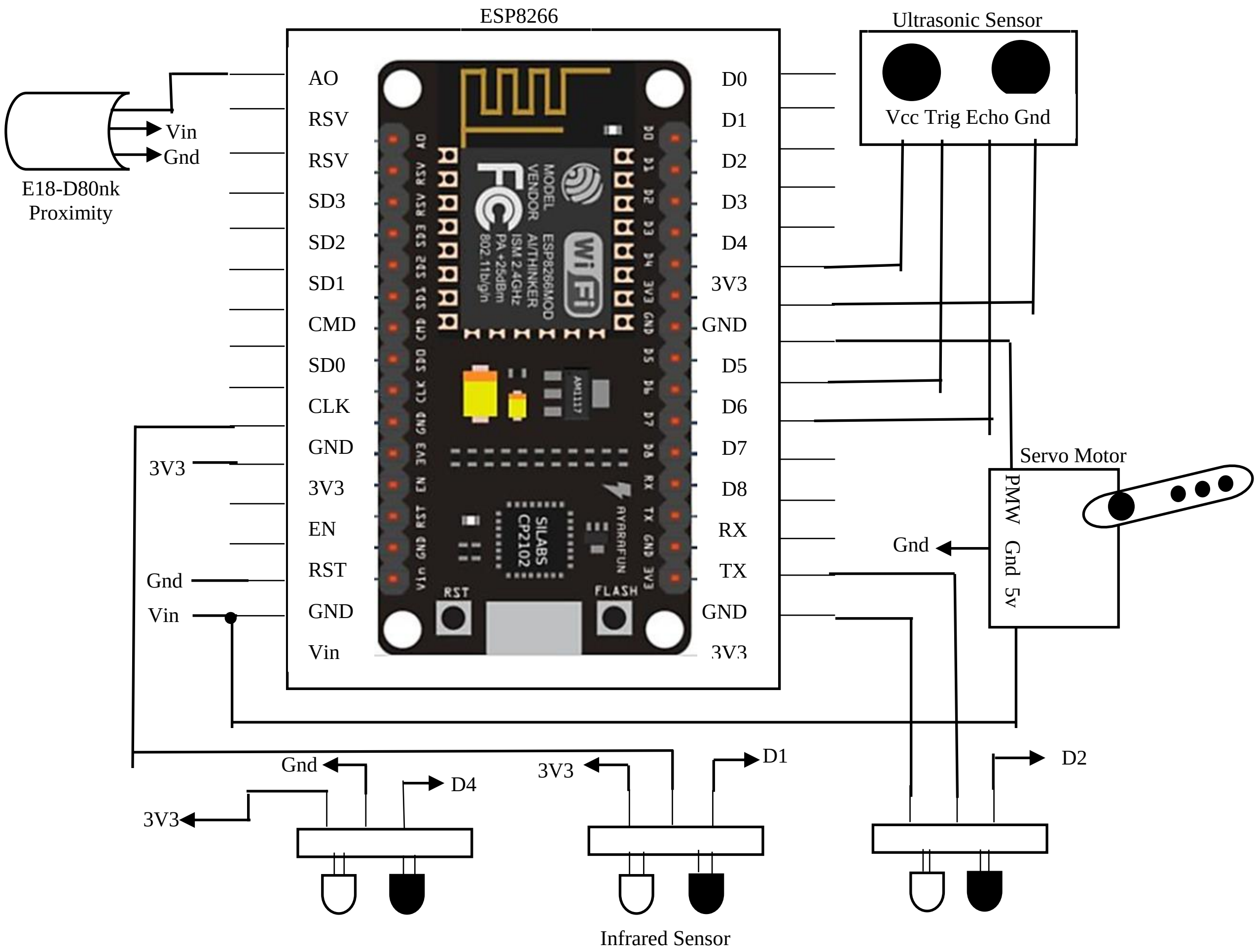


Figure 6. Hardware circuit board schematic

4.3. Trial

This section discusses testing the hardware and software of an automated vehicle parking system built to work according to design.

4.3.1. Ultrasonic Sensor Trial

Testing of the ultrasonic sensor (HC-SR04) includes whether the detector functions to detect vehicles that pass or stop in front of the sensor and also measures the correctness of the distance measured on the sensor system to the actual distance from the object to the sensor.

The test results show that the ultrasonic sensor successfully detects the object in front of it with 100% success at the sensor and object distance between 10 cm to 300 cm (Table 4) and with an accuracy of measuring the vehicle object distance up to 89%.

Measuring the accuracy of vehicle distances is done by comparing the sensor measurement results on the Node MCU serial monitor with the actual vehicle distance to the sensor with a standard measuring instrument. In addition, testing the accuracy of measuring the length of the ultrasonic sensor was carried out 30 times. Calculation of the accuracy of the sensor measurement results is using equations 1 and 2

Table 4. Testing the accuracy of ultrasonic sensor distance measurements

Trial	*The actual distance with a distance*	*Result of distance measurement from sensor*	*Difference in distance measurement*	*Error*
	In cm			*In %*
1	10	13	3	30
2	20	25	5	25
3	30	28	2	7
4	40	45	5	13
5	50	56	6	12
6	60	65	5	8
……	……	……	……	……
28	280	275	5	2
29	290	305	15	5
30	300	320	20	7

$$Error = \frac{\text{The difference in distance measurement x 100}}{\text{The actual distance}} \quad (1)$$

$$Sensor\ accuracy = 100\% - \text{Measurement error} \quad (2)$$

Servo motor trials were carried out to get the degree of movement of the servo motor to fit a specified angle or wanted. The accuracy of the servo motor in carrying out the degree of movement is 60.14% (Table 5).

4.3.2. Servo Motor Trial

Table 5. Servo motor trial results

Trial	*Angle instruction*	*Servo motor angle*	*Degree difference*	*Motor reaction*	*Accuracy (in %)*
1	30	20	10	Move	66.7
2	60	40	20	Move	66.7
3	90	50	40	Move	55.6
4	120	70	50	Move	58.3
5	150	80	70	Move	53.4

4.3.3. ESP32-Cam Trial

The ESP32-cam trial is an image-capture trial vehicle entering the parking area and storing it in the storage web server (Figure 7). A trial to test whether ESP32-cam works has made ten attempts and no errors occurred.

Figure 7. ESP32-cam trial and an example of an image captured by ESP32cam

4.3.4. Thermal-58 POS printer trial

This trial determines the results when the sensor detects a vehicle approaching and entering the parking area; then, the sensor successfully sends commands to the webserver to give the results of the available parking slot print. The trial results show that the sensor detects approaching vehicles entering the parking area and successfully sends commands to a web server to print available parking slots. Figure 8 shows an image of the POS 58 thermal printer.

Figure 8. Thermal-58 POS printer trial

4.3.5. E18D80NK Sensor Trial

Trials on the infrared proximity sensor E18-D80NK are to know whether the sensor can detect or fail to detect an object. If it succeeds in detecting objects in front of the sensor with a radius of 5 to 75 cm, then the light indicator will light up. The test results show that the sensor works well (Table 6).

Table 6. E18-D80NK Sensor trial Results

Trial	*Distance between object and sensor (in cm)*	*Object detected or not detected*
1	5	Detected
2	10	Detected
3	15	Detected
4	20	Detected
…	…	….
14	70	Detected
15	75	Detected

4.3.6. Infrared (IR) Sensor Trial

Infrared sensor testing ensures that the sensor can detect the presence of vehicles that have filled the parking slot. Testing is done by placing an object in front of the sensor. The sensor light will turn on, and if it does not detect an object in front of it, it will turn off.

The primary role of this infrared sensor is to provide instructions (using lights that turn on or off) to anyone that the parking slot is filled with vehicles or that the parking slot is still available (empty). The test results show that the infrared sensor works according to design or works well (Figure 9).

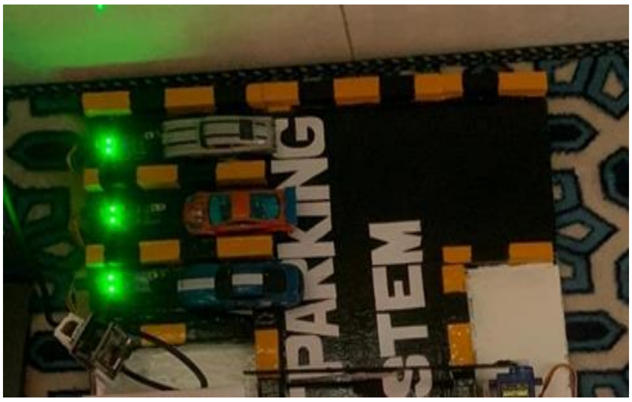


Figure 9. Infrared sensor trial

4.3.7. The Trial of the Whole System

In essence, the working principle of the entire intelligent parking system in this study is a combination of all the series of trials of various hardware systems that have been carried out. When the hardware system is enabled, the microcontroller initializes the sensors' input and output: ultrasonic, infrared, proximity, servo motors, esp32-cam, and thermal printers. The innovative system trial results in a parking run of 20 times to check if the system's hardware and web are running as desired or according to design.

4.3.8. Feasibility Test on Research Instruments Used to Collect Survey Data

This study conducted an instrument feasibility test that was used as a research data collection tool with the Pearson correlation test and Cronbach's alpha test. The results of testing the instrument on students' satisfaction in learning with Pearson correlation (Table 7) show that the instrument used has the correct validation, namely correlating items with a total score greater than 0.3. Meanwhile, the results of the instrument trials on students' satisfaction in learning-by-doing show that the instruments used have high enough reliability (Table 8) with a reliability coefficient or alpha correlation in the number 0.652.

Meanwhile, testing the reliability and validity of the instrument on the competency of student learning outcomes in learning using Pearson and Cronbach's alpha correlation (Tables 9 and 10) shows that the instrument used has high validation and reliability.

Table 7. Test results of student learning satisfaction instruments with Pearson correlation

		P1	P2	TotalP1P2
P1	Pearson Correlation	1	.486**	.846**
	Sig. (2-tailed)		.006	.000
	N	30	30	30
P2	Pearson Correlation	.486**	1	.877**
	Sig. (2-tailed)	.006		.000
	N	30	30	30
TotalP1P2	Pearson Correlation	.846**	.877**	1
	Sig. (2-tailed)	.000	.000	
	N	30	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Table 8. Instrument test results of student satisfaction with Cronbach's alpha

Cronbach's Alpha	N of Items
.652	2

Table 9. Instrument test results on the achievement of student learning competencies with Pearson correlation

		C1	C2	TotalC1C2
C1	Pearson Correlation	1	.545**	.883**
	Sig. (2-tailed)		.002	.000
	N	30	30	30
C2	Pearson Correlation	.545**	1	.875**
	Sig. (2-tailed)	.002		.000
	N	30	30	30
TotalC1C2	Pearson Correlation	.883**	.875**	1
	Sig. (2-tailed)	.000	.000	
	N	30	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Table 10. The results of the instrument test on student competence achievements with Cronbach's alpha

Cronbach's Alpha	N of Items
.652	2

4.4. Questionnaire

Questionnaires on students with quantitative ordinal data on each of the 30 samples of students studying individually and collectively using a Likert measurement scale show the results in Table 11, Table 12, Figure 10, and Figure 11. The learning-by-doing learning system provides satisfying learning for almost all students. It provides skilled and highly skilled learning outcomes for most students building an IoT intelligent parking system. As many as 33.3% were delighted, 46.7% were satisfied, 10% were quite happy, 10% were dissatisfied, and 0% were unhappy with learning by doing individually in building an IoT-based intelligent parking system. Besides that, there are as many as 46.7% very satisfied, 33.3% satisfied, 16.7% quite happy, 3.3% unsatisfied, and 0% (no one) are very dissatisfied with learning by doing in building an intelligent parking system collectively (Table 11 and Figure 10).

The findings of this study confirm that the application of learning by doing activities is a learning choice that can provide high satisfaction for students in education.

Regarding students' skills in learning by doing individually in building an IoT parking system, 13.3% are very proficient, 36.7% are proficient, 43.3% are moderately proficient, 6.7% are not experienced, and 0% are unskilled. Meanwhile, regarding the skills produced by learning by doing collectively in building an IoT intelligent parking system, 33.3% are very talented, 46.7% proficient, 20% are moderately professional, 0% are not experienced, and 0% are unskilled (Table 12 and Figure 11). The findings of this study ensure that the application of learning by doing activities provides learning outcomes with high proficiency, meaning that learning by doing can be an alternative to learning with unquestionable proficiency results.

Table 11. Students' satisfaction of learning by doing

Students. Perception	Student satisfaction in learning by doing in developing an IoT intelligent parking system			
	Individually		Collectively	
	In number	In %	In number	In %
Very satisfied	10	33.3	14	46.7
Satisfied	14	46.7	10	33.3
Quite satisfied	3	10	5	16.7
Not satisfied	3	10	1	3.3
Very dissatisfied	0	0	0	0

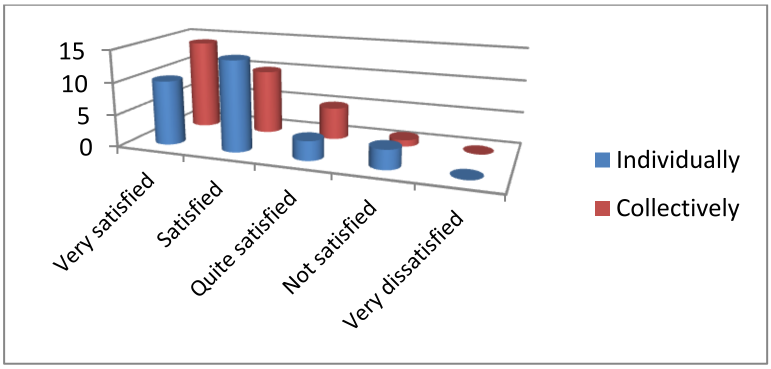


Figure 10. The level of student satisfaction in learning by doing in building an IoT-based intelligent parking system

Table 12. The level of student proficiency in building an IoT-based parking system with learning by doing

Students. Skill or Proficiency	Students' proficiency in learning by doing In building an IoT intelligent parking system			
	Individually		Collectively	
	in number	In %	in number	In %
Very proficiency	4	13.3	10	33.3
Proficiency	11	36.7	14	46.7
Quite proficiency	13	43.3	6	20
Not proficiency	2	6.7	0	0
Very not proficiency	0	0.	0	0

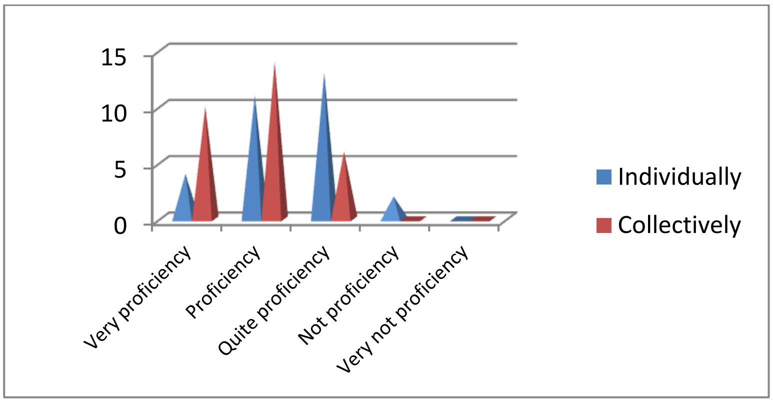


Figure 11. The level of student proficiency in building an IoT-based parking system with learning by doing

Due to the results of student skill levels and student satisfaction levels, learn collectively with a learning-by-doing approach in developing an IoT-based intelligent parking system with not proficient and very unskilled skill levels below 10% and also unsatisfied and very dissatisfied satisfaction levels not reaching 10% of all students who learn, it means that the finding of this study also strengthens the opinion of [1] that IoT learning is suitable to be carried out collectively (inclusively and participatory way).

Apart from that, the findings in this research prove that learning by doing provides learning success for students in learning to build IoT-based hardware control systems, and it is a novelty that has never been done by other researchers before. The implication is that learning by doing collectively in building IoT-based hardware systems can be an alternative learning model for students.

Table 13. Mann-Whitney test results to test the difference in learning satisfaction between those learning by learning by doing individually and collectively in building an IoT-based intelligent parking system

	LearningModel	N	Mean Rank	Sum of Ranks
Satisfaction	Individually	30	28.70	861.00
	Collectively	30	32.30	969.00
	Total	60		

	Satisfaction
Mann-Whitney U	396.000
Wilcoxon W	861.000
Z	-.856
Asymp. Sig. (2-tailed)	.392

The difference test with the Mann-Whitney statistical test shows that the significant level (2-tailed) comparison of satisfaction with the learning outcomes of learning by doing individually and collectively is 0.392 (Table 13) or greater than the probability value (alpha value) of 0.05. This means there is no difference in learning satisfaction between those learning by doing individually and those learning by doing collectively in building an IoT-based intelligent parking system.

Meanwhile, the difference test with the Mann-Whitney statistical test shows that the significant level (2-tailed) comparison of proficiency with the learning outcomes of learning by doing individually and collectively is 0.008 (Table 14) or lower than the probability value (alpha value) of 0.05. This means that there is a significant difference in learning skills between those who learn by doing individually and those who learn by doing collectively in building an IoT-based intelligent parking system, where, in this case, students who learn collectively by learning by doing are more successful than students who learn individually.

Table 14. Mann-Whitney test results to test the difference in learning proficiency between those learning by learning by doing individually and collectively in building an IoT-based intelligent parking system

	Learningtype	N	Mean Rank	Sum of Ranks
Skill	Individually	30	24.90	747.00
	Collectively	30	36.10	1083.00
	Total	60		

	Skill
Mann-Whitney U	282.000
Wilcoxon W	747.000
Z	-2.643
Asymp. Sig. (2-tailed)	.008

5. Conclusion

This research carried out learning by doing learning with satisfying and very satisfying results for most students learning to build IoT and intelligent parking systems. In addition, most students gain proficiency in building IoT-based and intelligent parking systems. This means that the learning-by-doing method can be a choice and can even replace learning models for students in practical educational technology learning.

Up to 30% of students are delighted, 33.3% of students are satisfied, 10% are pretty happy, 10% are not satisfied, and no one is very dissatisfied with learning by doing individually to build an IoT-based parking system. Meanwhile, 46.7% of students were delighted, 33.3% were satisfied, 16.7% were quite happy, 3.3% were dissatisfied, and 0% were very unhappy with learning by doing collectively to build an IoT-based parking system. The students' skills in learning by doing individually IoT-based innovative parking systems are 13.3% very proficient, 36.7% proficient, 43.3% moderately proficient, 6.7% not proficient, and 0% very unskilled in building IoT-based systems. Conversely, up to 33.3% of students are very talented, 46.7% are trained, 20% are pretty proficient, and the remaining students are not gifted, or 0% are unskilled in mastering learning by doing collectively in building an intelligent parking system. This research also reveals that there is no difference in the level of satisfaction between students who study learning by doing individually and students who study learning by doing collectively in developing an IoT-based intelligent parking system. Besides that, this research found a significant difference in the skills achieved by students between students who studied learning by doing individually compared to students who studied learning by doing collectively in developing an IoT-based intelligent parking system.

The novelty of this research is that previous researchers have never done this research. Another wonder is that this research proposes (testing) a learning-by-doing learning model for students learning IoT-based intelligent parking systems. Besides that, another novelty of this research is that it reveals that learning by doing carried out collectively has superior learning outcomes compared to the learning by doing learning technique carried out individually in developing an IoT-based intelligent parking system. In addition, the specialty or strength of this research work compared to previous similar research is to build a prototype of a smart parking system that opens and closes the parking gate automatically when a vehicle is about to enter or exit the parking area and provides directions to drivers whose parking spaces are still empty that previous related works have never made.

The drawback of this research is that students' learning by doing is limited to making prototypes of IoT-based intelligent parking systems and does not try out realities in the field except for built prototypes. In addition, the work is only limited to learning for students in making IoT-based systems and innovative parking systems without considering the durability of the hardware used, all of which serve as suggestions for further research.

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