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A Prototyping Tool of Free-Coding-Type Microcontroller Board for Design Education

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Abstract

As the scope of social expectations and roles in the design field has expanded, the demand for education to cope with changes in the technology environment is increasing in design education. In response to this trend, microcontroller board-type design-prototyping tools have also been introduced into design education, and much educational content is being developed. However, there is the perception that students who are majoring in design without engineering knowledge are still barred from entry. A variety of educational content and tools have been developed to solve these difficulties, although there are several limitations to their practical application. Especially, in the design education courses in universities, the functional expectation level for prototyping is high, but most of the content developed for solving the difficulties has been developed for the lower education levels, and it could be said that a great deal of learning is necessary to solve the problem. In this study, students were asked about microcontroller board utilization and their satisfaction with their design through questionnaires and with the developed microcontroller board development direction via Focus Group Interviews. Based on this, we tested microcontroller boards that eliminate the coding process and which students can use to create and prototype their work as a suggestion to fulfil demand. After using the board, both the usability and improvement of the product were checked. Confirmation of the usefulness of the free-coding-type microcontroller was obtained through this study along with the possibility of responding to various educational demands by applying the application design related to this product.

Keywords: *Design Education, Microcontroller Board, Design Prototyping, Prototyping Tool*

1. Introduction

1.1 The background and aim of the research

In recent years, design prototyping tools for microcontroller boards such as Arduino and related educational content have been introduced as a response to new technological environment changes in addition to education in the field of design education. However, there is the perception that this approach presents a barrier to students who have no knowledge of engineering, and this perception is an obstacle to actively acquiring and utilizing related knowledge. The reason for this can be found in Korea's elementary and middle school education curricula, but in recent years, related education has been supplemented in the basic curricula in response to social demand. However, one of the reasons for this is that the educational content and tools developed because of this demand are not actively utilized in the education field at universities. One of the causes this is the expectation level of the functional implementation of prototyping in design education at universities, but most of the content developed for solving the difficulties has mostly been developed for lower

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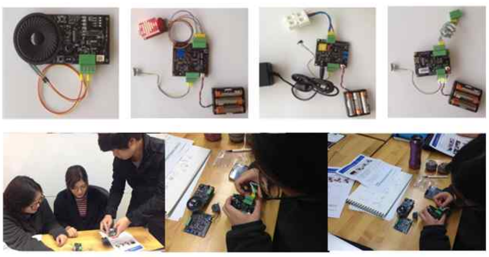
education levels. In this article, a prototyping tool for design education is proposed which can solve the difficulties based on this recognition and can realize a certain function in a short period of time. For this purpose, the design requirements were specified through prior research and investigation, after which board prototypes with microcontrollers were produced for educational programs and a functional verification was conducted with questionnaires.

1.2 Research methodology

The methodology for this study was as follows. First, we conducted basic research on existing microcontrollers. Second, we surveyed design students to understand their perceptions and satisfaction with microcontroller boards and to find out the necessity of developing a new microcontroller board. Third, we looked at the demand for them by design students and examined the necessary functions for microcontroller boards. Fourth, FGIs (Focus Group Interviews) were conducted for board developers and designers to define the setting values of sensors and modules, the communication module, and the application specification. Last, the satisfaction of design students was investigated through experimental tasks on prototype microcontroller boards.

1.3 Research background

The current state of basic education for educational design was investigated through previous studies and the characteristics of simplified educational tools based on microcontrollers were analyzed. In addition, to set the direction of educational design research, a pilot study was conducted at the university using a microcontroller toolkit that simplified the coding process based on this content (Figure 1). To examine the utilization of the toolkit, the pilot study was conducted over a short period of time during the preliminary education and practice for university students who did not have a basic knowledge of engineering technology: a total of 8 hours over 2 days on subjects such as 3D printing. It was designed not only as a simple prototyping toolkit but also for creativity based on design methods based on the basic design process consisting of a basic theoretical program for understanding creativity, idea concepts, prototyping for the expression of ideas, idea elements through life observation, understanding prototyping tools, storytelling, and prototyping.



Contents of the pilot education program	
Basic theory	1. Understanding Creativity 2. Finding Ideas 3. What is Prototyping for Expression of Ideas?
Expressive Practice	1. Understanding Prototyping Tools 2. Finding Ideas through Life Observation 3. Design Storytelling 4. Prototyping

Figure 1. The pilot study

To draw out the problems in creativity education, teacher and student interviews were carried out in advance. In the interviews with the teachers, there were many points that related to classes that were repeated: the one-sided delivery of scientific and technological knowledge and the interest of the students has decreased because of boredom with the theory lessons. In the student interviews, there was a strong opinion that increasing group interest and the process of imitating the correct answers were regarded as problems. Based on this, the major problems with the existing design course and three basic design policies were set, the content for which is reported in Table 1.

Table 1. The Issues and the Basic Design Policy for the Study

Issues	Basic Design Policy
- Subjects with the correct answers - Learning by imitation - Toolkit assembly-oriented curriculum - Inadequate systematicity toward each step - Lessons focused on scientific principles - Lack of a critical mind	1. Learning by applying the design process 2. Discovery of perspective based on a sympathetic theme for daily life 3. Freedom of idea expression through solutions to difficulties

2. Understanding Microcontrollers

A microcontroller is a small computer with input/output (I/O) and operations that allow the precise control of devices, although it does not have the ability to manage complex processes. However, they are small and low cost and are widely used in a variety of electronic products for embedded systems. Recently, they have been attracting attention as essential devices for establishing the Internet of Things (IoT) environment, which has raised their value. Microcontrollers have traditionally been used in electrical engineering and computer science for teaching software and hardware structures. However, as science and technology education become more important and the social demand for software education increases, students are also being more generally educated on microcontrollers.

2.1 Research methodology

It is a big task to express a designer's ideas accurately. The process of prototyping a product or user experience designing is a very important part of the design process for expanding into each area. Particularly, a mockup that reproduces actual functions is produced with the help of an engineer to produce and operate internal mechanical parts and printed circuit boards, but in the design process prototyping repeats the production and modification and pursues improvement, albeit it is not always easy to get help from an engineer. A typical microcontroller board developed to meet the needs of designers is Arduino.

(1) Arduino

Arduino (Figure 2) is a single-board microcontroller based on open source development. It is made up of a board based on Atmel AVR. Recently, a product (Arduino Due) has been developed using Cortex-M3. Arduino can take values from multiple switches and sensors, and control external electronic devices such as light-emitting diodes (LEDs) and motors to create objects that can interact with the environment. There are many integrated development environments for software development that use Adobe Flash processing and software such as Max/MSP that can work together. There are also a growing number of companies that use Arduino for business. The toy company LEGO has robot toys and training programs using Arduino for students and adults in North America. The automobile company Ford uses Arduino to create automotive hardware and software to interact with vehicles using a program called Open XC.

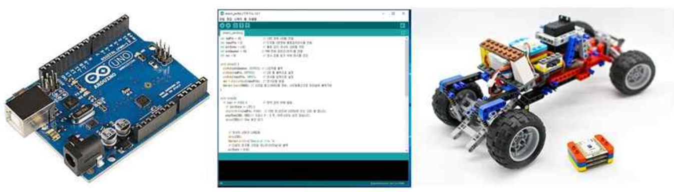


Figure 2. Arduino and its application

(2) Raspberry Pi

Raspberry Pi (Figure 3) is a very small computer with RAM, a CPU, a USB port, an HDMI input, and a LAN port. It runs a Linux-based operating system called Raspbian OS on an SD card. Unlike ordinary computers, Raspberry Pi has the advantage of being able to directly project and program various sensors and actuators by connecting with them.

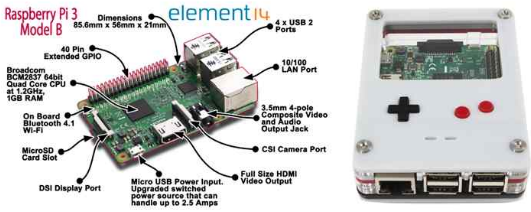


Figure 3. Raspberry Pi and its application

(3) BeagleBone

Unlike Arduino and Raspberry Pi that use open source and easy-to-use developmental environments, the focus of BeagleBone (Figure 4) is on building a highly reliable real-time environment based on open source development. Because of this basic concept, the computational power is normal but the I/O is abundant, and the Programmable Real-time Unit (PRU) subsystem has been built to have full real-time performance. The PRU provides a different level of performance in signal processing because of a digital I/O latency of only 5 ns. However, unlike Raspberry Pi, it lacks a USB port and video encoding, making it unsuitable for use as a computer or entertainment device, and the lack of tutorials and open source code makes it difficult for beginners to use it.

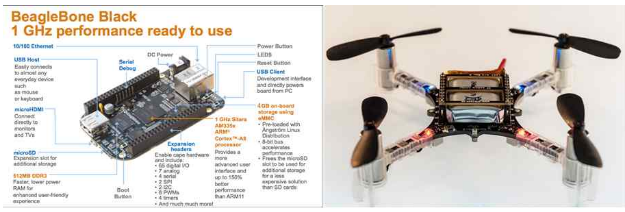


Figure 4. BeagleBone and its application

2.2 Utilization of microcontrollers in design education

As a result of the diversification of the design field and the expansion of role demands, interactive prototyping education has been activated in the field of design education research, and Arduino is being used as a representative tool. These prototyping tools are advantageous for rapid prototyping using an open source platform that can connect hardware and software relatively easily. If designers make the right use of open source environments, they can develop prototypes that can be visualized directly. Currently, much educational content such as books and online lectures has been introduced, and many educational institutions utilize it. However, as mentioned previously, the expectation level of the functional implementation of prototyping in the design education at universities is high even though most of the content developed for solving the difficulty is developed for the lower education levels before university. There is a limitation that prototyping tools are not universally available for design students.

3. Student Survey

3.1 The survey overview

A survey is a series of processes in which the characteristics of interest cannot be measured, such as opinions or behaviors, by creating appropriate questionnaire items to obtain the desired information. This means conducting a research study on a sample population to describe the phenomenon. In this section, the survey design is reported for the students before designing microcontroller prototypes to find their level of satisfaction with the mainly used microcontroller boards and grasping the necessary functions for microcontroller board development in the future. The target and scope of the survey are reported in Table 2. The survey was conducted on 100 design students attending Kookmin University.

Table 2. The Survey Target and Scope

Method	On-site survey
Subjects	100 design students (50 males, 50 females)
Range	Satisfaction with existing microcontroller boards The need for new microcontroller board development The required sensors and functions for the new microcontroller boards
Time period	2018.03.02–2018.03.15

3.2 The results of the survey

The analysis for the survey shows the results of each question in terms of mean and standard deviation. An attempt was subsequently made to use the results of the survey as basic data for microcontroller board development. Table 3 summarizes the results of the satisfaction level with existing microcontroller board usage.

Table 3. The satisfaction level with existing microcontroller boards

No.	Question	Average	Standard deviation
1	Is programming of the microcontroller board easy to access?	2.18	0.82
2	Is the connection (cable connection) between the microcontroller board and the sensor easily accessible?	2.77	0.83
3	Is the communication module easy to use when using the microcontroller board?	2.79	0.89
4	Did you understand the principles and applications of the sensor when using the microcontroller board?	2.02	0.66
5	Is the resistance of the microcontroller board easy to use?	2.12	0.82
6	When using the microcontroller board, were the I/O value interlock adjustments easy to access?	2.6	0.94
7	Are you satisfied with your current microcontroller board?	2.07	0.79
8	Do you think it is necessary to develop a microcontroller board for the mock-up and study?	4.09	0.71
9	Do you think it is necessary to develop an application for controlling the I/O values?	3.81	0.86

Strongly Negative	Negative	Normal	Positive	Strongly Positive.
1	2	3	4	5

As a result of the questionnaire survey, it was found that the design students had difficulty with coding, applying the sensors, using the resistance value, controlling the output values, and interlocking the adjustment values in the prototyping process. In addition, the demand for microcontroller board utilization to carry out a working mock-up and related studying was confirmed along with the demand for application development that can control the I/O values interlocked by using the communication module during the prototyping process. In this questionnaire, we surveyed 37 input devices and 14 output devices to understand the I/O functions required for prototyping and academic performance, the results of which are summarized in Table 4.

Table 4. The Required Input Devices for the New Microcontroller Boards

No.	Input	Function	Average	Standard Deviation
1	Ultrasonic distance sensor	- Detects the distance to the object using ultrasound	3.97	0.89
2	Infrared obstacle sensor	- Detects the infrared rays reflected by an obstacle	2.71	0.77
3	Infrared human body sensor	- Detects the infrared rays reflected by the human body	3.01	0.95
4	Accelerometer	- Detects the x,y,z acceleration	2.01	0.66
5	Temperature sensor	- Detects the temperature (-55 to +125 °C)	2.16	0.77
6	Vibration sensor	- Detects the movement or vibration of an object	2.72	0.75
7	Magnetic sensor	- Detects the strength of the magnetic field	2.83	0.86
8	RGB SMD LED module	- Detects the color of light	3.01	0.89
9	Photo Interrupt module	- Object pass detection	2.85	0.73
10	Digital temperature humidity sensor module	- Humidity measurement range 20–90%, Temperature Measurement Range 0–50 °C	2.84	0.87
11	Tilt sensor	- Detects tilting or the tilt	3.83	0.81
12	Illumination sensor	- Detects brightness	3.04	0.75
13	Small reed switch module	- ON/OFF by sensing if a magnet is close	2.96	0.76
14	Infrared remote-control module	- Infrared light reaches the detector	2.43	0.85
15	Flame detection sensor	- Detects the infrared wavelength from a flame	1.99	0.73
16	Knock sensor	- Detects the vibration and impact of metal in a plastic case	2.98	0.82
17	Sound Sensor	- Detect the amount of external sound	2.44	0.94
18	Heart rate sensor	- Measures heart rate with fingers	3.08	0.81
19	Weight sensor	- Measures the weight of a placed object	2.41	0.85
20	Barometer module sensor	- Pressure sensing	3.19	0.82
21	Gas sensors	- Detects the gases or gases listed previously by type	2.39	0.97
22	Soil humidity sensor	- Sensor for measuring the humidity of a pot or soil	3.46	0.93
23	Bending sensor	- Measures the degree of bending	2.29	0.94
24	Water level sensor	- Detects the water level	3.62	1.01
25	Optical dust sensor	- Measures fine dust in the air such as cigarette smoke	2.91	0.74
26	Pressure sensor	- Measures the strength of a pressing force	2.45	0.75
27	Conductive rubber or plastic	- Senses the stretching of a rubber band	2.09	0.78
28	Speech recognition sensor	- Simple English command recognition	3.78	0.78
29	GPS receiver	- Locates with GPS	2.81	0.64
30	Touch sensor	- Touch on/off	3.65	0.79
31	Position sensor	- Detects the pressed position	3.02	0.75
32	Fingerprint sensor	- User fingerprint recognition	3.02	0.75
33	Rotary encoder module	- Measures the rotary rotation count	2.06	0.81
34	Current measurement sensor	- Measures the current magnitude	3.85	0.86
35	Button module	- Press button for on/off	4.13	0.70
36	Microphone module	- Turn on/off vocal commands	3.95	0.84
37	Fingerprint sensor	- Recognizes the fingerprint and turns on/off	3.44	0.96

As a result of examining the 37 input devices required for the prototyping and academic performance, the necessity for the following input devices was high. The button module showed the highest value with an average of 4.13, then the ultrasonic sensor (3.97), the microphone module (3.95), the current measurement sensor (3.85), the tilt sensor (3.83), and the speech recognition sensor (3.78).

Table 5. The Required Output Devices for the New Microcontroller Boards

No.	Input	Function	Average	Standard deviation
1	DC motor	- Adjustable rotation speed	4.11	0.68
2	Step motor	- A motor that can adjust the exact angle of rotation	4.21	0.67
3	Speaker	- Generates the desired sound	3.83	0.91
4	Underwater pump motor	- Pumps that can pump water	2.83	0.90
5	LED	- Turns light on/off	4.32	0.61
6	Infrared light-emitting module	- Emits infrared light	2.95	0.78
7	Laser light-emitting module	- Emits laser light	3.06	0.85
8	RGB color LED module	- Creates any color	4.01	0.69
9	Manual Buzzer Module	- Sound signal notifier (a loud beeping sound)	2.92	0.80
10	Piezo buzzer module	- Sound generation by frequency	2.97	0.77
11	LED Chain	- 25 RGB LEDs connected to display various colors	3.76	0.95
12	LCD module	- 16 x 2 display of Korean, alphabet, numbers, and special characters	3.71	0.93
13	Segment	- Shows the desired number	3.39	0.88
14	Dot matrix	- Possible partial light emission on a matrix	3.94	0.85

The output device required for the prototyping and academic performance of the design students showed the highest average value of 4.32 was the LED, followed by the step motor (4.21), DC motor (4.11), RGB color LED module (4.01), dot matrix (3.94), and speaker 3.83 The need for a device was high.

4. The focus group interviews (FGIs)

4.1 An overview of the FGI

The FGI is a collective in-depth interview technique. As a representative survey method for qualitative surveys, 10 or fewer people are selected according to certain qualification criteria which focus on exploring and understanding their in-depth motives, attitudes, values, and desires. For the FGIs in this study based on the results of the previous survey, we interviewed 7 engineers and designers related to board development and conducted in-depth interviews on the development of a new microcontroller board for the student designer. This survey was conducted using the interview method consisting of questions and answers. The survey scope and content are listed in Table 6.

Table 6. The Survey Scope and Content

Subjects	2 board developers, 2 application developers, 3 designers	
Scope and Content	1st	- The effectiveness of the microcontroller board development - The microcontroller board primary development specifications decision - I/O cable selection - Bluetooth module selection
	2nd	- Application development based on I/O operations - Communication protocol for the microcontroller board and application interworking
Date conducted	1st	2018.03.19
	2nd	2018.03.26

4.2 The FGI results

The implications of the FGIs are as follows. The development of a precoding-type microcontroller for design students could solve some of the obstacles caused by difficulties in the coding for and application of sensors for Students who lacked engineering knowledge of I/O. The possibility of improving accessibility to the microcontroller board was confirmed, as shown in Figure 5.

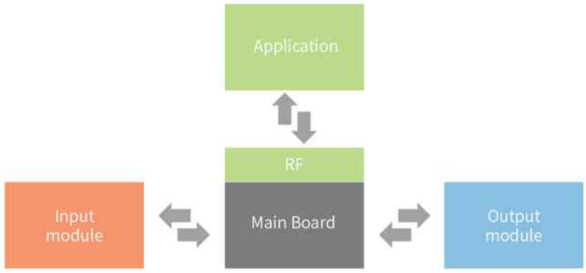


Figure 5. The configuration of the mainboard, input device, and output device from the results of the FGIs

The input and sensor modules of the first prototype based on the results of the previous survey and the FGIs were selected as two types of limit switches; ultrasonic, electrostatic, tilt sensors; and a microphone, as reported in Table 7. ASCII code is widely used in data communication and can be used for control operations such as start, end, and line of communication (Table 8).

Table 7. The Specifications and Sensor modules for the Input

	Input		Function
1	Limit Switch	A	- Sends an electric signal to the mainboard each time the button is pressed
		B	- Sends an electric signal to the device as soon as it is pressed and released
2	Ultrasonic sensor		- Detects all objects that reflect ultrasonic waves. - Transmits the distance between the end of the sensor and the object in meters.
3	Touch sensor (electrostatic sensor)		- Detects the micro-electricity coming from the human body and sends it to the mainboard.
4	Tilt sensor		- Sends the result of the x-axis to the mainboard - Sends the result of the y-axis to the mainboard.
5	MIC		- Inputs sound and sends it to the mainboard.

Table 8. The Mainboard and Input Device Protocol Package

Head	Output	Value4 up	Value3	Value2	Value1 down	Checksum
HEX	HEX	HEX	HEX	HEX	HEX	HEX
ASCII ‘M’	Input	Integer digits including minus			Decimal	Head + Input code +4 bytes
Ex)0x4D	odd number	0x00	0x00	0x00	0x00	0xXX

The output device and the sensor modules were selected as a servomotor, DC motor, LED, LED dot matrix, RGB color, and speaker, as conveyed in Table 9.

Table 9. The Output Module Specifications

	Output	Function
1	Servomotor	- Transfer data area: the angle can be input from 0–180°. - Transfer data area: stop time can be input from 0–255 s.
2	DC Motor	- Transmission data area: forward rotation can input 0–255 s. Performs forward rotation for this duration. - Transfer data area: stop time can be input from 0–255 s. - Transfer data area: reverse rotation can be input from 0–255 s.
3	LED Dot matrix	- 8 fonts (D7 to D0) and stop time (s) data are output.
4	LED	- One high-brightness LED configuration - Even if two or more LEDs are connected, they are turned on/off by command.
5	RGB Color	- One LED with 3 colors - Even if two or more LEDs are connected, they are turned on/off by command. - When the area item (value of 1 or more, retention time) is transmitted, the LED emits light in seconds and automatically turns off.
6	Sound Recorder	- Send a large value (non-zero value) to the transmit data area, including 1 at the master, and the software trigger pulls the device to operate. - Output the recorded sound.

Table 10. The Mainboard and Output Device Base Protocol Package

Head	Output	Value4 up	Value3	Value2	Value1 down	Checksum
HEX	HEX	HEX	HEX	HEX	HEX	HEX
ASCII ‘D’	Servomotor	Transmission data area			-	Head + Input code +4 bytes
		-	Angle	Stop time (S)		
	DC Motor	Transmission data area			-	Head + Input code +4 bytes
		Forward rotation (S)	Stop time (S)	Reverse rotation (S)		
	LED Dot matrix	Transmission data area			-	Head + Input code +4 bytes
		Font (D7~D0)		Stop time (S)		
	LED	Transmission data area			-	Head + Input code +4 bytes
		1 or more value		Stop time (S)		
	RGB Color	Transmission data area			-	Head + Input code +4 bytes
		Color Code (0~255)		Stop time (S)		
	Sound Recorder	Transmission data area				Head + Input code +4 bytes
Ex)0x4D	even number	0x00	0x00	0x00	0x00	0xXX

The setting values of the I/O devices required for the application development are summarized in Table 11. The setting values of the input devices have the basic setting values for the ON/OFF function, the step distance, and the time adjustment and the values for the speed control, the number setting, and the interlocking time are determined as the setting values in the output devices.

Table 11. The Required Settings for Application Development

Input		Output	
Limit switch A	ON/OFF function	Servomotor	Angle setting / direction control / speed control
Limit switch B	ON/OFF function	DC Motor	Speed control / Direction control / Time control
Ultrasonic sensor	Distance adjustment	LED Dot Matrix	DOT ON/OFF / Time adjustment / Text function
Electrostatic sensor	Detection time adjustment	LED	LED number setting / LED designation ON / OFF function

			Adjusting the number of flashes / Adjusting the flashing speed
Tilt sensor	X-axis adjustment / y-axis adjustment	RGB Color	Color value adjustment / Time adjustment Adjusting the number of flashes / Adjusting the flashing speed
MIC	Recording function / time adjustment	Sound Recorder	Volume control

5. Free-coding-type microcontroller board prototyping

5.1 The microcontroller mainboard prototype configuration

Based on the functional requirements for the I/O and control set through questionnaires and the FGIs, free-coding-type microcontroller boards and application prototypes were produced. The mainboard is 6.8 cm long and 6.8 cm wide with 4 connectors. Figure 6 shows the fabricated components. The connector can be composed of one output and three input devices, two input and two output devices, etc. and is designed to cope with a variety of cases other than 1:1 correspondence. In addition, the sensor board is made up of a board 4 cm wide and 3 cm high separated from the mainboard so that it can cope with various designs. The control of I/O is carried out by an iOS-based application, and the entire process of using the microcontroller board is shown in Figure 7.

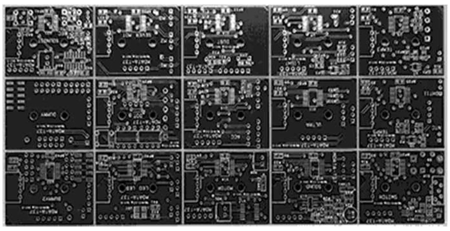
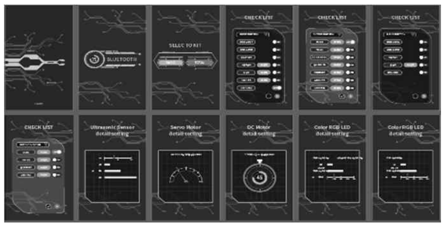
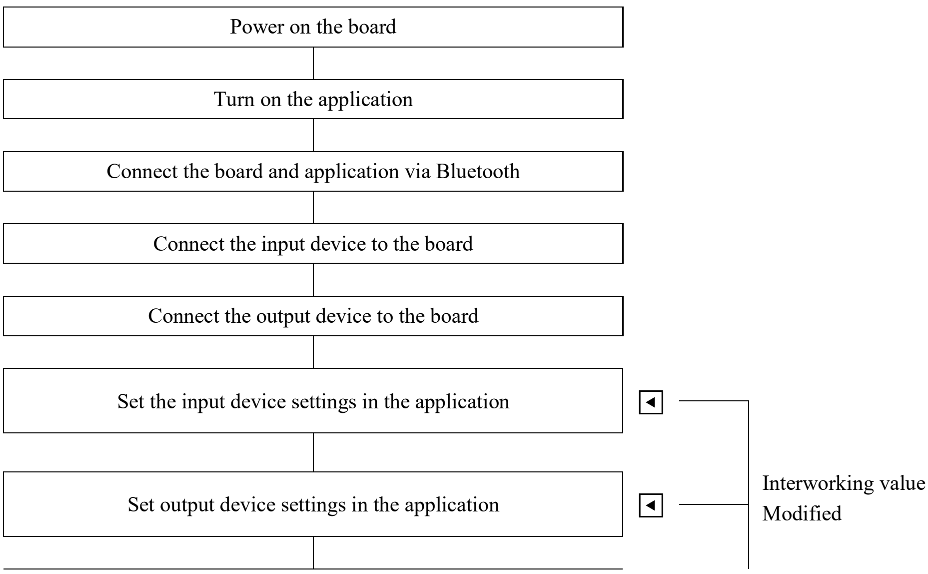
(a)	(b)	(c)
		

Figure 6. The prototype configuration for the first microcontroller board: (a) the mainboard (68 x 68 mm), (b) the sensor board (40 x 30 mm), and (c) the application.



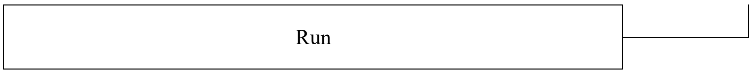


Figure 7. The process of configuring the prototype for the first microcontroller board.

5.2 Validation

In this section, experiments were conducted with the 100 design students to evaluate their satisfaction with the microcontroller board prototype. The scope of the experiments is summarized in Table 14 and the experimental tasks are reported in Table 15. With Task 2, an attempt was made to grasp the satisfaction of accessing the communication module, while Tasks 3, 4, 7, and 8 were applied to understand the satisfaction of the convenience of accessing the microcontroller board and sensors. Tasks 5, 9, and 11 were to test the satisfaction with the ease of controlling the I/O values between the board and the sensor, while Task 11 was applied to measure the satisfaction with the sensor application.

Table 14. The Scope of the Investigation

Investigation method	Experimental Tasks and Surveys
Subjects	100 design students
Scope of investigation	Experimental tasks based on the microcontroller board development Satisfaction questionnaire based on the microcontroller board development
Survey period	2018.08.10 – 2018.08.17

Table 15. Experimental Tasks and Content

No.	Task	No.	Task
1	Power on the board.	7	Connect board and input device (limit switch A).
2	Connect the board and application.	8	Connect the board and output device (LED).
3	Connect board and input device (ultrasonic sensor).	9	Set the input value (3 times click) and the output value (LED ON).
4	Connect the board and output device (servomotor).	10	Make sure that the setting value is output.
5	Set input value (1M), output value (90°).	11	Set the ultrasonic sensor input value (3M) and output value (LED ON).
6	Ensure that the setting value is output.	12	Confirm that the setting value is output.

Figure 7. The Task Experiment

Based on the task experiments, we conducted questionnaires and interviews concerning the satisfaction with the microcontroller board prototype. The results of each question were analyzed by frequency, average, and standard deviation. Based on the results, we intend to use this data to improve the microcontroller board in the future. The results of the survey are shown in Table 16.

Table 16. Experimental Items and Content

No.	Questions	Average	Standard Deviation
1	Was programming the new microcontroller board easily accessible?	4.16	0.61
2	Was the connection between the new microcontroller board and the sensor easily accessible?	4.11	0.68
3	Was the use of the communication module on the new microcontroller board easily accessible?	3.99	0.69
4	Is the application of the sensor on the new microcontroller board easily accessible?	4.01	0.71
5	Were the new microcontroller board's I/O value controls easily accessible?	4.12	0.70
6	Are you satisfied with the use of the new microcontroller board?	4.04	0.72
No.	**Interview**		
1	How could the new microcontroller board be improved?		

As a result of evaluating the satisfaction with the precoding-type microcontroller board for design students, it was found that the averages for programming access (4.16), connecting between the sensors (4.11), applying the sensors (4.01), interlocking control of I/O (4.12 and 4.04, respectively), and so on, which were higher than for the conventional microcontroller board. The additional interviews confirmed the necessity to reduce the board size, diversification of the output devices, and to segment the I/O value interlocks.

6. Conclusion

In this study, we investigated the satisfaction of design students with existing microcontroller boards used in prototyping and grasped the demands for microcontroller board development that can be easily used for design prototyping and related academic performance. Based on this, a free-coding-type microcontroller board prototype was fabricated. The preliminary questionnaires were based on the average and standard deviation of each item, and the design students of the existing microcontroller board showed an average satisfaction level of 2.07, while the low difficulty of prototyping and the need for microcontroller development was found to be 4.07. This shows that there was a demand for improvement since the satisfaction with the existing microcontrollers used for prototyping was low. On the other hand, microcontroller input devices required by design students showed high average satisfaction values for ultrasonic sensors, microphones, current measurement sensors, tilt sensors, speech recognition sensors, etc. Output devices including LEDs, step motors, DC motors, RGB color LED, Dot matrix, and speakers showed high average satisfaction values. Based on this, FGIs were carried out that helped to specify the development direction for a microcontroller board composed of a mainboard, a sensor board and a control application. After conducting an evaluation with experimental tasks to determine the satisfaction with the prototype, an average of 4.04 was obtained and the positive response to the free-coding-type microcontroller board production direction was confirmed. Based on this research, we plan to expand the I/O functions of free-coding-type microcontrollers and improve their application usability in the future. In addition, we expect to solve the entry barriers for design students' use of microcontrollers and contribute to the diversification of design education.

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