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A Preliminary Study of the Application of Prototyping Tools for Design Education Plans; Focusing on Open Source Microcontroller Boards

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Abstract

In the past, design has been recognized as a means to determine colors, shapes, and functions Recently, however, it has been accepted in a wider sense, namely designing the entire service, including product and user experience design. In this way, in addition to creativity and expressive power that designers have as their main competence, according to the expansion of this design object, designers are required to have comprehensive abilities in related fields and accompanying technical professional abilities. If designing as a technology application as a direction toward this situation, design education can be carried out by approaching technology as a method of expression or design subject. It can also be an effective alternative towards improving the understanding of technology. Meanwhile, many small microcontroller board products with advanced functions and multi-functional specialized programming integrated development environments (IDEs) are becoming widespread due to their open source, low cost, and scalable features. However, students in the design department who lack the basic knowledge of science and engineering have difficulties learning, which requires considerable time and is required for practical use. From this point of view, we have made advancements in the technical understanding of design education by conducting fundamental research to the effectiveness of microcontroller-based prototyping tools as means of expression. We also conducted basic education of microcontroller boards for a certain period of time on students who majored in design in conjunction with the basic survey and investigated the obstacle factors using a questionnaire. Through these surveys, we have confirmed the necessity of designing microcontroller boards of low difficulty, which simplify the coding process that can act as a barrier in difficulty for design students to apply smoothly in design education. In addition, we intend to carry out a basic study on the guideline of microcontroller design for design education and composition of education programs.

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

1. Introduction

The fourth industrial revolution, represented by AI, IoT, and robot technology, is being actively discussed; however, industrial changes are required. In addition, the market is faced with a situation where the material needs are satisfied through highly equalized products and services, the social structure is complicated, and the demands of users are diversified and deepened. The field of design has been required to play an important role as a creative industry along with the changes in this industry. Thus, the range of design objects has been greatly

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expanded to a different area from the past, when it was simply developed around manufacturing industries. As the expected and demanded ability of designers is diversified, design education for job competitiveness should be continuously pursued. The purpose of this study is to identify the importance of prototyping as one of the design education models for the improvement of creativity and technical application and to search for the usability of microcontroller boards.

2. Interpretation of creativity

There is no question that the central competence required of a designer is creative ability. Often, creativity is expressed as something different from existing thinking, where it is taken to mean ‘inspiration.’ However, it must be applied to creativity ability education through concrete interpretation beyond these abstract definitions in design education. When we look at the results that have been proven so far in the systematic arrangement of creation and non-creative thinking, there is no significant difference between these accidents. In other words, the relevant statistics show that it was difficult to distinguish between skilled and unskilled differences in these accidents. Creative activity is only a special kind of problem-solving activity characterized by novelty, freedom, persistence, and intricacy (Allen Newell, 1959). Thus, creativity is an ability that can be improved by planned education.

2.1 Prototyping as a training tool for creativity

Prototyping refers to the process of incorporating feedback into a system design after a user has been tested with a development model. It is a means to streamline the development process by communicating between the developer and the user, as well as grasping user feedback. One of the great advantages of prototyping is that developers can communicate with each other, receive feedback from various users, and repeat the improvement process to induce new ideas. This process greatly shortens the development cycle and allows the development from the user's point of view to accurately grasp the user's needs and increase the user’s satisfaction, with the advantage of early detection of errors and easy change (Humanitas Technology, 2013). By using prototyping effectively to meet the needs of users, it is possible to induce user participation and use it as a means of communication between the user and the developer. In recent years, the use of prototyping has been further expanded, and many start-ups based on ideas have been used as a means of promoting business fundraising and developing business items.

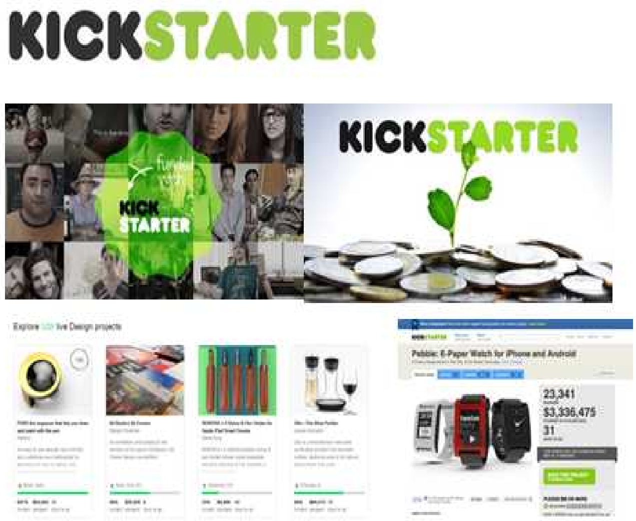

Figure 1. Funding site for start-up KICKSTARTER page
Image Source: www.kickstarter.com

2.2 The Prototyping process

Although the process of prototyping varies by device or system, it is generally divided into five stages, where the important point is that the process repeats itself between each stage and cycle (Humantitas Technology, 2013). Each step is as follows.

- Step 1: To analyze user requirements, the developer communicates the requirements to the user.
- Step 2: Developers develop prototypes using the related tools based on the previously derived requirements, focusing on the main functions of the system that is to be developed.
- Step 3: The user uses the developed prototype to demonstrate whether the requirements are fulfilled and makes further suggestions for supplementation.
- Step 4: Developers should revise and complement the prototype based on the findings and suggestions and return to Step 3 to re-check the requirements. Then, steps 3 and 4 are repeated until the user's requirements are met.
- Step 5: Customer evaluation is conducted, whereby the developer collects the information needed for future development and improvement.

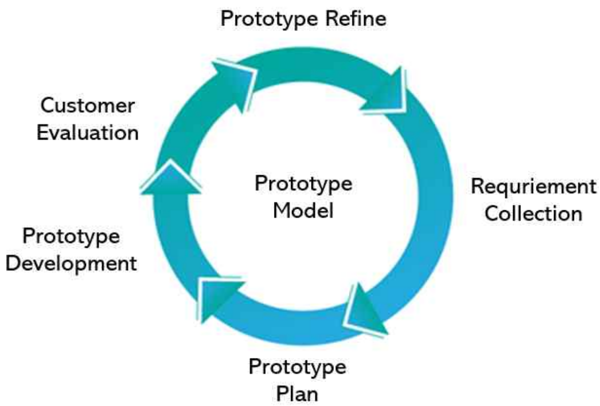

Figure 2. The process of prototyping

Image Source: Human Computer Interaction Introduction, *Jin-woo Kim*, 2012

2.3 Prototyping Use Case

(1) **Haptic Drive**
The Haptic Drive, designed by Miha Feuš, is a device that interprets the driving information of a vehicle. It attaches to an analog input device to give physical feedback to the touchscreen, will be. The display, including the buttons, responds haptically to the user's input.

(2) The **SmartWatch 'PEBBLE'**
PEBBLE was a successful example of crowdfunding on the Kickstarter site. It attracted much attention due to the interest in SmartWatches at the time. It received funding after securing consumer confidence by releasing the prototype in which the function was implemented.

(3) **Open BCI Evolution**
Open BCI, an EEG machine that provides constant control functions such as lighting and robots through brain waves, was produced at a low cost. The prototype was made by attaching an Open BCI board to a helmet, and this process improved the fit.

(4) **Wearable Beacon**
Recognizes the digital device found around the wearable device and reacts with light. A study on the use of this wearable device, conducted by Matt Martin, was done through prototyping technique. and is a study by Matt Martin, who is currently attending a master's course at the University of Auckland, New Zealand.

Figure 3. The process of prototyping
Image Source: Human Computer Interaction Introduction, *Jin-woo Kim*, 2012

3. Prototyping Tool

There are a number of tools on the market that are based on prototyping; for example, there are prototyping tools for UI design, tools for apps and web designers, and tools for hardware design. In this chapter, we will discuss the types of microcontroller board prototyping tools used in hardware development.

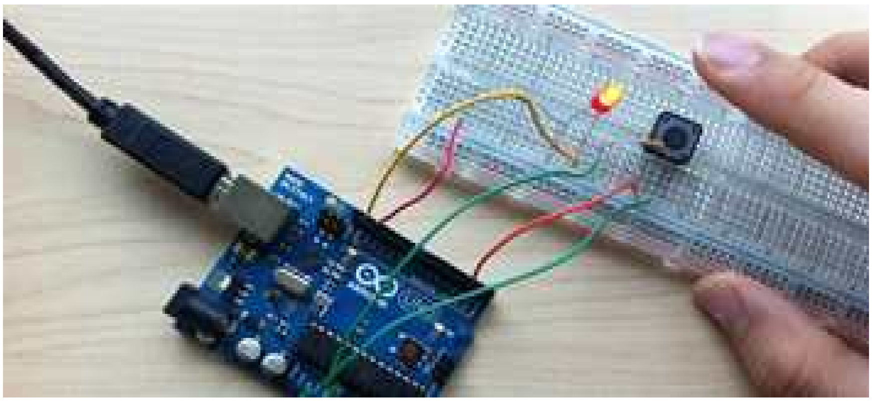

Figure 4. Arduino
Image Source: www.arduino.cc

3.1 Open source concepts for prototyping

One of the most common examples of open source software is Android, which accounts for 80% of the world's smartphone OS and the browser Firefox. In addition to its ability to detect bugs, open source software has the advantage of providing high-quality services at a lower cost and faster development speed, thus allowing many great programmers to participate in development. These open source features have the effect of promoting the development of the related industries through the expansion of developer users, and the company may disclose it for business purposes or to return the achievement to society via a university or research institute (see Figure 5). On the other hand, open source hardware refers to the free disclosure of information such as hardware design (3D CAD data) and the design of electronic products (circuit diagram on the board) and software. With a manufacturing machine such as this data and a 3D printer, one can create and directly modify a product oneself. The concept of open source spreading in these recent software fields is being developed in the field of hardware in earnest, and novel ideas can be transmitted to the across the Internet instead of being owned exclusively by a single enterprise.

Figure 5. Open source examples used in Web services
Image Source: cloudinteropelements.cloudapp.net

In addition, with the advent of personalized production tools such as 3D printers and microcontroller boards, individuals have become able to produce IoT products. Through the spreading of the "maker movement," personalized products can be shared in online communities (Figure 6). For example, in 'Thingsverse,' which is a 3D CAD data sharing site, many authors allow free downloads and changes. Another site, 'Instructable,' advertises DIY products, explains how to make many users detailed, and distributes programming files for microcontroller boards. Just as open source software allows individuals to develop high-quality Internet services and mobile apps, highly personalized products may also be created through this software in the future. There are also several open source hardware projects that can go beyond individual hobbies and aim at actual production. For example, the open source hardware project 'OSVehicle' (Figure 6), which was created in 2013, has 10,000 members who are currently in the testing phase of the products, which are to be for personal use.

Figure 6. Makers movement and 'OSVehicle'
Image Source: www.flickr.com/photos/jadon/
www.osvehicle.com

Although there are not many examples of open source hardware being released by global manufacturing companies as compared to such personal movements, the release of technologies to the public is becoming increasingly common. For example, in June 2014, Tesla's CEO Elon Musk stated that Tesla's rival was not an EV maker but the high number of gasoline vehicles (Elon Musk, 2014). All EV-related patents were released. Toyota also announced the opening of their fuel cell vehicle patent in January 2015, which became a popular topic. If the open source hardware flow becomes stronger, there will also be a case where the company is open to the public (NIKKEI, 2015). Thus, personalized manufacturing machines represented by 3D printing have been popularized in response to such trends, and the precision of low-priced machines is still incomplete (Figure 7). Many of the problems faced by the individual, such as low-end 3D printers, are in need of improvement, such as speed problems or maturity problems, but these problems are expected to be resolved quickly. As such, alternative approaches to solving specific functions directly using open source hardware will expand rapidly, and these are very effective means of expressing ideas in design education at the current level.

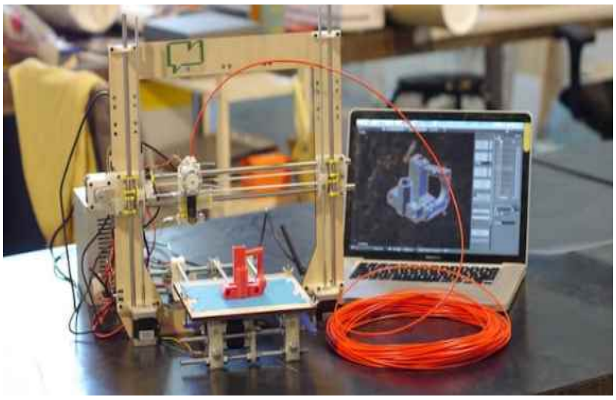

Figure 7. Open source 3D printer
Image Source: www.flickr.com/photos/126207443@N02/

3.2 Types and Features of Microcontroller Boards

In the past, professional and sufficient knowledge about objects and computers was required in order to make IoT type products, which has been receiving attention recently. However, personalized microcontroller boards such as Arduino and Raspberry Pi have emerged, allowing for systems to be configured by developers with only a basic knowledge of computing (Figure 8). In addition, small microcontroller boards, which were originally intended as development boards for prototyping, may be used for mass production or small-scale production, as they are loaded with various functions and supplied at a low price as the supply progresses.

Figure 8. Microcontroller Boards
Image Source: www.mechasolution.com

(1) **Arduino**
Arduino is a system composed of an AVR microcontroller, an integrated development environment with a C++-style Arduino language called “sketch,” as a board with input and output ports. Arduino is a kind of single-board microcomputer that can be controlled from the host computer's software (e.g. Processing, Max / MSP, Adobe Flash, Super Collider, Pure Data etc.), as well as standalone interactive device development. Information on the EAGLE file is available to the public for free. It is also possible to buy assembled boards, which has produced the opportunity to spread the concept of open source hardware (NIKKEI BP, 2010). The Arduino project was launched in Italy in 2005; it was intended to manufacture prototyping systems that were cheaper than those used by students at the time. The design group has succeeded in developing a platform that is much cheaper and easier to use than many competing products. With Arduino, it is relatively easy to operate the microcontroller. While Arduino can easily upload firmware compiled via a USB port, it usually takes a cumbersome process such as uploading via AVR, WinAVR, etc. via an ISP device. Another advantage is that it is relatively inexpensive compared to other products and supports various operating systems such as Window OS, Mac OS, and Linux. Also, according to the open source policy, the board layout is also open to other companies and individuals (Wikipedia).

(2) **Raspberry Pi**
Raspberry Pi is a reproduction of Accom's BBC Micro (Accom Computers, 1981), which was once popularized as an educational computer in the United Kingdom and aims to promote basic computer science education in schools. Model A and Model B are also derived from BBC Micro. Among the supported computer languages is BBC Basic, which is used by BBC Micro and is equipped with an ARM processor developed by AICOM in hardware. Instead of mounting an internal hard disk or SSD, it uses an SD card or microSD as storage for uptime and long-term storage (Wikipedia). The difference between Raspberry Pi and Arduino is the presence of an OS, which is close to a small PC and is advantageous for performing more complex tasks.

(3) **Intel Galileo**
Intel Galileo is a personal, single-board computer based on Arduino's first Intel x86 architecture, designed for manufacturing and education. Intel Galileo supports an expansion card called the Arduino's Shield and can benefit from Arduino's software development environment and libraries. On it, one can run existing Arduino software, namely Open Source Linux and Sketch; likewise, Intel Galileo can be developed on OS X, Microsoft Windows, or Linux. Intel Galileo is the first product to have a low-power, small Intel Quark with Intel Quark SoC X1000. Intel Quark was developed for such applications as Internet usage and wearable computers (Wikipedia).

(4) **BeagleBone**
BeagleBone is a low-power, low-cost single-board computer developed by Texas Instruments with the cooperation of Digi-Key. BeagleBone was designed in accordance with the philosophy of open source and was created to demonstrate the SoC technology performance of Texas Instruments’ OMAP3. The board was developed by a small team of engineers and aimed at providing users the ability to learn open source hardware and software from each other via the large community of beagle.org. BeagleBone's successor, BeagleBone Black, has dramatically reduced the costs and improved the functionality of the board (Wikipedia).

Table 1. Microcontroller Board Feature Evaluation

board type	image	expandability	economic feasibility	difficulty	development environment	performance	specialized function
Arduino		B	B	B	B	D	E

Raspberry Pi		A	A	C	B	B	C
Intel Galileo		B	D	B	B	C	B
BeagleBone		A	B	D	C	A	B

A: strong positive; B: positive; C: normal; D: some negative; E: negative

4. Basic Education Survey

In addition to the basic research, we conducted basic training on microcontrollers for students who were majoring in design and investigated the obstacles to utilization through questionnaires. Among the microcontroller boards examined, Arduino was selected for its ease of use, economy, and ease of access to coding sources and related components. The contents of the training were based on tool basics, LED flashing, LED control using brightness sensors, and the motor control using sensors. Table 2 shows the subjects of the education and questionnaire.

Table 2. Arduino basic education composition

No ,	participant	hour	Number of students	tool
1	Kookmin University Design Major Undergraduate Grades 1,2	6	38	Arduino
2	Kookmin University Design Major Undergraduate Grades 3	6	21	Arduino
3	Kookmin University Design Major Undergraduate Grades 4	6	20	Arduino
4	Kookmin University Design Major Graduate-level	6	13	Arduino

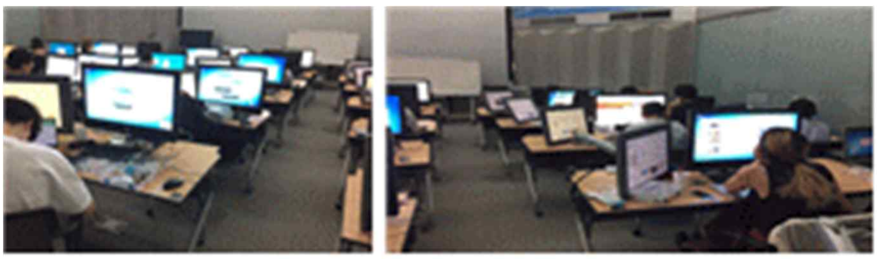

Figure 9. Microcontroller Boards Basic Education

4.1 Questionnaire

After conducting basic education on Arduino, we conducted surveys on the students who participated in the education. The questionnaire consisted of 12 questions in total, and the results of each question are shown in Table 3 and expressed in terms of mean and standard deviation. Based on the questionnaire, we assessed the question items for which the singularity is expected.

Table 3. Questionnaire survey analysis

No	questions	average	standard deviation
1	Interested in Arduino?	3.94	0.62
2	Do tools like Arduino help you in your future activities?	4.03	0.76
3	Did you feel Arduino was difficult?	3.90	0.92
4	Do you think that Arduino is highly utilized in design work?	4.21	0.80
5	Do you think you need more specific learning about Arduino?	3.95	1.00
6	Do you think that Arduino learning will help you get a job?	3.67	0.89
7	Do you think that Arduino learning will help you start a business?	3.96	0.85
8	Did you understand how to obtain Arduino related parts or open source code?	3.70	0.94
9	Do you think there was enough time to understand the outline of Arduino?	1.98	0.82
10	Do you intend to purchase and use Arduino in the future?	2.26	0.71
11	Is the size of the Arduino suitable for use in prototyping the design?	2.98	1.48
12	Interested in Arduino in the past?	3.35	1.19

1: strong negative; 2: negative; 3: normal; 4: positive; 5: strong positive

4.2 Sub-conclusion

The findings of the survey indicate that design students have many possibilities using tools such as Arduino overall, but they find that they are burdened with learning. Particularly, there was a strong perception that it would take a considerable amount of time for learning. This relative technical difficulty and the necessity of time investment were found to be significant obstacles to the acquisition of motivation. Another unusual point is that the device and size of the tool were found to be major limitations on the formability of the design. This survey confirms the obstacles to microcontroller board utilization in design prototyping.

5. Conclusion

Through this survey, we have studied prototyping using the microcontroller board, and we have looked at characteristics of typical microcontroller boards distributed in the market. As a result, the difficulties of prototyping technology for individual developers have been reduced due to the expansion of the concept of open source type hardware. In the past, CAD systems have been introduced as a means of expression in the design process and have become a means of communication between engineers and designers. In the same context, it can be expected that open source systems can be effectively utilized as a means of communication and expressiveness among developers in the product development process. Therefore, we should look for more active use of design education. However, as can be seen from the study, there are relatively high barriers to entry for design students who have studied art practicum, despite the fact that the difficulty of the technique has been lowered. In order to solve this problem, it is necessary to overcome the difficulty of the coding process and to define the function definition specialized for design prototyping in order to give learning motivation. To do this, we plan to develop a system that specializes in design prototyping as well as research to enhance utilization in design education through planning research of educational curriculum.

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