In the current era, which is often referred to as the "knowledge and information age," there is a need to educate those with creative convergence talents, who have multidisciplinary abilities, combining the talent, imagination, and creativity associated with the humanities, as well as knowledge about science and technology, to create new values. As such, a system of education that will cultivate the capabilities that are demanded by future society is essential, key elements of which are the practical ability to solve problems in creative ways and the ability to adapt flexibly (Choi, Jun-Seop, 2003). In this paradigm, studies on Arduino, which can enhance one's ability to think logically, problem-solve, and develop creative convergence capabilities, have been conducted in many areas. The Arduino model provides an environment in which students can study the basic concepts of programming, science, and technology in a fun and easy way that gives them practical experience. Moreover, the strength of the Arduino model is that it is able to unfold the fusion classes of science, technology, engineering, and math (STEM) education, as well as other similar topics, through diverse prototyping activities (Sanders, 2009).

The Turtle Ship is part of Korea's proud scientific and technological heritage (Je, Jang-Myeong, 2006), and has been evaluated as one of the top seven masterpiece battleships in the world (Hoppe, 2016). It is a cultural inheritance that has received a great deal of interest and attention, both domestically and internationally. If the Arduino platform, which enables students to learn the basic concepts of science and technology in an integrated manner through actual experiences,

An Arduino-based Turtle Ship model was developed to enable students to develop their technological and humanities-based knowledge in an integrated manner through actual experiences.

by

Won-Woong Kim, Jun-Seop Choi, and Kyoung-Ah Kim
easy and fun way, could be combined with this cultural inheri-
tance, it would serve as a teaching-learning material that can
be the basis for creative convergence educational activities. In
other words, students can naturally become familiarized with the
basic capabilities of Electronic and Control Technologies (ECT)
through actual experiences, while also increasing their recogni-
tion and value related to the cultural inheritance. Thus, this study
contrived the Arduino-based Turtle Ship model, which will enable
students to develop their technological and humanities-based
knowledge through flexible education, as well as enhancing the
potential of creative convergence education. The experimental
group consisted of eight senior students, in teams of two, major-
ing in communications and electronics at Suwon Technical High
School, Gyeonggi-do Province, Korea, who participated in the
intensive major course during their summer vacation.

The Turtle Ship

In 1592, the Japanese army led by Toyotomi Hideyosi invaded
Korea (then the Joseon Dynasty). This 16th century war became
a historically significant issue involving Korea, Japan, and China
(then the Ming Dynasty), developing into an international war in
Northeast Asia. This war has been referred to as the Japanese
invasion of Korea in 1592, but we will refer to it hereinafter as the
"Imjin War." The Turtle Ship is the world’s first iron-clad ship to
have been used in battle. Commanded by Admiral Yi Sun-Sin, a
great naval commander of Joseon, after the Turtle Ship partici-
pated in the first naval battle of Sacheon during the Imjin War,
it became an object of fear for the naval forces of Japan. The
Turtle Ship is a warship that has a special structure in which the
cover plates, which serve as the roof and the cover, cover the
upper part of the deck. With its thick cover plates and the sharp
iron spikes installed above the cover plates, the Turtle Ship can
block the enemy from boarding. As well, it was able to withstand
enemies’ arrows and rifle shots to a certain extent.

In Yi chungmugong jeonseo (Complete Works of Admiral Yi Sun-
Sin), which was compiled at the Gyujanggak Royal Library in
year 19 of King Jeongjo (1795), 200 years after the end of the Imjin
War, it was recorded that the thickness of the outer plates of the
Turtle Ship is 4 chi (approximately 12-13 cm). With this strong
defense capability, the Turtle Ship was one of the most power-
ful material foundations that supported the victories of the naval
forces of Joseon, while also functioning as a close-assault ship in
spearhead areas of the sea battles during the Imjin War.

Underwood (1934) explained about the Turtle Ship in the Imjin
War that "Its success, its fame then and now, and the terror
which it and its commander inspired in the enemy, bear witness
to its novelty and to its superiority over any preexisting ships." (p.
75). And, in a textbook about the history of the United States,
Creating America (2005), although it was very different type from
the Turtle Ship of Joseon, it was introduced that: "During the
Revolution, the Americans built the first combat submarine—the
Turtle" (p. 204).
Methodology

In order to achieve the aims of this research, this study was completed through the following research methods:

- The basic functions and characteristics of the Arduino and the actuator in the breadboard were analyzed.
- The circuit diagram and the pattern diagram of the control module of the driving device were designed. Based on this, the interface board, which is the actuator controller, was made.
- The interface board based on the Arduino and the hull of the Turtle Ship were combined.
- The development of the Turtle Ship model was finally completed by experimenting with the assembled Turtle Ship model on the water's surface and addressing any problems.

Design and Making of Interface Board

Before the interface circuit, which was the control module of the driving device for the Turtle Ship model, was designed, the Arduino and the electronic components (DC motor, servomotor, variable resistor, etc.) were interconnected and the performance and the characteristics of these components were confirmed. Next, the students designed the circuit in teams based on the basic knowledge and experience of circuit theory and electronic circuit design they had gained in their freshmen and sophomore years, and solved the various difficulties they encountered during the process through mentoring between teams, questions, and discussions. A software program called “Fritzing,” which was provided online for free, was used as the circuit designing program, and the team that finished designing the circuit configured the interface circuit on the breadboard and checked the overall operational status.

To perform experiments with the completed interface circuit, first, the program that drives the hardware was sketched in IDE (Integrated Development Environment), an Arduino integrated development environment; this sketch was transmitted to the Arduino board. The servomotor library <Servo.h> for operating the servomotor and the library <SoftwareSerial.h> for creating a virtual serial port were referenced. In the early stage of the programming experiment, the students experienced an unexpected problem due to a conflict with the default-set transmission and receive ports (Rx, Tx) when uploading the program to Arduino from the computer through serial communication. However, it was considered that the students would be capable of solving this problem without the aid of the instructor through brainstorming between learners, discussion between teams, and case analysis using the internet, so the students were instructed to search for the cause of the problem using various methods. As expected, the students identified through self-regulating discussions and cooperation that an error could occur due to a conflict between the communication port used for uploading the program and the serial communication port, and were able to solve this problem using the <SoftwareSerial.h> library to virtually enable the serial communication. The students expressed their sense of accomplishment and increased confidence in their learning.

According to the contents of the code statement, the mySerial (4, 5) object was created and Rx (4) and Tx (5) pins were set after referencing the library, and servo0, which was the object of the Servo class was created. In order to control the speed of the DC motor, the value of the variable resistor was received through A0, which was the analog signal input terminal of Arduino and output through No. 3 (PWM) pin after mapping to a value be-
In addition, the output signal from the No. 3 pin of the Arduino was connected to the L293B No. 1 pin (enabled terminal), which was the DC motor driver IC, to change the motor speed according to the size of the input value. The signal that controlled the servomotor was assigned to the No. 8 pin of the digital port on the Arduino board, and it was configured to reset the angle of the servomotor to 90° when the power was turned on. This aimed to set the default direction of the Turtle Ship model to “forward.”

If only void Setup () and void Loop () are used for programming in the coding process, it would be limited to deliver the concept of “feedback (call)” to learners. Therefore, the students were guided to create separate functions for each functionality in the coding process. For example, only the relevant function was allowed to be called and executed if it was intended to execute a certain function in the if-statement, establishing the structure of systematic programming. In other words, the functionalization (modularization) of available codes was applied to allow the students to learn the concept of control through feedback, rather than programming for simple hardware operation, enabling the students to cultivate systematic thinking skills and technical problem-solving abilities. Although the students made numerous errors during the coding process in terms of spelling, grammar and differentiation between uppercase and lowercase letters, it was considered that they would cultivate their self-initiated problem-solving ability by repeatedly carrying out the process, including cross-checking with their partners, mentoring, discussion between teams, and data search using the Web.

After the operation test of the interface circuit through the program was completed, the prototype was produced before producing the actual interface board. The prototype had the form of a Styrofoam board, the same size as the omnipotent electronic board that would be used as the interface board, directly connected with the Arduino board and peripheral electronic parts using jumper wires, and this prototype enabled the estimation of exterior, structure, and connection method of the interface board.

Next, the pattern diagram was first designed in order to arrange the components on the universal board that was used for the interface board and to connect the circuits. A position in which the wires were unavoidably crossed in the pattern drawing design process was connected using a jumper wire, and the parts were

---

### Table 1 Standards Addressed Related to Standards for Technological Literacy

| STL #2-FF | Complex systems have many layers of controls and feedback loops to provide information. |
| STL #8-H | The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results. |
| STL #8-J | The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved. |
| STL #9-K | A prototype is a working model used to test a design concept by making actual observations and necessary adjustments. |
arranged in intervals of 1 column or more to prevent interference between the parts. According to the pattern diagram, the components were arranged on the universal board. On the solder side of the board, the component leads were soldered, completing the circuits. The standards that align with this production procedure are listed in Table 1. Technology standards are from *Standards for Technological Literacy: Content for the Study of Technology* (STL) published by the International Technology Education Association, now the International Technology and Engineering Educators Association (ITEA/ITEEA, 2000/2002/2007).

Finally, the peripheral devices, including the DC motor, the servomotor, the battery (6V) etc., were connected to the PCB header. By turning on the power switch, the movements of the actuator were confirmed. The condition of the rotation of the DC motor, which is used as the power source for forward and backward movements of the Turtle Ship, as well as for changes in the speed of the motor according to changes in the variable resistance values, could be monitored. By operating the rotation axis of the servomotor that is used to drive the steering apparatus from 0° to 180°, it was possible to check the overall movements of the actuators that were connected to the interface board.

**Installation**

For the hull of the Turtle Ship model, the frame of the Solar Power Turtle Ship made by Academy Plastic Model Co. Ltd., which can be assembled without any separate crafting tools, was used. At the front part of the hull of the Turtle Ship model, a light and small Li-Po battery were installed. In the middle, a gearbox, where a link connected with the oars is rotated by the rotations of the coreless DC motor, was placed. Furthermore, at the back of the hull, the servomotor was installed. The gear box, a mechanical device to move the oars, and other parts connected to the gear box were purchased from the market and utilized after remodeling them for the purpose of this study. The main idea is as follows. First, connect the cordless DC motor to the center of the gear box. Second, the motor rotates, and then the gear of its axis rotates the main gear in the center of the gear box. Lastly, the sub-gears connected with the main gear can rotate the linkage. After installing the rotating body in the axis of the gear box, the linkage was set up with the pins and paddles. As the end of each paddle is connected with the linkage, the paddles rotate while they move in a forward or backward direction.
By considering the buoyancy, center of gravity, driving force, etc. of the hull of the Turtle Ship model and by measuring the weights of each component with an electronic scale, each component was arranged on the floor of the hull in a way that maintained the balance of the ship. The battery and servomotor were fixed to the body of the ship using silicone, so that they would not shake when the ship is moving. The steering apparatus was used for the servomotor by modifying the model. It was made to convert the direction of the ship when the body of the ship is actually running, using an elastic and resilient rubber band on the servomotor’s horn.

In order to install the interface board on the deck of the Turtle Ship model, a T-shaped prop was inserted on the pole, the upper part of the gearbox. Afterwards, on the upper side of the T-shaped prop, the interface board was fixed. Next, after combining the body and deck of the Turtle Ship model (the cover for upper part of ship), the jumper wire, which was linked to the actuator and the power supply, was connected to the socket terminals of the board.

Experiment and Improvements

The following is a summary of the results of the water tank experiment, which was carried out to examine and enhance the performance of the developed Turtle Ship model. In the water tank, the Turtle Ship model was floated on the water to identify its buoyancy, driving condition, etc. First, the power switch of the interface board was turned on, and through the “Bluetooth Controller” app installed on a smartphone, the movements of the Turtle Ship model were controlled. By controlling the forward and backward movements of the Turtle Ship model, which change according to the direction of the rotation of the oar, and by controlling the left or right turning of the hull, which is changed by rotating the steering apparatus left or right, the performance of the Arduino-based Turtle Ship model was checked. In addition, considering that the hull was rolled by the change of the main board’s center of gravity and incline, it was identified that the center of the hull of the Turtle Ship was unstable. The problem of the center of the hull of the Turtle Ship being unstable due to the rolling phenomenon was addressed by adjusting the balance of the incline of the main board and arranging the sequence of the jumper wires.

Conclusions

In this study, a model of a Turtle Ship, which is evaluated as one of the world’s top seven battleship masterpieces as well as a key Korean scientific and technological heritage, was combined with an Arduino-based interface board that enables students to learn the basic concepts of ECT in an easy and fun way. Through this combination, an Arduino-based Turtle Ship model was developed to enable students to develop their technological and humanities-based knowledge in an integrated manner through actual experiences.

In order to achieve the purpose of this study, an interface board needed to drive the Turtle Ship model was designed and produced. By assembling the hull of the Turtle Ship on which the interface board and the various peripheral devices were installed, the Turtle Ship model was finally completed. In the end, the problems with the Turtle Ship model that were discovered during the water tank experiment were identified and improved. The following is a summary of the main results obtained through this study:

• Students will cultivate their basic scientific and technological capabilities by designing and producing the Arduino-based interface board.
• Students will enhance their ability to think logically and problem-solve by designing and programming the circuit.
• The development of the Arduino-based Turtle Ship model will serve as a foundation on which students can develop their ECT and humanities-based knowledge in an integrated manner.
Students today do not want to receive meaningless instruction from teachers who are not fun or engaging. As well, students are able to feel a sense of pride while also partaking in diverse opportunities by making something by themselves. Education models that are focused on making materials involve multiple problems and innovative answers. Therefore, an educational environment in which the students can cultivate their problem-solving ability and creative convergence ability for the real world will be continuously developed by reinforcing practical activity-based education for students to enjoy learning and concentrate in class by themselves.

References


Kim, Won-Woong is a Technology and Engineering Education Teacher at Suwon Technical High School in Gyeonggi-do Province, Republic of Korea. He can be reached at weonwoong-kim@gmail.com.

Choi, Jun-Seop is a Technology Education Professor at Korea National University of Education, Republic of Korea. He can be reached at choijs@knue.ac.kr.

Kim, Kyoung-Ah is a Technology Education Teacher at Dojang Middle School in Gyeonggi-do Province, Republic of Korea. She can be reached at sweetpie99@hanmail.net.

This is a refereed article.