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A Case Study of Educational Content using Arduino based on Augmented Reality

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Abstract

The representative branch of ICT education is Arduino. However, there are various problems when teaching using Arduino. Arduino requires a complex understanding of hardware and software, and this can be perceived as a difficult course, especially for beginners who are not familiar with programming or electronics. Additionally, the process of connecting the pins of the Arduino board and components must be accurate, and even small mistakes can lead to project failure, which can reduce the learner's concentration and interest in learning Arduino. Existing Arduino learning content consists of text and images in 2D format, which has limitations in increasing student understanding and immersion. Therefore, in this paper analyzes the necessary conditions for sprouting 'growing kidney beans' in the first semester of the fourth grade of elementary school, and builds an automated experimental environment using Arduino. Augmented reality of the pin connection process was designed and produced to solve the difficulties when building an automation system using Arduino. After 3D modeling Arduino and components using 3D Max, animation was set, and augmented reality (AR) content was produced using Unity to provide learners with more intuitive and immersive learning content when learning Arduino. Augmented reality (AR)-based Arduino learning content production is expected to increase educational effects by improving the understanding and immersion of classes in ICT education using Arduino and inducing fun and interest in physical computing coding education.

Keywords: *Augmented Reality(AR), Physical Computing, Arduino, Educational content development*

1. Introduction

Information and communication technology in the era of the 4th Industrial Revolution is being used in various fields, and representative technologies include artificial intelligence, internet of things, big data, AR/VR, and smart factories. These cutting-edge technologies are interacting with each other and creating new types of services, products, and industries. Due to this industrial development, coding education is becoming

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an essential curriculum for students rather than an option. This also emphasizes the importance of developing a convergence curriculum of general subjects and ICT utilization in the education field, redefining the role of ICT in the modern education system. ICT education linked to the curriculum reflects the trends of the times and plays an essential role in helping students acquire the skills and knowledge necessary for future society. Coding education methods are divided into two types. The first is a physical computing process that allows users to learn various technologies from the basics of coding to actual project development using hardware and software, and the second is a software curriculum for solving algorithmic concepts and given problems. Students prefer the physical computing learning process to the software coding curriculum for acquiring text-based computing thinking. The software coding curriculum can be boring, but the physical computing learning process uses various teaching tools to make hardware, and when hardware construction is completed, the process of uploading code to hardware through the coding process to drive related parts is checked. Through this process, students can strengthen their problem-solving skills, creative thinking, and technical learning through learning how real hardware and software interact. In educational settings, scientific experiments are still conducted using traditional methods. To give an example of growing kidney beans in 'The Life Cycle of a Plant' in the first semester of the 4th grade of elementary school, students water the kidney beans directly after going to school in the morning and observe the sprouting process. Therefore, in this paper, we automate the actual experimental environment by implementing an automatic water supply device for kidney beans using Arduino for growing kidney beans in the science curriculum of 4th grade elementary school. To solve the difficulties of ICT education, we design and produce augmented reality learning content that runs pin connection animations of Arduino and moisture-related parts. By using this content to learn the pin connection process when building hardware for Arduino and water supply components, students can solve pin connection difficulties that appear in the process of assembling actual devices and increase the accuracy of the hardware connection process. In addition, using the augmented reality based Arduino learning content produced in this paper can increase students' understanding and immersion in classes and maximize the effectiveness of learning. Additionally, this physical computing process can automate the experiment environment in science subjects, so compared to the existing traditional experiment environment, the automated experiment environment will also improve the accuracy of experiment results.

The structure of this paper is as follows. Chapter 2 describes related research on the use of augmented reality-based educational content, which becomes the basic theory of this paper. In Chapter 3, augmented reality based Arduino learning content for ICT education is designed to automate the experiment environment for growing kidney beans in the first semester of the fourth grade of elementary school. Chapter 4 explains the implementation process of augmented reality based Arduino learning content, and concludes in Chapter 5.

2. Related studies

2.1 Educational content using Arduino

Arduino consists of a microcontroller(MCU), 14 digital pins, 6 analog pins, and a reset button. Of the 14 digital pins, 6 digital pins are capable of PWM output. Arduino is an open source platform. Arduino's official website provides various materials, including circuit diagrams and compatible sensor information, and coding learning is possible using integrated development environment(IDE) software.

In the paper "The effect of physical computing with arduino based laboratory", scientific theories were confirmed through experiments using Arduino. Based on his theory of the relationship between light and distance, he constructed an Arduino circuit and conducted an experiment to measure the temperature and intensity of light. By using only Arduino, we achieved the same educational purpose as when using expensive scientific equipment [1]. There is augmented reality content that explains the Arduino pin connection process [2]. This study teaches students who are new to Arduino how to properly connect the Arduino board and sensors. Through this, students can receive Arduino education in an easy and fun way. There is a study that developed educational content to create black-crowned crane works using Arduino [3]. Through this research, students had the opportunity to indirectly experience black-crowned cranes, an endangered species, by creating their ideas on an Arduino board. Arduino can be used very effectively to integrate various curriculum contents and information education. When analyzing trends and research on tools and programming languages used in physical computing education, programming education research using physical computing has gradually increased since 2013, and Arduino and Scratch are used most frequently [4]. It is analyzed that the reason why Arduino shows a high frequency of use in physical computing education research is that it can use various types of sensors more easily than other tools, has the advantage of being inexpensive, and can use educational programming languages.

2.2 Educational use of augmented reality content.

With the convergence of rapidly developing smart devices and new technologies in the era of the Fourth Industrial Revolution, we are experiencing a variety of technologies in our daily lives. Among these, technologies such as virtual reality, augmented reality, and mixed reality are attracting attention. The portability issue of smart device cameras and displays, which are essential elements of augmented reality implementation, has reached an important turning point due to the development of smartphones[5]. Augmented Reality is a field related to Virtual Reality and is a computer graphics technology that synthesizes virtual images or 3D virtual image information in the real environment to make them look like real objects . Figure 1 is the execution screen of an augmented reality based realistic content app for elementary school science textbooks developed by the Ministry of Education and the Korea Education and Research Information Service and run by EduNet T Clear [6].

Figure 1. Realistic Content in Digital Textbooks

Augmented reality-based educational content enables visual, auditory, and tactile experiences among the five human senses, and supports experiential learning by providing a virtual learning environment similar to the real thing[7]. The level of learning concentration shown in classes using augmented reality content was high enough to surpass the novelty, presence, and effectiveness of the medium of the augmented reality content [8].

2.3 Convergence education comprehensive plan and cases

The comprehensive plan for convergence education announced by the Ministry of Education in 2020 is as follows. The future society needs new talent, and in line with this, there is a need for change in traditional education methods. By integrating mathematics and science with technology, engineering, and art, we seek ways to establish an educational foundation for nurturing talent with both scientific literacy and artistic sensibility, and combine subjects such as mathematics, science, and technology to develop convergent thinking skills. The goal is to revitalize convergence education to improve problem-solving skills [9].

Figure 2 is an example of developing and operating various out-of-school spaces and convergence curriculums through collaboration with schools and institutions using convergence education resources, that is, libraries, museums, and makerspaces.

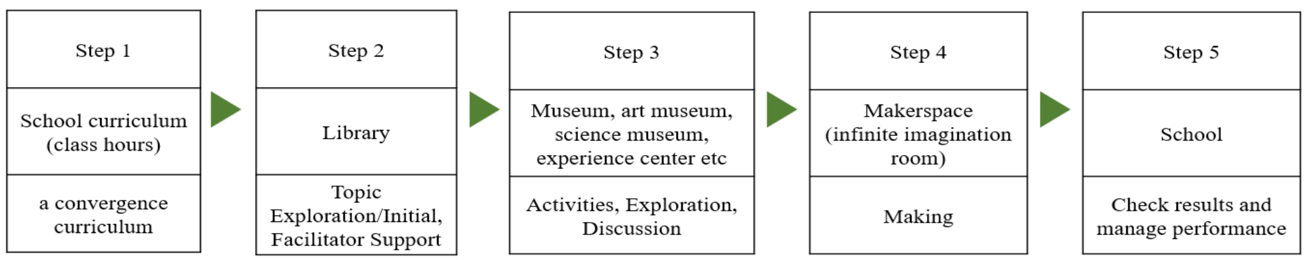


Figure 2. A case of developing and operating a convergence curriculum

3. Design of AR based Arduino Learning Content for ICT Education

3.1 Design of AR based Arduino learning content

The design process of augmented reality based Arduino learning content for ICT education is as follows. Analyze the conditions necessary for the sprouting of 'Growing Kidney Beans' in the first semester of the 4th grade of elementary school and build an automated experiment environment. In order to build an automated experimental environment, relay modules and water pumps are configured to automatically supply moisture if the amount of moisture in the soil is insufficient according to the amount of moisture checked by the Arduino Uno board and soil moisture sensor. In order to solve the difficulties in the Arduino connection process in the process of building an automated system, 3D model Arduino and moisture-related parts, such as soil moisture sensor, relay module, and water pump, in 3D Max. The pin connection process is produced in animation. The completed 3D modeling is uploaded to Unity, and pre-made images are used as markers to create augmented reality Arduino learning content that runs on smart devices. In Unity, where production is completed, use the Build menu to create an Android app and execute the final augmented reality Arduino learning content. Figure 3 is an augmented reality-based Arduino learning content design process.

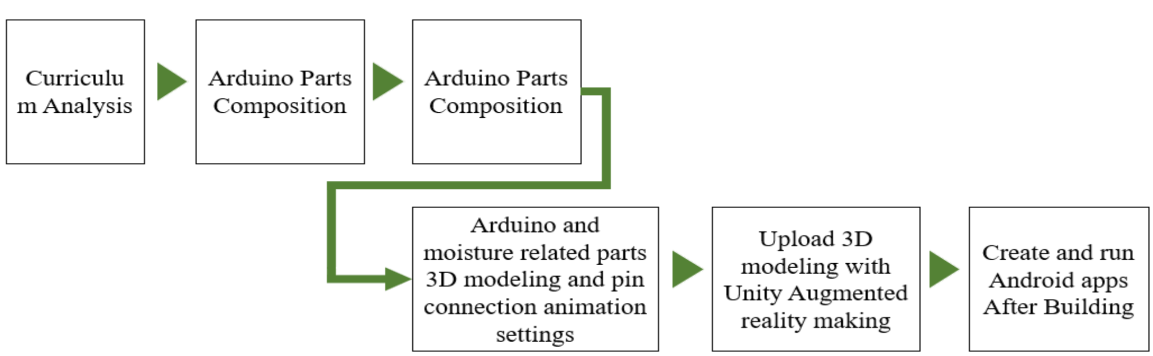
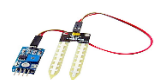


Figure 3. Design Process of AR based Arduino Learning Content

Table 1 shows the budding process of kidney beans for the automation of the experiment, and the composition of Arduino parts is as follows. The soil moisture sensor checks the moisture of kidney beans, checks the moisture of the kidney beans, and automatically supplies moisture through relay modules and water pumps if the moisture content is insufficient.

Table 1. Composition of Science Experiment Automation Parts

Arduino Parts Composition	Image	Function
Arduino Uno		Connect with parts and run results
Soil moisture sensor		Check the amount of water in the soil
Water Pump		Water supply
Relay Module		Control the power of the water pump

Augmented reality was designed after setting an animation explaining the location of the pin to be connected with 3D modeling of Arduino, soil moisture sensor, relay module, and water pump. The purpose of the augmented reality content designed in this paper is to help students who are new to physical computing understand the concept and use of the Arduino board. Augmented reality Arduino learning content is executed by projecting the corresponding sensor image onto a smartphone when using Arduino and showing the pin connection locations of the Arduino board and components. The pins connecting the Arduino board and moisture-related components are visually expressed, and the process of connecting the sensor pins and the board pin numbers is expressed through a repetitive animation. Augmented reality educational content is used as reference material for student pin connection during coding education. Figure 4 is the overall structure of augmented reality based Arduino learning contents for ICT education.

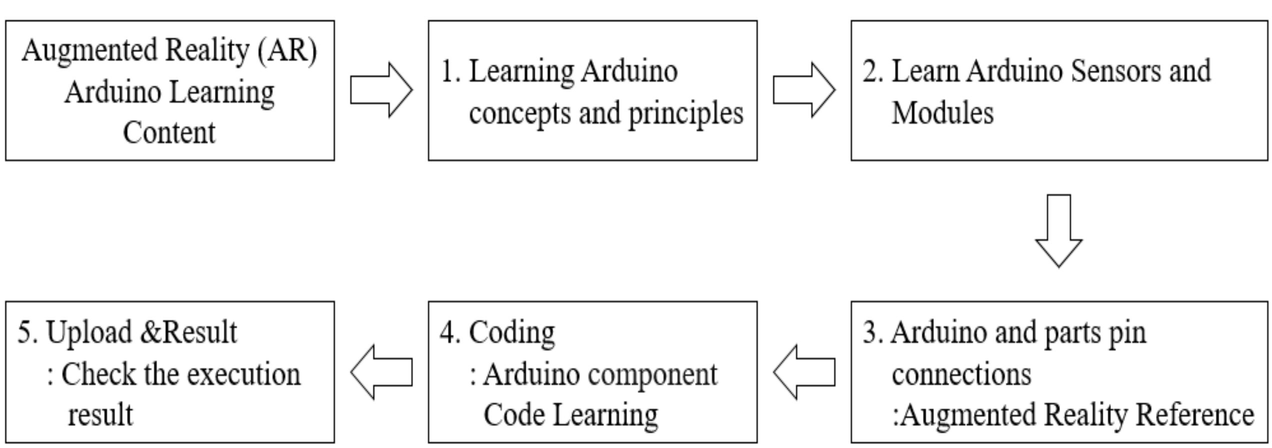


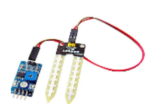
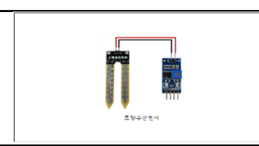
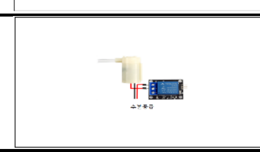
Figure 4. The overall structure of Arduino learning contents based on AR for ICT education

Physical computing learning consists of a total of 5 parts. The first explains the concepts and principles of the Arduino board, and the second learns the uses of soil moisture sensors, relay modules, and water pumps. Third, using a smartphone, you can run 3D augmented reality in which the animation of the pin connection process between the Arduino board and component parts is repeatedly executed to complete the hardware of the Arduino and components while watching the animation of the Arduino pin connection. Augmented reality Arduino learning content repeatedly runs animations of the pin connection process between Arduino and components, which helps understand the hardware construction process. Fourth, learn the code that implements the execution code of the Arduino board and its components in C language. Fifth, upload the code to the Arduino board to confirm the construction of an automated system for the 'Growing Gangnam Beans' experiment. The augmented reality Arduino learning content designed in this paper increases understanding of physical computing learning using Arduino, increases immersion, and improves interest.

3.2 Design of AR learning content components

Table 2 is an augmented reality execution image when connecting the pins of the Arduino and soil moisture sensor, and an augmented reality execution image when connecting the pins of the water pump and relay module, and is a marker source image for executing.

Table 2. AR tracking image

Arduino Parts Composition	Arduino Parts	AR Tracking Image source
Soil moisture sensor		
Water Pump and Relay Module		

The pin-connected animation of the AR Arduino learning content for the automation experiment of 'growing Gangnam beans' is as follows. Connect the soil moisture sensor and Arduino. The connecting pins are as follows. The GND pin of the soil moisture sensor is connected to the GND of the Arduino, the VCC pin is connected to 5V, and the A0 pin is connected to the A0 pin of the Arduino. The GND pin is connected to the GND of Arduino, the VCC pin is connected to 5V, and the A0 pin is connected to the A0 pin of Arduino. The connection pin between the water pump and Arduino connects the VCC pin of the water pump to Arduino's No. 5 pin, and the GND to Arduino's GND. The connection pins between the relay module and Arduino are: NO of the relay module is connected to VCC of Arduino, COM pin is connected to VCC of water pump, GND is connected to GND of Arduino, VCC is connected to 5V of Arduino, and S is connected to pin D4 of Arduino. Table 3 shows the connection pins for Arduino and components.

Table 3. Connecting pins to Arduino and components

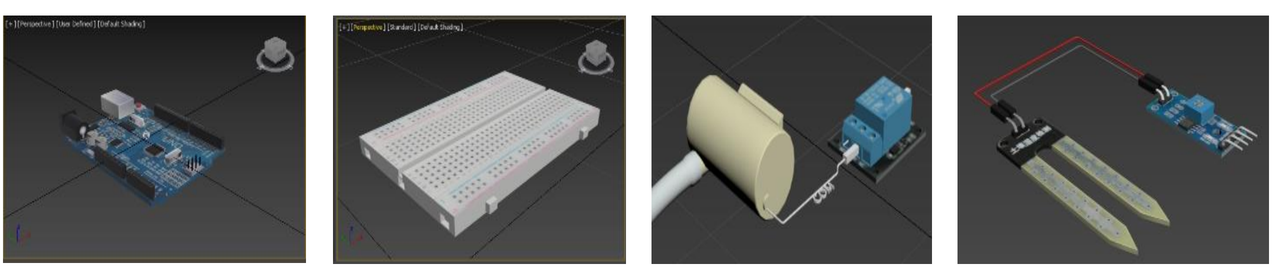
Arduino Parts Composition	Connecting Pin	Arduino Pin
Soil moisture sensor	VCC	5V

	GND	GND
	D0	-
	A0	A0
Water Pump	VCC	Relay Module(COM)
	GND	GND
Relay Module	NO	VCC
	COM	Water Pump VCC
	NC	-
	GND	GND
	VCC	5V
	S	D4

4. Implementation of AR based Arduino Learning Content

4.1 Implementation of 3D object modeling

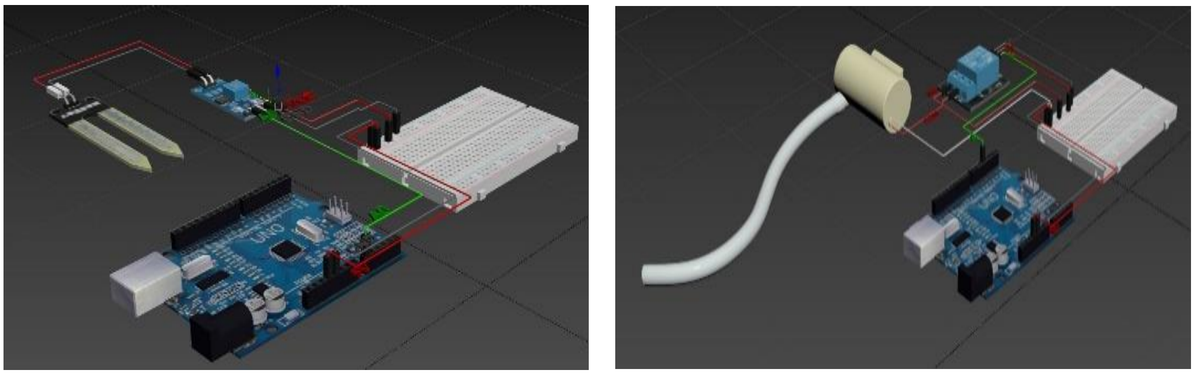
In this paper, 3D objects were implemented to implement augmented reality. The implementation process is as follows. Referring to the Arduino board, use shapes such as boxes, cylinders, and capsules in 3D Max to show the Arduino board's built-in processor, exterior, soil moisture sensor, water pump, and relay module. Photos of the top, bottom, left, and right of the actual parts. Create a material by imaging it. Apply the material of the final 3D modeling. In Figure 5, (a) is the Arduino Uno implemented in 3D Max, (b) is the brake board, (b) is the water pump and relay module, and (d) is the soil moisture sensor.



(a) (b) (c) (d)

Figure 5. 3D object modeling

After setting the material, animation is applied to the process of connecting the jumper cable to Arduino and each pin. The animation is set to a total of 360 frames, and after activating Autokey, set the animation of the process of connecting the jumper cable and each pin in units of 40 frames starting from 120 frames. After rendering, where animation settings are completed, export the ‘fbx’ file including animation and complete the final 3D modeling for augmented reality production. Figure 6 is the final 3D modeling with animation set to be used in augmented reality implementation. In Figure 6, (a) is the final 3D modeling of the water pump and relay module with animation of the pin connection process, and (b) is the final 3D modeling of the soil moisture sensor with animation of the pin connection process.

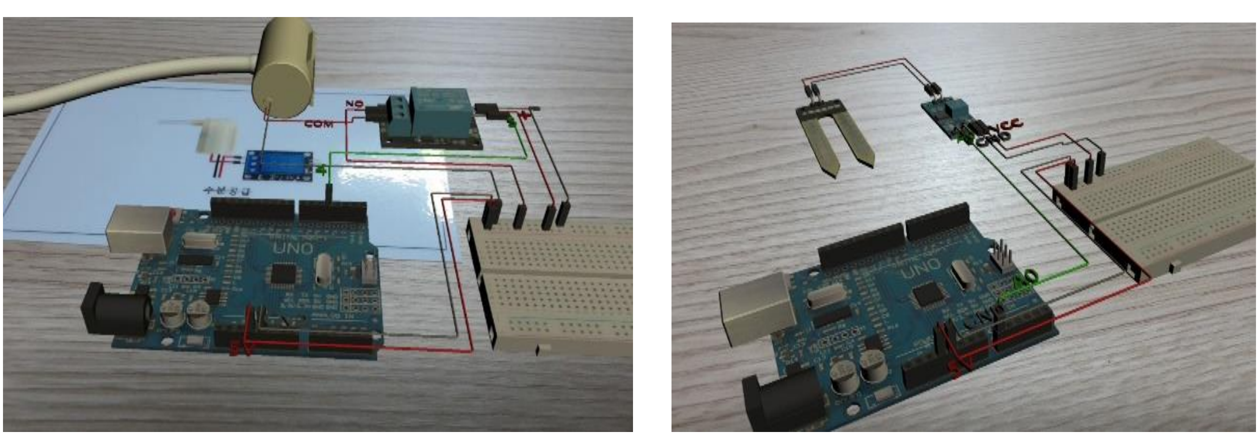


(a) (b)

Figure 6. 3D animation modeling

4.2 Implementation of AR based Arduino learning content

Unity tools were used to create augmented reality content. The animation of the pin connection process and the augmented reality implementation process are as follows. Create the C01 and C02 folders in the 'Model' folder to import the source image. Upload 3D objects to each folder. In the Hierarchy window, add AR Session and AR Session Origin under the XR menu. To activate the image tracking function, select AR Session Origin and click 'Add Component' in the Inspector window to add AR Tracked Image Manager. After selecting the Reference folder, create ReferenceImageLibrary to be used in Tracked Image Prefab. Click 'Add Image' to register the source image for augmented reality execution by dragging it from the Image folder to Texture 2D format and set Specify Size to 0.5. Register the created ReferenceImageLibrary in the Serialized Library of the AR Tracked Image Manager window. After creating the GameObject, move 3D Modeling to the GameObject subdirectory, create a Prefab by dragging the GameObject to the Prefab folder, and register it in the Tracked Image Prefab to complete the augmented reality Arduino learning content in which the pin connection process is executed. Figure 7 is the final implementation screen of the augmented reality Arduino learning content. In figure 7, (a) shows augmented reality content for the soil moisture sensor for moisture detection, and (b) shows a screen that implements animations for the water pump and relay module in augmented reality.



(a) (b)

Figure 7. Augmented reality content execution screen for Arduino education

5. Conclusion

In this paper, augmented reality-based Arduino educational content was produced. The learning content produced in this paper solves the pin connection problem that lecturers and learners find most difficult when teaching ICT using Arduino and seeks new methods for effective delivery of ICT education. AR based Arduino learning content solves the difficulty of connecting pins related to Arduino and provides a more accurate learning experience for both educators and learners. Through this, we will be able to improve understanding and practice skills in ICT education and improve the quality of physical computing education. Students implement an automatic water supply device for an experiment in the ‘Growing Gangnam Beans’ curriculum in the science curriculum by referring to augmented reality-based learning content that animations the pin connection process of Arduino and water-related parts. Education using augmented reality-based Arduino learning content automates the experiment environment of learners' science subjects, and through this process, the accuracy of the experimental results will also be improved. The combination of augmented reality based Arduino learning content with the convergence of ICT education and science subjects will be able to change the existing traditional method of education. Additionally, the use of new technologies that combine reality and virtuality will make it easier to understand and apply complex scientific concepts and ICT technologies. The combination of Arduino and Augmented Reality is expected to improve students' creativity and problem-solving skills, while inducing interest in technology, presenting future-oriented learning methods, and improving the quality of education through the convergence of ICT education.

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