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# THE EFFECT OF OUTDOOR INQUIRY PROGRAM FOR LEARNING BIOLOGY USING DIGITAL TWIN TECHNOLOGY

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**Abstract.** *The outdoor inquiry has a significant meaning in learning biology, but it has a problem that is difficult to be frequently implemented in the school garden due to causes. On the other hand, alternative activities using the virtual world have been proposed, but due to a lack of reality and passive use, the continuity of the activities is low, and there are doubts about the effect on the affective domain. Therefore, this study developed a class program in which students directly construct a virtual world and explore living organisms using the digital twin platform. Also, researchers checked the changes in students' affective domain according to the application of the learning program. A teaching and learning strategy for learning biology was composed through the review of research and statistical analysis performed changes of the affective domain. The experimental group changed more positively than the control group in the affective domain of learning biology due to replicating the school garden so that living organisms can be explored indoors and outdoors. Consequently, class programs for learning biology can positively affect the learner's affective domain when it is provided with improved realism by digital twin, self-directedness, and autonomy to compare real space and object.*

**Keywords:** *affective domain, digital twin, learning biology, outdoor inquiry, school garden, virtual world*

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## Introduction

In the 21st century, rapid digitalization has progressed throughout society, but changes in education have been slower than in other fields. In science education, there have been attempts to apply various digital technologies for effective learning from a convergence perspective, such as using the virtual world and artificial intelligence. Metaverse technology such as virtual and augmented reality have been applied to dangerous experiments, repetitive attempts or pilot tests, ecosystems in cyberspace, and museum experience programs. However, due to one-time activities that aroused interest, difficulties in applying to each school class due to technical barriers to entry, and negative perceptions of digitalization, it did not lead to significant changes or an overall paradigm shift.

On the other hand, the sudden COVID-19 pandemic has acted as a factor accelerating the digitization of the social system, including education, and has called for a radical paradigm shift in education (Fauville et al., 2021). It also served as an opportunity to reveal the digital infrastructure gap held by schools, the digital teaching and learning competency gap of teachers, and the digital literacy gap of students (Reimers, 2022). On the other hand, the change in the educational paradigm using Edutech enables time-space expansion of learning by continuously and actively utilizing advanced technology such as artificial intelligence and virtual reality in learning activities beyond the level of experience for simple interest (Holmes et al., 2019).

Post-pandemic education requires different learning methods in offline and online contexts, and expanding educational activities using virtual space presents new possibilities for science teaching and learning. In particular, learning biology has the new possibility of teaching and learning to utilize the virtual world online compared to other scientific education areas. Learning biology has successful learning effects when indoor and outdoor activities are carried out in parallel or together, and activities to observe and explore living organisms in a real natural environment are known to have various effects on learners' affective areas (Wells et al., 2015). It is generally agreed that providing outdoor inquiry activities is essential for learning biology, but the actual performing of outdoor activities is complex due to practi-



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cal limitations (Behrendt & Franklin, 2014; Dillon et al., 2006). In order to observe and explore various organisms outdoors, one needs help not only from experts or biological guides but also students must be able to use illustrations or auxiliary materials to expect the effect of inquiry learning outdoors. The physical collection has recently been limited for normative reasons and bioethics, and visiting time is limited due to the nature of the outdoors (Behrendt & Franklin, 2014).

Alternative learning activities using metaverse, such as indirect experience videos and virtual experience activities, are provided to compensate for this problem, but simply presenting digitized three-dimensional spaces has limitations in conveying diversity and reality in the real world. In addition, the high level of digital literacy and professional equipment required to create virtual spaces is another reason for the low utilization of metaverse technology in the educational field. Ultimately, the digital gap between students, teachers, and students can also affect bio-learning activities using the virtual world. Therefore, teachers should try to provide an alternative environment where students can freely continue to explore and learn about living organisms by overcoming the limitations of outdoor inquiry activities. Then, what is some alternative learning method to overcome various limitations like the digital divide in education using metaverse, and what teaching and learning strategies can enhance students' interest in learning biology and learning sustainability?

### *Digital Twin as an Alternative for Learning Biology Outdoor and Indoor*

Recently, learning using the metaverse platform has been proposed as an alternative activity that can compensate for providing an interactive experience similar to reality (Dwivedi et al., 2022; Kuznetcova et al., 2019). Metaverse is generally used as a term for an environment in which one can interact and communicate with others in a virtual space. Generally, the metaverse can divide into four types; virtual reality (VR) creates a three-dimension space similar to reality, augmented reality (AR) can augment and possibly brings digital content to the real world, life-logging records and shares real-world data in digital space, and mirror-world moves the real world to virtual space (Tilak et al., 2020).

Among the types of the metaverse, virtual reality is a digital implementation of a similar space to the real world and has the advantage of providing a sense of immersion by interacting with content. In particular, it can provide a sense of space and freedom, so teachers or students can easily visit and experience places with spatiotemporal constraints in cyberspace. On the other hand, it is difficult for anyone to implement it quickly because virtual reality requires 3D rendering technology, and it is only possible to add or modify various contents if they are experts (Kelton, 2007; Suzuki et al., 2020).

The virtual world can provide a sense of immersion as a space that imitates the real world, but despite various advantages, the virtual world generated by prior VR technology does not reflect the real-world information equally, like length, width, and size (Tao et al., 2019). However, digital twin technology that implements real-world information equally in the virtual world is providing a solution to these deposits of virtual reality due to recent improvements in image processing hardware and artificial intelligence technology (Liu et al., 2021; Tao & Zhang, 2017).

The digital twin is a virtual replica that generates the same output value as a physical object for an input value and can define as an algorithm that describes a physical object's potential or actual components (Grieves & Vickers, 2017; Söderberg et al., 2017). The digital twin concept includes the components of an existing physical object, a replica of a virtual world, the transfer of data from a physical object to a virtual replica, and the flow of data from a virtual replica to a physical object (Thelen et al., 2022). The digital twin was proposed 20 years ago but was first implemented in 2011 to reproduce aircraft rescue behavior digitally (Tuegel et al., 2011), and has since been recognized as a method for product management and production in various fields and is now recognized as a significant high-tech technology leading the future industry (Lu et al., 2020).

The development of big data and artificial intelligence expands the range of digital twins and enables the construction of twins by digitally replicating physical entities, processes, and systems, such as living and inanimate objects. In addition, real-time monitoring is possible by improving the interconnection between real-world physical objects to share data with the goal of optimization and digital replicas in cyberspace (Rathore et al., 2021). The digital twin is a technology that enables innovative work, monitoring, diagnosis, and prediction in various fields, and its utilization in education is very high. In particular, in terms of mediating online learning and authentic learning, digital twins have the advantage of expanding opportunities for practice or hands-on learning to infinity (Rathore et al., 2021; Sepasgozar, 2020).


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Therefore, utilizing digital twin technology can overcome the limitations of one-time activities, passive experiences, and a lack of realism in outdoor learning biology using the metaverse. Furthermore, if the spaces and characteristics of living organisms in outdoor inquiry activities are replicated in the virtual world, continuous learning and monitoring can also be achievable indoors.

*The Strategy of Metaverse Utilization for Learning Biology Outdoor and Indoor*

In creative thinking, learning is effective when experiencing indoor learning activities for knowledge generation and understanding concepts and collaborative inquiry activities for practical experience (Pulgar, 2021; van der Zanden et al., 2020). Especially in the case of learning about living things, the learning effect is excellent when indoor and outdoor activities are combined, and activities of observation and exploration of living organisms in the natural environment are known to provide a positive effect on the learner's affective domain (Wells et al., 2015). Therefore, indoor and outdoor activities for learners should be necessary for the practical application of learning biology. However, some restrictions exist, like the lack of teachers' expertise in outdoor activities, the difficulty of on-site visiting, and the activity time constraints (Behrendt & Franklin, 2014; Dillon et al., 2006). New methods using virtual experience were suggested as alternative activities to overcome these problems shown during field trips. However, evaluating the use in the school field is inconsistent regarding continuity and effectiveness (Behrendt & Franklin, 2014).

After the COVID-19 pandemic, the metaverse expanded to everyday use in various fields, and the possibility of educational usage is newly emerging (Kuznetcova et al., 2019). These days, if the biology teacher can effectively apply the interactive learning method in the virtual world to the real world, they could exceed the spatial limit of learning activity. For example, the learning effect could improve on the class having spatial difficulty due to the limited activity places, such as exploring living organisms in the field.

Considering the utilization of the metaverse in the educational field, biology teachers should be able to build a virtual world quickly, and students should be able to operate various contents and functions of the metaverse. Also, teachers can save time and expand the activity space required for biology inquiry and learning through the metaverse. If teachers want to investigate and classify organisms in a convergent method using the metaverse, they could go outdoors with students to explore and collect them after the hands-on learning activity. For the construction of the virtual world, they should overcome various limitations, such as the selection of the inquiry site, the method of transportation, the presence or absence of target organisms, a preliminary survey of the visiting route on-site, damage to the ecosystem due to organism collection, and weather on D-day. Also, students and teachers in the virtual world could conduct social interactions between users and content.

Therefore, this new interaction method affects the learner's affective domain, like motivation, attitude, and task commitment (Akour et al., 2022; Stokel-Walker, 2022). Therefore, it is necessary to organize and utilize the virtual world for places teachers and students can quickly and frequently visit to combine learning biology indoors and outdoors easily. Also, it needs to consider the effect on students' affective domain in terms of teaching and learning and organize classes using the virtual world according to the school's situation and the student's characteristics.

*Research Aim*

It is essential to develop teaching and learning methods to guide the effective use of digital technology to respond appropriately to changes in the educational field, such as the increased possibility of activities in cyberspace due to the expansion of digital technology in education (Petrie, 2022; Vincent-Lancrin, 2022). Also, class activities with various digital technologies can provide customized learning opportunities in learners' problem-solving process experience by expanding learners' information search and utilization (Collins & Halverson, 2018; Yair et al., 2001). In this context, it has made challenging attempts to develop learning programs using advanced digital technologies such as artificial intelligence and the metaverse in various teaching areas. Also, recently with the development of AI technology, in the case of metaverse platforms, entry barriers to using innovative technologies using digital twin technology, a concept of replicating real-world spaces and objects to virtual spaces, are decreasing (Liu et al., 2021; Rathore et al., 2021).

If anyone can easily replicate real space in the virtual world with the development of artificial intelligence technology, teachers and students who do not have professional digital knowledge can implement the virtual world and effectively use it in classes. Then, how can anyone easily use the virtual world in their classes without


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professional knowledge as an alternative activity to overcome the limitations of outdoor activities in biology classes? Therefore, the researchers established the following research aims to address these questions.

First, it was intended to create a virtual world with a high sense of reality by using the digital twin and to organize a class program that allows students to learn biology. Students should be able to easily create the virtual world without using complex digital devices and technologies to solve the problem of high entry barriers in using the virtual world. In addition, to resolve the lack of reality, it is necessary to replicate the size of the space, the characteristics and size of the object, and the shape of the space. Therefore, researchers set the aim to create a virtual replica using a digital twin platform by simple digital devices in the school field and organize a class program that explores living things.

Second, it was organized into an experimental group and a control group to confirm the main effect and group effect to confirm the impact of the experience of digital twin classes on the student's affective area. Exploration of living things outdoors can affect the learning motivation and tendency to continue learning. However, the positive impact on students' affective areas is somewhat low or case-by-case due to low learner initiative and difficulty in solving professional problems. In addition, experience in learning biology using the virtual world also has a lower noticeable effect on the student's affective domain because of a low sense of reality and lack of interaction. Therefore, researchers set the goal to analyze the main effect of the experience of learning biology programs indoors and outdoors on the student's affective domain and the group effect of using digital twin technology.

## Research Methodology

### *General Background*

It can induce immersion in learning motivation and activities to students when learners are free to organize, control, and control objects in science experience activities using the virtual world (Dede et al., 2017; Psotka, 1995). In this context, it was intended to build a virtual world using a metaverse platform with digital twin technology replicating and manipulating the real world's space in cyberspace. In addition, students can freely explore any time and place when they can easily access living organisms outdoors (Subramaniam et al., 2018), and foster a positive attitude toward students' biological and ecological environment when outdoor experience activities are easy to access (Farmer et al., 2007). Therefore, the garden plant in the school was selected as a digital twin target as a place where data on the space corresponding to the physical object that is the target of the digital twin can be continuously obtained. This study set up research aims to clarify the utilization possibility and the effect of digital twin utilization learning programs on students' affective domain in biology class. Most of all, students must have the essential skill of digital literacy for generating and operating the digital twin, and they need to be taking the biology curriculum to inquire about living organisms. In addition, since it is necessary for anyone to easily create and operate a digital twin, high school students who freely handle digital devices such as smartphones and have basic knowledge of biology were selected as the subjects of the study.

### *Participants*

From the perspective of creating digital twins, students need a certain level of digital device knowledge to acquire image data for virtual space construction self-directedly, adjust the location of virtual space in detail compared to physical space, and upload interactive content. In addition, basic knowledge of identification and classification is required for students to produce bio-related content to be presented in a virtual space. According to these needs, high school students in Korea aged 18 or older were recruited per this study's digital twin software policy. While most schools disagree with consistent classes using the digital twin, forty-four students studying at school A in South Korea participated in this study. The researcher received the school's official permission and students' voluntary research participation. Therefore, two classes in that school were recruited as application places to test research aims.

Forty-four students from a public school in Korea participated in class activities to replicate school garden spaces and organisms in digital spaces and to check the effect of learning biology programs on students' affective areas. All the students were taking 'Biology II' courses and completed the 'Biology I' course, which included a national curriculum on biology in Korea. Students were divided into different classes to ensure interaction and team activities in students' activities, and the students were divided into a plant classification program group and


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a plant classification class group using digital twin technology to check changes before and after the learning program experience.

The purpose and contents of the study were explained to all participating students before conducting the class program and pre-examination, and students submitted a voluntary participation agreement. The response to pre-test results was obtained by providing a survey paper to confirm changes in the affective domain before starting the first activity, and students' follow-up responses were obtained using the same survey after the last class activity. Among the students who responded, three were omitted from the analysis due to partially participating in the class for absence or some test questions. Therefore, the results of the pre-post response of twenty-one people in the control group who conducted plant classification classes and twenty people in the experimental group who conducted plant classification classes using digital twins were used for analysis.

An introductory survey was conducted during the pre-test period to confirm the individual metaverse experiences of the students who participated in the study (Table 1). All the students had experienced a metaverse, which was mainly divided into the first experiences in elementary or high school. 68.29% of students were experiencing metaverse in game type, while 31.71% of students were experiencing learning or other types. In response to the preference for metaverse, 73.17% said good, and no student said dislike. In addition, 56.1% of students frequently contacted a metaverse, and only 2.44% answered that they rarely contacted it. Therefore, most of the students in the study were familiar with the metaverse, and only a few had little contact with the metaverse. The school to which the students participated in the study belonged had a classroom equipped with three 360° cameras, eight laptops, and twenty-four tablet PCs as digital devices for use during class, and students had access to the wireless Internet. Also, all students carried smartphones and were available whenever necessary.

**Table 1**
*The Ratio of Participant Characteristics of Metaverse*

| Experience period | | Experience type | | Preference | | Contact frequency | |
|---|---|---|---|---|---|---|---|
| Answer | % | Answer | % | Answer | % | Answer | % |
| Elementary school | 43.90 | Game | 68.29 | Very good | 43.90 | Very often | 19.51 |
| Middle school | 7.32 | SNS | .00 | Good | 29.27 | Often | 36.59 |
| High school | 48.78 | Learning | 26.83 | Moderate | 21.95 | Moderate | 31.71 |
| | | Etc. | 4.88 | No so good | 4.88 | Occasional | 9.76 |
| | | | | Dislike | .00 | Rarely | 2.44 |

*Note.* The ratio was calculated using the response results of 41 students finally used for data analysis and is a percentage of the ratio of the number of respondents to all respondents.

*Construction of the Learning Program*

Related prior studies were analyzed to develop project activities to explore plants living in school gardens using digital twin technology, and learning steps, strategies, and contents were presented. Plant objects placed in virtual spaces were searched and identified in advance for the list of plant species found in the actual school garden so that students could use them. The species and generic names of plants were presented based on the plant list of the National Institute of Biological Resources, and some species that were immature or could not be identified due to damage to plants were excluded.

In order to formation of the learning program in which students directly implement virtual spaces and experience inquiry activities, the learning process was decided through consideration of outdoor inquiry programs and creative problem-solving processes. In addition, teaching and learning strategies and learning contents were presented using the characteristics of the metaverse platform to give students the degree of freedom to lead activities and interactions. To construct a plant inquiry learning program using digital twin technology, various research


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related to scientific problem-solving processes and social interaction were analyzed, and teaching and learning strategies were derived by considering outdoor experience activities and research related to the educational use of the metaverse.

The scientific inquiry resulted from modeling scientists' problem-solving processes from the learning perspective (NRC, 2000). Also, the scientific problem-solving process can be divided into the discovery context to generate explanatory knowledge and the verification context to confirm the suitability of the generated knowledge (Klaur et al., 2002). In the cognitive constructivist perspective, problem-solving processes can be divided into problem definition and information discovery, searching for solutions to reach goals, generating and evaluating solutions, explaining problem-solving status, and value judgment through communication (Wang & Chiew, 2010). From this perspective, NSES suggests that the scientific inquiry process in science classes consists of question definitions from current knowledge, brief explanations or hypotheses, simple investigation planning and composition, evidence-based explanations, consideration of other explanations, delivery of explanations, and verification of explanations (NRC, 2000). Therefore, scientific inquiry activities can be divided into the discovery of scientific problems, tentative explanations, and verification of tentative explanations of discovered problems. The discovery process includes exploration and generation of information or inquiry problems provided to learners; the verification process includes evaluation and explanation of solutions, and recognition of value judgment and communication on inquiry results.

The plant's inquiry learning process outdoors is generally divided into before outdoor activity, outdoor activities, and after outdoor activity (Braund & Reiss, 2004). On the other hand, inquiry activities in virtual space present detailed learning steps such as scientific observation and classification, learning biology, pre-survey, in-virtual space exploration, and post-virtual activity organization (Rowe & Humphries, 2004; Subramaniam et al., 2018). In addition, it is necessary to construct a relationship between the virtual space and the outdoor activity of plants for effective learning (Potkonjak et al., 2016). According to these discussions, plant inquiry using the digital twin can consist of discovering a problem or object on scientific inquiry, exploring digital twin technology for scientific inquiry, generating the digital twin about outdoor space, and applying scientific inquiry activity.

The discovery step corresponds to the preparation process for outdoor exploration and digital twin data collection of plants living in the school garden. In particular, this step is the process of discovering problems or objects on scientific inquiry, and students directly establish plans for outdoor inquiry and learn basic knowledge for plant observation and identification indoors. Regarding preparation for outdoor plant inquiry, it includes information on search paths, habitable plants, and investigation methods in the school garden. Also, regarding digital twin data acquisition, available camera tools, filming methods, and filming locations are set in advance. Students are allocated to team members who individually contribute to each task for convergent problem-solving that shares the same goal in collaborative activities.

The exploration step corresponds to plant exploration and data acquisition of digital twin outdoors according to the plan established in the previous step. The students discover and identify plants in the school garden following the plan, including exploration routes and methods, and record the plants' characteristics using mobile devices. At that time, three-dimensional spatial photography for digital twin data acquisition is performed, and image correction is practiced if real-time correction is required about image data. If an error in direction or position occurs after acquiring a three-dimensional image, the immediate correction is more effective for digital twin generation than post-correction. Team activities like finding and identifying plants and taking and correcting three-dimensional spatial images consist of a divergent problem-solving process for focusing on individually assigned tasks for outdoor inquiry.

The generation step is exploring digital twin technology students will use to solve scientific problems and create the digital twin themselves. According to cognitive constructivist perspectives, cognitively structured experiences correspond to essential learning factors (Matthews, 2000). In addition, learning activities using the virtual world can improve learning motivation and induce immersion in activities when learners are free to directly adjust and control objects (Dede et al., 1999; Psotka, 1995). From this point of view, the main activity of the student is operating the software to correct and create virtual space. Artificial intelligence in the platform automatically creates a 3D digital twin of a school garden when the 3D spatial image data taken in the previous step is uploaded to the cloud through the app or web page.

Anyone can easily create a 3D space, but detecting intentional and unintentional biases contained in spatial data and correcting and supplementing it must be performed to prevent distorted results in processing data using artificial intelligence (Akter et al., 2021; Byrne, 2021). Therefore, the broad scanning of the created virtual space using a mini-map and sky view function to correct image data is performed for discrimination, whether distortion


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or errors in space. Also, the structure of the space, the description of the characteristics of the plant, excluding the shape and location of the plant, and additional photos, videos, web links, Etc., should be added directly by the student using the tag function. In addition, virtual tour functions can be used in digital twins, so students can plan and organize virtual tour orders and content to share results with others. Therefore, this step composes divergent problem-solving activities with individual goals to organize data, such as creating interactive content, explanations, and observation resulting in the created 3D digital twin space.

The application step is a communication process that announces plants living in the school garden using digital twins and shares virtual tours for plant introduction creatively organized by student groups. The advantage of education using the virtual world is that it shows multiple accessibility and invisibleness (Carvajal et al., 2020), and it is necessary to provide a sense of reality by providing interchange opportunities that deal with the virtual and real world at the same time for practical educational effects (Potkonjak et al., 2016). Therefore, students must present and share the results by group using the results of plant exploration conducted in the exploration stage and the data attached to the digital twin space in the creation stage.

During this process, students create URL links that access digital twins, provide virtual tour functions, and share them with students so that other students can experience and compare individual virtual and real worlds. In addition, from the perspective of developing students' creative thinking and transferring learning, investigating plant images establishes and presents by utilizing the advantages of digital twins for school gardens. For example, the measurement function provided by the digital twin platform can be used to measure the height of trees, the expansion width of tree branches, the distribution area of certain plant species, and the speed of expansion of plant species habitats over time in cm.

Unlike the experimental group, the control group, which does not use Digital Twin, uses the results to produce information on plants and exploration methods living in the school garden using digital collaboration tools such as cloud document tools and presentation production tools and present and communicate by the team. Therefore, both groups are active in the same area and plant species, but the experimental group introduces the results of the inquiry through the implementation of the virtual world, and the control group presents the results as a presentation (Table 2).

**Table 2**
*Learning Content and Method between Experimental Group and Contrary Group*

| Learning step | Experimental group | Control group |
|---|---|---|
| Discovery | · Basic knowledge learning for plant observation and identification<br>· Planning of plant exploration outdoor activities<br>· Setting observation paths and methods for plants in the school garden<br>· Camera preparation for spatial image acquisition<br>· Setting the method and the point of 3D image acquisition | · Basic knowledge learning for plant observation and identification<br>· Planning of outdoor plant exploration activities<br>· Set searching paths and observation methods for habitable plants |
| Exploration | · Exploration of plants according to the inquiry plan<br>· Observation and recording of the plant features with a mobile device<br>· The identification of found plants (using assistant AI and mini-illustration book)<br>· The Acquisition of the 3D image and calibration by mobile device | · Exploration of plants according to the inquiry plan<br>· Observation and recording of the plant features with a mobile device<br>· The identification of found plants (using assistant AI and mini-illustration book) |
| Generation | · Operation of the digital twin platform and authoring app<br>· Uploading of 3D images to the cloud and Generation of the digital twin as the virtual space<br>· Checking and correcting distortion or error in space image<br>· Adding tags in virtual space (plant feature description, photos, images, web links, Etc.)<br>· Organization and presentation of the virtual tour of each group | · Determination of how to present the results of plant exploration<br>· Generation of the presentation contents (descriptions, photos, and clips of the plant)<br>· Exhibition of boards, infographics, Etc, about inquiry results. |
| Application | · Sharing of the digital twin URL links<br>· Introduction of the virtual tour created by each team<br>· Presentation of plants living in the school garden using digital twin<br>· Presentation of ideas of plant inquiry when applying the digital twin<br>· Self-assessment and peer review among teams | · Introduction of presentation materials produced by teams<br>· Presentation of plants living in the school garden<br>· Presentation of ideas for another plant inquiry<br>· Self-assessment and peer review among teams |

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*Application of the Learning Program*

New innovative technologies can spread quickly through networks, but the personal gap in utilizing technology is so large that simplification and guidance in the methodological aspects of utilizing technology are needed (Reimers, 2022). Using advanced technologies in science classes should focus on instrumental use for the efficiency of interactive learning rather than on us as a purpose (Chen et al., 2020; Guan et al., 2020), and providing learners with an experience of taking the lead can have a positive impact on the defining area of learning (Dede et al., 2017).

It is necessary to check how it affects students by confirming the degree of change in affective areas such as learning motivation, task obsession, and learning attitude of students who have experienced classes in teaching and learning programs developed according to this perspective. To this end, six classes per two hours were organized to be provided to student groups participating in plant inquiry learning programs using digital twins and classes to be provided to student groups participating in general plant inquiry classes. Two science education experts and four biology teachers were asked to review the validity of the class guidance plan, including the learning process and strategy of the class program, and the content validity index (CVI) was 94%, confirming that it was an appropriate composition.

A total of 12 hours of classes were conducted in the experimental and control groups, and 3 hours were conducted for each stage according to the class stage leading to discovery, exploration, generation, and application. The artificial intelligence app, which will be used to explore plants in outdoor activities, is installed on all students' smartphones before class to be used immediately as soon as the activity begins. In the case of the experimental group, to save time in creating a digital twin, all devices were prepared in advance to use the school's tablet pc and 360° camera. All students freely used the tablet PC provided by the school and used a laptop for team activities.

*Generation and Operation of Digital Twin*

The generation of the digital twin was performed using Matterport App (Matterport Inc.) to construct a virtual school garden space for students. Among various metaverse platforms that use digital twin technology, it is easy for users to access and operate for virtual reality generation, and it can be implemented just on mobile phones (Ramakrishnan et al., 2021; Sulaiman et al., 2020). Above all, digital twin technology through artificial intelligence can accurately express the size and location of objects or spaces present, even if it is highly realistic because it can be measured in cm. In addition, teachers or students can add content in the virtual world by tagging interactive content such as text, images, and videos, and various functional software like machine learning artificial intelligence can be called and used through a link to a web page.

VR platforms such as Google Street can create virtual spaces, but an additional program must use to replicate real-world objects in the cyber world through digital twins. On the other hand, it is optimized for quickly creating digital twins for buildings in virtual space. Outdoor environments can replicate if buildings, walls, columns, and trees can be used as a reference point for accurately recognizing surrounding objects. In addition, when the user uploads a 3D scan image of a target space aimed to replicate to the web cloud, artificial intelligence automatically configures an optimized replication space. Above all, the fact that 3D scanning taken with mobile phones and 3D cameras can quickly be composed in three dimensions increases educational utilization. In addition, users can attach text, images, videos, and web links in the replicated virtual space using the VR interface, and collaboration activities are possible through various functions.

The user needs to create an account for a free digital twin space, and he could use multiple spaces and user accounts by subscription. Even if it is possible to post the 3D space to other people by providing a link to a space, a paid subscription could be required to edit the many spaces simultaneously. It would help if students prepared a camera or mobile phone to shoot target space to compose a digital twin space. However, a 360° camera can use an existing camera to capture, and it is also possible through the camera of a mobile phone can install the app. If the user uploads the 2D Capture images of the target space to the web cloud, then automatically constructed into 3D digital twins through AI. Therefore, students need not study and train in the knowledge of VR construction. The artificial neural network deep learning model for the digital twin can be used without separate payment; when the number of captured images increases, the time required to check the results can be longer. When using a mobile phone, the position to focus on is displayed when capturing space in place so that students can hold it with their hand and shoot, but a tripod is required to use a 360° camera (Figure 1).


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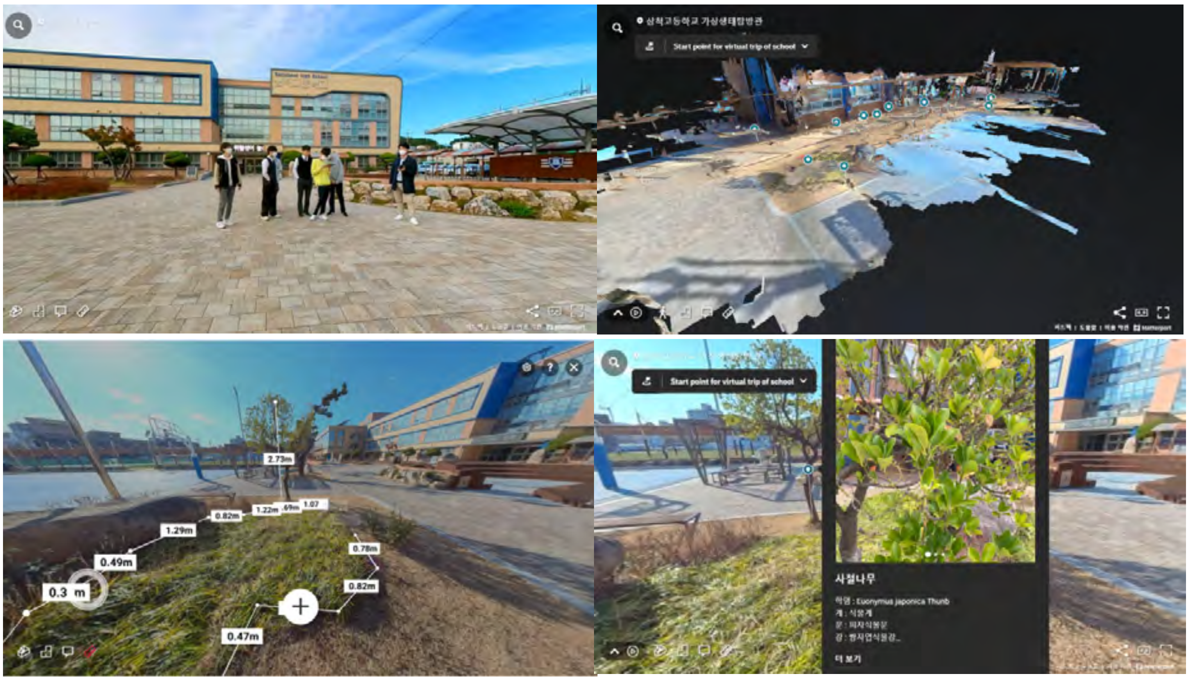
**Figure 1**
*Example of Students' Virtual Activity Using Digital Twin App*




*Note.* 1) The teacher and students go outdoors to observe, investigate, and identify the plants in the school garden. 2) After the cloud upload 360° spatial data through a mobile device, students can automatically create a digital twin for the school garden. 3) Students can edit the space through an app on a mobile device to operate multi-function; start location, labeling, guide tour, tagging, memo, privacy blur, multi-view, and trimming. 4) Students can measure the length, width, and area of tall trees or plant communities that are difficult to measure and freely use the tagging function to post plant characteristics and ecological features found during the investigation.

*Measurement of Effect on Affective Domain*

Experience in a new form of learning program using digital technology has a positive effect on the level of motivation related to student participation (Akour et al., 2022; Stokel-Walker, 2022), and experience activities about the nature environment can affect attitudes and learning biology (Ayotte-Beaudet et al., 2017; Wells et al., 2015). Factors that should be considered for measuring students' affective domain changes are the level of motivation, the intention to participate in learning, the attitude to participate in learning, and the task commitment to continue learning (Foronda et al., 2017; Makhija et al., 2018). Attitudes to participate in learning to reflect positive or negative perceptions of learning that students are currently performing, and task commitment can provide information on the tendency to immerse and continue learning activities they are participating in (Farmer et al., 2007; Kasperiuniene et al., 2016).

In this context, the learning motivation test (Keller, 2009) was used to measure the changes in the affective domain in learning biology, and researchers checked sub-factors changes; attention, relevance, confidence, and satisfaction. The questions for each sub-factor include some reverse questions, including twelve attention-focused questions, nine relevance questions, nine confidence questions, and six satisfaction questions. The combined result of the question response corresponds to the level of motivation for learning activities. Cronbach'α was very high at .91, as a result of calculating by putting it into 20 independent students to confirm the internal reliability of the test paper translated into Korean. 21-question learning attitude test (Byeon, 2022) was used to confirm the change in students' attitudes toward biology. The test uses positive and negative words as extremes and contains reverse questions to prevent random answers. In addition, a task-commitment test (Byeon, 2022) consisting of 25 questions was used to confirm the tendency to continue learning biology activities.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*Analysis of Effect on Affective Domain*

Students responded online before the first class and immediately after the end of the last class to each survey. After response data collection, the response results were statistically analyzed to confirm the effect of applying the learning program before and after the classes between the experimental group and the control group. Learning disposition was presented before the learning motivation, learning attitude, and task commitment test for learning biology, and the results of the pre-post response of each test paper calculated the average value and performed variance analysis. In addition, a chi-square test was conducted on metaverse and learning biology-related tendencies to determine whether there are differences in student factors that can affect the group effect.

It is necessary to confirm the main effects of the experience of indoor and outdoor parallel biology class programs conducted by both groups on students' affective domain to analyze the effect of classes conducted on student groups in this study. Therefore, a linear regression analysis was conducted by setting the group of students participating in the class activities as dummy variables for the main effect analysis and setting the pre-test results as independent variables and the post-results as dependent variables. Afterward, the group effect was confirmed by conducting a one-way distributed analysis of learning motivation, learning attitude, and task obsession using the group as a factor to confirm the effect of the class program applied independently to each group on the affective area.

**Research Results**

*Learning Disposition of the Metaverse and Biology*

It is necessary to analyze students' learning tendencies of biology and the metaverse before confirming the effect of the application of the class program on students. Therefore, independent samples t-tests were conducted using student responses to the interest, the awareness of the importance, and the preference of related occupation of the metaverse and biology learning (Table 3).

**Table 3**
*Learning Disposition Difference Between Two Groups*

| Learning disposition | *EG* | | *CG* | | *t* | *p* |
|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | | |
| Interest in the metaverse learning | 4.35 | .75 | 4.00 | .95 | -1.309 | .920 |
| Awareness of the importance of the metaverse learning | 4.10 | .85 | 3.71 | .96 | -1.361 | .735 |
| Preference for the metaverse-related occupation | 3.40 | 1.05 | 2.57 | 1.21 | -2.343 | .341 |
| Interest in the biology learning | 4.05 | .945 | 3.90 | 1.04 | -.466 | .312 |
| Awareness of the importance of the biology learning | 3.90 | 1.02 | 3.86 | 1.01 | -.135 | .901 |
| Preference for the biology-related occupation | 3.00 | 1.23 | 2.95 | 1.28 | -.126 | .179 |

*Note.* EG = experimental group, CG = control group.

There was no significant difference in the analysis results of students' responses on the learning propensity and interest in the metaverse and biology learning between the experimental and control groups. Therefore, it was necessary to identify individual factors that may affect participation in the learning program developed in this study. According to the result of the chi-square test conducted to check the effect of student factor, it was following for the presence or absence of experience in the metaverse learning $\chi^2 = 1.003$, $df = 1$, $p = .317$, and as a result of the mainly used metaverse type $\chi^2 = 3.864$, $df = 4$, $p = .425$. In addition, the chi-square test results for the acquisition method of the metaverse information were $\chi^2 = 6.113$, $df = 5$, $p = .295$, and the results for the contact frequency of the metaverse information were $\chi^2 = 2.621$, $df = 4$, $p = .623$. The acquisition method of the biology information was $\chi^2 = 3.578$, $df = 3$, $p = .311$, and the analysis results for the contact frequency of biology information were $\chi^2 = .739$, $df = 4$, $p = .946$. Therefore, there was no difference in the group regarding the metaverse and


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biology experiences and information between the experimental and control group students. Therefore, it can be regarded as a homogeneous group with little difference between the experimental and control groups in the metaverse and biology learning context.

*Main Effect of the Application of the Learning Program*

It is necessary first to check the main effect of whether the indoor and outdoor parallel class program applied to the experimental group and the control group causes a change in the affective domain of learning biology to analyze the group effect of digital twin application. The main effect analysis was conducted through linear regression analysis of 41 students in the two groups' biological learning motivation, learning attitude, and task-obsession test results before and after class. As a result of conducting a linear regression analysis using the group as a dummy variable and setting the pre-test result as an independent variable and the post-test result as a dependent variable, the variance analysis results for the generated model were statistically significant (Table 4).

**Table 4**
*The Regression Model on the Student's Affective Domain*

| Model | Estimate | *SE* | 95% CI | | *p* |
|---|---|---|---|---|---|
| | | | *LL* | *UL* | |
| Learning motivation [a] | .864 | .108 | .645 | 1.083 | <.001 |
| Learning attitude [b] | .627 | .107 | .409 | .844 | <.001 |
| Task commitment [c] | .971 | .123 | .721 | 1.220 | <.001 |

*Note.* Total $N$ = 41. CI = confidence interval; *LL* = lower limit; *UL* = upper limit.
[a] Dependent variable = post motivation, $R^2$ = .678. [b] Dependent variable = post attitude, $R^2$ = .560. [c] Dependent variable = post task commitment, $R^2$ = .672.

According to the affective area's pre and post-test results according to the application of classes by group, learning motivation increased from pre-result ($M$ = 122.83, $SD$ = 17.46) to post-result ($M$ = 143.05, $SD$ = 20.53). In addition, the learning attitude increased from pre result ($M$ = 87.22, $SD$ = 12.02) to post result ($M$ = 97.93, $SD$ = 11.82), and the task commitment increased from pre result ($M$ = 88.98, $SD$ = 10.25) to post result ($M$ = 100.71, $SD$ = 13.47). Through the main effect analysis results, the increase in the level of the affective domain after class was statistically significant compared to before the class program was applied in this study. Therefore, it can be interpreted that the experience of the indoor and outdoor combined biology inquiry class positively affects students' motivation, attitude, and task commitment to learning biology.

The regression model coefficients derived from the analysis showed significant pre-test to post-test, so it can be interpreted that both groups have main effects from the application of indoor and outdoor parallel classes. In addition, since the group variable was found to be statistically significant, it was confirmed that there was a difference in effects according to the group (Table 5).

**Table 5**
*Coefficient of Model about The Change of Student's Affective Domain*

| Measurement | Model | *B* | *SE* | ***β*** | *t* | *p* |
|---|---|---|---|---|---|---|
| Learning motivation | Group | -14.002 | 3.738 | -.345 | -3.745 | .001 |
| | Learning motivation | .864 | .108 | .735 | 7.972 | <.001 |
| Learning attitude | Group | -6.969 | 2.553 | -.298 | -2.730 | .01 |
| | Learning attitude | .627 | .107 | .637 | 5.831 | <.001 |
| Task commitment | Group | -7.146 | 2.498 | -.268 | -2.861 | .007 |
| | Task commitment | .971 | .123 | .738 | 7.870 | <.001 |


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*Group Effect by the Application of Learning Program*

This study developed a learning program using digital twin technology so teachers and students can easily explore outdoor plants and have various interactive experiences. In addition, students were divided into an experimental group and a control group to confirm the impact of the developed learning program on students were applied. The learning program using a digital twin was applied to the experimental group, and a program without a Digital twin was applied to the control group to confirm the group effect. The average for each group was calculated by conducting the test of students' affective domain according to the experience of the teaching and learning program of the experimental group and the control group (Table 6).

**Table 6**
*Mean of Pre-test and Post-test for Affective Domain between Students Groups*

| Measurement | | Experimental group | | | | Control group | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Pre-test | | Post-test | | Pre-test | | Post-test | |
| | | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Motivation of learning biology | | 123.50 | 16.58 | 150.80 | 17.83 | 122.19 | 18.64 | 135.67 | 20.58 |
| Sub-factor | Attention | 42.80 | 5.29 | 51.85 | 6.53 | 42.57 | 6.28 | 47.05 | 6.96 |
| | Relevance | 32.00 | 4.41 | 38.30 | 5.12 | 30.76 | 4.93 | 34.62 | 5.56 |
| | Confidence | 26.85 | 5.62 | 33.75 | 5.21 | 27.57 | 5.33 | 30.38 | 5.78 |
| | Satisfaction | 21.85 | 2.89 | 26.90 | 3.01 | 21.29 | 3.91 | 23.62 | 3.67 |
| Attitude of learning biology | | 89.30 | 13.96 | 102.80 | 10.47 | 85.24 | 9.77 | 93.29 | 11.37 |
| Task commitment of learning biology | | 90.40 | 9.78 | 105.75 | 11.04 | 87.62 | 10.74 | 95.90 | 14.06 |

The mean of the experimental group's post-test results increased more than the pre-test results on the motivation for learning biology at 27.30, while the mean of the comparison group's result increased to 13.48. For both groups, the mean of the post-test results was higher than the pre-test results, confirming that the instructional program applied to the students could positively affect the affective domain. Therefore, the change in each sub-factor of the motivation was calculated in detail to confirm the cause of the difference in the level of motivation for learning biology between the two groups. The experimental group's mean change of attention factor was higher at 9.05 than the control group's change of 4.48, and in the relevance factor, the experimental group's mean change was higher at 6.30 than the control group's 3.86. In addition, the confidence factor change was higher in the experimental group, 6.90, than in the control group, 2.81. The change of satisfaction factor in the experimental group at 5.05 was higher than control group at 2.33. In the overall factor of motivation, it indicated a relatively high increase in the experimental group's mean.

In addition to learning motivation, the mean change in the experimental and control groups for attitude and task commitment of learning biology was calculated. The mean of the attitude of learning biology in the experimental group increased to 13.50, higher than the control group's change of 8.05. In addition, the experimental group's mean change of task commitment of learning biology was higher at 15.35 than the control group's change of 8.29.

In both the experimental and control groups, the post-test results increased compared to the pre-test results. These changes can be interpreted as an increase in students' positive perception and tendency to continue learning about biology, including learning motivation, due to the experience of direct inquiry activities in the natural environment and learner-led activities. On the other hand, the fact that the change in the experimental group was more significant than that of the control group can be interpreted as positively affecting the sub-elements of learning motivation by creating, manipulating, and controlling the virtual world directly through digital twins. In addition, positive perception and continuity of learning biology were relatively increased due to students' participation and immersion increased using a new digital technology called Digital Twin.

In both groups, the post-test results about the motivation of learning biology were higher than the pre-results, and the average for each detailed area also increased significantly afterward. In other words, it means that both


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the experimental and control groups can positively change their motivation for learning biology through the experience of biology teaching and learning programs for plant exploration. In addition, the experimental and the control groups showed higher post-test results than the pre-test results on the attitude and task commitment of learning biology, so the teaching and learning programs experienced by students can positively affect learning biology attitudes and task commitment. Also, since the change in the experimental group was more significant than the control group, the experience of classes using digital twins could be positive for students' learning motivation, perception of biology, and intention to continue learning. Therefore, One-way ANOVA was conducted to confirm whether these effects were statistically significant (Table 7).

**Table 7**
*One-way ANOVA for the Change of Students' Motivation for Learning Biology*

| Measurement | | | *SS* | *df* | *MS* | *F* | *p* |
|---|---|---|---|---|---|---|---|
| Motivation of learning biology | | Between group | 10744.590 | 3 | 3581.530 | 10.468 | <.001 |
| | | Within group | 26688.105 | 78 | 342.155 | | |
| Sub-factor | Attention | Between group | 1159.045 | 3 | 386.348 | 9.722 | <.001 |
| | | Within group | 3099.845 | 78 | 39.742 | | |
| | Relevance | Between group | 677.050 | 3 | 225.683 | 8.922 | <.001 |
| | | Within group | 1972.962 | 78 | 25.294 | | |
| | Confidence | Between group | 594.885 | 3 | 198.295 | 6.575 | .001 |
| | | Within group | 2352.395 | 78 | 30.159 | | |
| | Satisfaction | Between group | 387.924 | 3 | 129.308 | 11.138 | <.001 |
| | | Within group | 905.588 | 78 | 11.610 | | |
| Attitude of learning biology | | Between group | 3446.566 | 3 | 1148.855 | 8.721 | <.001 |
| | | Within group | 10275.495 | 78 | 131.737 | | |
| Task commitment of learning biology | | Between group | 3893.627 | 3 | 1297.876 | 9.742 | <.001 |
| | | Within group | 10391.312 | 78 | 133.222 | | |

*Note.* SS = Sum of square, MS = Mean of square.

According to the result of ANOVA, motivation of learning biology and sub-factors showed that the post-test results in both groups increased statistically significantly compared to the pre-test, and there were also differences between groups. In other words, it means that the change in the pre-and post-test results of the experimental group increased at a significant level compared to the control group. Accordingly, the effect size within the group was calculated using the pre and post-test results to confirm the effectiveness of the class program applied in this study on learning motivation.

The effect size on the experimental group was Cohen's $d$ = 1.238, and Cohen's $d$ = .936 in the control group, and both groups showed an effect size of a high level of learning motivation. Therefore, the biology class program applied to both groups positively affected the motivation of learning biology within groups. Consequently, experiencing outdoor life exploration classes that cross indoor and outdoor can improve students' attention, relevance, confidence, and satisfaction with biological learning and positively affect changes in learning motivation.

The statistical analysis of variance in the attitudes and the task commitment for learning biology showed that the post-test results in both groups increased significantly compared to the pre-test results, and differences between groups existed. These results mean a statistically significant difference in the attitude toward learning biology of the experimental group and the change in task commitment for learning biology compared to the change in the control group. Accordingly, the effect size within the group was calculated to confirm the effect of the class program applied in this study on the attitude and task commitment to learning biology.

As a result of calculating the effect size using the pre and post-test of the two groups, the effect size about the attitude of learning biology within the experimental group was Cohen's $d$ = 1.094, and the comparison group was Cohen's $d$ = .759, showing a very high-level effect. In addition, Cohen's $d$ was calculated using the results of the task commitment test for learning biology, the experimental group was Cohen's $d$ = 1.472, and the control group was Cohen's $d$ = .662, indicating that the teaching and learning program at each group effectively improved task commitment. Consequently, the biology class program applied to both groups positively affects students' affective domain.


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Since it has been confirmed that the effect size of the class applied to the group is significant, it is necessary to statistically check whether there is a difference in the degree to which the class applied to each group provides a positive effect on the students' affective domain. Therefore, to confirm the effect size of the class program applied independently to the two groups, the partial eta square value was calculated using the pre-test result as a covariate and the post-test result as a dependent variable. The partial eta square value of the learning motivation for learning biology was $\eta^2 = .270$, and the group effect size was very high. Therefore, analyzing the differences between groups and the effect size confirmed that the experimental group could induce a much more positive effect than the control group. Also, the partial eta square value about the attitude of learning biology was $\eta^2 = .164$, and the task commitment of learning biology was $\eta^2 = .177$. Therefore, it confirmed that the experimental group could induce a much more positive effect on the attitude and task commitment than the control group according to the analysis results of the differences between groups and the effect size.

In conclusion, affective areas such as learning motivation, attitude, and task obsession for learning biology changed significantly in the control group that applied learners' self-directedness and indoor and outdoor life exploration classes. Digital twin classes were more positive in the experimental group than in the control group.

## Discussion

Exploring various organisms outdoors is essential for learning biology, offering advantages that indoor activities cannot provide. However, outdoor activities for teachers come with limitations in the real world. As a result, virtual reality technology, which transports exploration sites to virtual spaces, has been proposed as a way to learn about organisms. With the advancement of digital technology, the potential for the educational use of the metaverse is growing. However, successful learning becomes possible only when effective teaching and learning strategies are employed to properly utilize these technologies for scientific education (OECD, 2022). From this perspective, this study presents the following considerations for using virtual reality in learning.

First, the virtual world should be constructed so that students can feel more realistic. Traditional virtual reality learning activities require professional skills because they rely on computer graphics implemented through rendering, so some users feel less realistic (Cobb, 2009; Garrison, 2016). In addition, from the student's point of view, virtual world control is complex and requires passive use, reducing the opportunity for interaction, which can negatively affect the affective domain (Fauville et al., 2021; Nadler, 2020). On the other hand, the more similar the virtual environment is to reality, the more realistic students perceive the virtual space, and the more effective learning experience can be induced (Kwon, 2020). Therefore, to use immersive virtual space for learning, it needs to provide the same level of space and experience as possible. Unlike the rendering-based space generation method using computer graphics programs, this study maximized the sense of reality by replicating real space and objects using a digital twin platform that constructs space with artificial intelligence through 3D photography. It was shown that there was a very high level of effect in the affective domain change of the experimental group participating in this study, and the effect on the level of learning motivation and task commitment was greater than that of the control group. These results can be attributed to the fact that students could measure and interact with the actual size of objects and spaces in the virtual space in the experimental group that provided the exact size and shape of 3D space, objects, and locations reflecting depth and distance.

Second, it is necessary to provide freedom for learners to organize the virtual world and interact with various interactions easily. The level of motivation for learning participation may vary depending on the degree of freedom given in learning activities and the initiative of activities, and motivation for learning participation is the driving force for continuing learning (Karatas et al., 2017). In particular, in science learning activities, providing learners with self-directedness and freedom can positively affect learning motivation and learning (Dede et al., 2017). In addition, learning participation attitudes reflect students' positive or negative perceptions of the learning they are currently performing, and task commitment can provide information on their tendency to immerse themselves in and continue their learning activities (Farmer et al., 2007; Kasperiuniene et al., 2016). Unlike activities that only utilize passively provided virtual reality, this study provided the initiative for experimental group students to directly create digital twins in the virtual world and use them by adding various interaction objects. In addition, students can immediately check and compare with the real one in the school garden during the action in a virtual reality space, and it can arise to form a positive perception of living things. The experimental group's results that created and utilized the digital twin themselves showed that providing students with a degree of freedom through a change in attitude toward learning biology and task commitment was necessary.


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Summarizing the above discussions, using the virtual world as an alternative to outdoor biology inquiry activities can lead to learners' motivation to participate, a positive perception, and a tendency to continue learning biology when learners can construct and interact freely. To this end, various digital twin platforms should be provided so anyone can easily construct and operate a realistic virtual space. It is very encouraging that the effect on the affective domain of the experimental group that experienced digital twin-based exploratory learning activities in this study is more favorable than the control group, which means that indoor and outdoor exploratory activities linked to the virtual world can be effective in changing students' perception of actual learning biology.

**Conclusions and Implications**

This study used digital twins to create a realistic virtual world, apply it to outdoor inquiry classes, and investigate the effect on students' affective areas. Researchers could present several conclusions and implications based on various research findings and discussions.

First, an outdoor inquiry class for learning biology using the virtual world with a high sense of reality using digital twins was able to organize. Ironically, the biggest problem in learning using the virtual world is its unrealism. In other words, learners who are users must passively consume the virtual space that developers provide. Even images perceived in the real world, different levels of graphic space, and limitations that cannot be compared to the real world reduce students' sense of presence. However, in this study, the digital twin platform allowed students to create virtual replication spaces in school gardens with simple digital devices and compare them to the real world. Therefore, this study confirmed the possibility of implementing hybrid learning that can be converged between the real world and the virtual world, which is aimed at the educational environment of the future digital society.

Second, providing students with a sense of realism and initiative in activities can positively affect learning biology in the real world through virtual world activities. Another problem in learning using virtual reality is passivity and isolation. Virtual spaces created by experts cannot be expanded or modified by users, and new content can be added only by developers. However, the digital twin platform allows anyone to modify or update virtual spaces by sharing and adding content. In addition, team activities can resolve individual isolation caused by learning using virtual reality, and interactions between virtual and real worlds increase opportunities for interaction between humans. Increasing learners' initiative and interaction can positively affect the motivation, perception, and learning continuity of learning biology about the real world through virtual world activities.

In this study, an outdoor inquiry program for learning biology using the digital twin focuses on allowing students to freely replicate, organize, and manipulate the real world with simple digital device manipulation. Therefore, we can propose the following implications.

First, anyone can easily create and utilize a virtual world to expand to a variety of learning biology fields. The learning program using the digital twin platform in this study focuses on learners creating dynamic learning content that is more than just 3D space and continuously interacting with the real world. Therefore, it can be used to implement new ways and ideas in learning biology that broadens the boundaries of indoor and outdoor learning. For example, digital twin data acquired continuously at a particular point can monitor changes in plant populations over time. In addition, visualized 3D and multimedia information about ecosystems in different regions can be continuously updated and used for long-distance project learning. Also, various uses such as simulating dangerous experiments, individualized classes for students with different experiments, and saving time through repetition of the same experiment will be possible.

Second, anyone anywhere can use the virtual world just using a mobile device, helping bridge the digital divide. The digital divide in learning using virtual reality is occurring at national, regional, school, and home levels, and without professional equipment and expertise, students could not even create a virtual world. These problems cause differences in opportunities for teachers and students to build and experience a virtual world, and they act as problems that widen the digital divide. However, the virtual space replication activities and educational utilization proposed in this study can be used at the student level without professional knowledge, only on mobile devices with internet access. Therefore, if anyone can choose the target space they want to explore, quickly replicate it in the virtual world, and use it for learning, they can close the digital gap.

**Declaration of Interest**

The authors declare no competing interest.


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**References**

Akour, I. A., Al Maroof, R. S., Alfaisal, R., & Salloum, S. A. (2022). A conceptual framework for determining metaverse adoption in higher institutions of gulf area: An empirical study using hybrid SEM-ANN approach. *Computers & Education: Artificial Intelligence, 3*, Article 100052. https://doi.org/10.1016/j.caeai.2022.100052

Akter, S., McCarthy, G., Sajib, S., Michael, K., Dwivedi, Y. K., D'Ambra, J., & Shen, K. N. (2021). Algorithmic bias in data-driven innovation in the age of AI. *International Journal of Information Management, 60*, Article 102387. https://doi.org/10.1016/j.ijinfomgt.2021.102387

Ayotte-Beaudet, J. P., Potvin, P., Lapierre, H. G., & Glackin, M. (2017). Teaching and learning science outdoors in schools' immediate surroundings at K-12 levels: A meta-synthesis. *Eurasia Journal of Mathematics, Science and Technology Education, 13*, 5343-5363. https://doi.org/10.12973/EURASIA.2017.00833A

Behrendt, M., & Franklin, T. (2014). A review of research on school field trips and their value in education. *International Journal of Environmental and Science Education, 9*, 235-245. http://dx.doi.org/10.12973/ijese.2014.213a

Braund, M., & Reiss, M. (2004). The nature of learning science outside the classroom. In Braund, M. & Michael, R. (Eds.), *Learning science outside classroom* (pp. 1-12). Routledge Flamer. https://discovery.ucl.ac.uk/id/eprint/10024149/10/Reiss_Braund%20%20Reiss%202004%20The%20Nature%20of%20Learning%20Science%20Outside%20the%20Classroom.pdf

Byeon, J. H. (2022). Development of teaching and learning model for biology class using artificial intelligence. *Brain, Digital, & Learning, 12*, 51-67. https://doi.org/10.31216/BDL.20220004

Byrne, M. D. B. (2021). Reducing bias in healthcare artificial intelligence. *Journal of PeriAnesthesia Nursing, 36*, 313-316. https://doi.org/10.1016/j.jopan.2021.03.009

Carvajal, D.A., Morita, M.M., & Bilmes, G.M. (2020). Virtual museums. captured reality and 3D modeling. *Journal of Cultural Heritage, 45*, 234-239. https://doi.org/10.1016/j.culher.2020.04.013

Chen, X., Xie, H., & Hwang, G. J. (2020). A multi-perspective study on artificial intelligence in education: Grants, conferences, journals, software tools, institutions, and researchers. *Computer & Education: Artificial Intelligence, 1*, Article 100005. https://doi.org/10.1016/j.caeai.2020.100005

Cobb, S. C. (2009). Social presence and online learning: A current view from a research perspective. *Journal of Interactive Online Learning, 8,* 241-254. https://www.ncolr.org/jiol/issues/pdf/8.3.4.pdf

Collins, A., & Halverson, R. (2018). *Rethinking education in the age of technology: The digital revolution and schooling in America*. Teachers College Press.

Dede, C., Salzman, M. C., Loftin, R. B., & Spargue, D. (1999). Multisensory immersion as a modeling environment for learning complex scientific concepts. In Feurzeig, W., & Roberts, N. (Eds.), *Modeling and simulation in science and mathematics education* (pp. 282-319). Springer. https://doi.org/10.1007/978-1-4612-1414-4_12

Dede, C.J., Jacobson, J., & Richards, J. (2017). Introduction: Virtual, augmented, and mixed realities in education. In Liu, D., Dede, C., Huang, R., & Richards, J. (Eds.), *Virtual, augmented, and mixed realities in education* (pp. 1-16). Springer. https://doi.org/10.1007/978-981-10-5490-7_1

Dillon, J., Rickinson, M., Teamey, K., Morris, M., Choi, M. Y., Sanders, D., & Benefield, P. (2006). The value of outdoor learning: Evidence from research in the UK and elsewhere. *The School Science Review, 87*, 107-111. http://www.gettingpractical.org.uk/documents/SSRThevalueofoutdoorlearning.pdf

Dwivedi, Y. K., Hughes, L., Baabdullah, A. M., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M. M., Dennehy, D., Metri, B., Buhalis, D., Cheung, C. M., Conboy, K., Doyle, R. M., Dubey, R., Dutot, V., Felix, R., Goyal, D. P., Gustafsson, A., Hinsch, C., Jebabli, I., … & Wamba, S. F. (2022). Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management, 66,* Article 102542. https://doi.org/10.1016/j.ijinfomgt.2022.102542

Farmer, J.R., Knapp, D., & Benton, G. (2007). An elementary school environmental education field trip: Long-term effects on ecological and environmental knowledge and attitude development. *The Journal of Environmental Education, 38*, 33 – 42. https://doi.org/10.3200/JOEE.38.3.33-42

Fauville, G., Luo, M., Queiroz, A. C. M., Bailenson, J. N., & Hancock, J. (2021). Zoom exhaustion & fatigue scale. *Computers in Human Behavior Reports, 4*, Article 100119. https://doi.org/10.1016/j.chbr.2021.100119

Foronda, C. L., Hudson, K.W., & Budhathoki, C. (2017). Use of virtual simulation to impact nursing students' cognitive and affective knowledge of evidence-based practice. *Worldviews on Evidence-Based Nursing, 14*, 168–170. https://doi.org/10.1111/wvn.12207

Garrison, D. R. (2016). *E-learning in the 21st century: A community of inquiry framework for research and practice.* Routledge. https://doi.org/10.4324/9781315667263

Grieves, M. W., & Vickers, J. H. (2017). Digital twin: Mitigating unpredictable, undesirable emergent behavior in complex systems. In Kahlen, J., Flumerfelt, S., & Alves, A. (Eds.), *Transdisciplinary perspectives on complex systems* (pp. 85-113). Springer. https://doi.org/10.1007/978-3-319-38756-7_4

Guan, C., Mou, J., & Jiang, Z. (2020). Artificial intelligence innovation in education: A twenty-year data driven historical analysis. *International Journal of Innovation Studies, 4*, Article 13. https://doi.org/10.1016/j.ijis.2020.09.001

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial Intelligence in Education: Promise and Implications for Teaching and Learning*. Center for Curriculum Redesign. https://discovery.ucl.ac.uk/id/eprint/10139722

Karatas, S., Bagriacik-Yilmaz, A., Dikmen, C. H., Ermis, U. F., & Grubuz, O. (2017). Interactions in distance education environments: A trend analysis. *Quarterly Review of Distance Education, 18*, 63-82. https://link.gale.com/apps/doc/A520673934/AONE?u=anon~6de3a5d0&sid=googleScholar&xid=b620fa41


https://doi.org/10.33225/jbse/23.22.781

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/


Kasperiuniene, J., Jariwala, M., Vaskevicius, E., & Satkauskas, S. (2016). Affective engagement to virtual and live lectures. In Dregvaite, G., & Damasevicius, R. (Eds.), *Information and software technologies. ICIST 2016. Communications in Computer and Information Science, Volume 639* (pp. 499–508). Springer. https://doi.org/10.1007/978-3-319-46254-7_40

Keller, J. M. (2009). *Motivational design for learning and performance: The ARCS Model Approach*. Springer. https://link.springer.com/book/10.1007/978-1-4419-1250-3

Kelton, A. J. (2007). Second life: Reaching into the virtual world for real-world learning. *ECAR Research Bulletin, 17*, 1-13. https://www.educause.edu/ir/library/pdf/ERB0717.pdf

Klaur, K. J., Willmes, K., & Phye, G. D. (2002). Inducing inductive reasoning: Does it transfer to fluid intelligence? *Contemporary Educational Psychology, 27*, 1-25. https://doi.org/10.1006/CEPS.2001.1079

Kuznetcova, I., Glassman, M., & Lin, T. J. (2019). Multi-user virtual environments as a pathway to distributed social networks in the classroom. *Computers & Education, 130*, 26-39. https://doi.org/10.1016/j.compedu.2018.11.004

Kwon, C. (2020). The effect of the degree of anxiety of learners during the use of VR on the flow and learning effect. *Applied Sciences. 10*, Article 4932. https://doi.org/10.3390/app10144932

Liu, M., Fang, S., Dong, H., & Xu, C. (2021). Review of digital twin about concepts, technologies, and industrial applications. *Journal of Manufacturing Systems, 58*, 346–361. https://doi.org/10.1016/j.jmsy.2020.06.017

Lu, Y., Liu, C., Wang, K.I., Huang, H., & Xu, X. (2020). Digital twin-driven smart manufacturing: Connotation, reference model, applications and research issues. *Robotics and Computer-integrated Manufacturing, 61*, Article 101837. https://doi.org/10.1016/j.rcim.2019.101837

Makhija, A., Richards, D., de Haan, J., Dignum, F., & Jacobson, M.J. (2018). The influence of gender, personality, cognitive and affective student engagement on academic engagement in educational virtual worlds. In *AIED 2018: Artificial intelligence in education* (pp. 297-310). Springer. https://doi.org/10.1007/978-3-319-93843-1_22

Matthews, M. R. (2000). Appraising constructivism in science and mathematics education. In Phillips, D. C. (Ed), *Constructivism in education: Opinions and second opinion on controversial issues* (pp.161-192). The University of Chicago Press. https://doi.org/10.1177/016146810010200706

Nadler, R. (2020). Understanding "Zoom fatigue": Theorizing spatial dynamics as third skins in computer-mediated communication. *Computers and Composition, 58*, Article 102613. https://doi.org/10.1016/j.compcom.2020.102613

National Research Council (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. National Academy Press. https://nap.nationalacademies.org/read/9596/chapter/1

OECD (2022). *Trends Shaping Education 2022*, OECD Publishing. https://doi.org/10.1787/6ae8771a-en.

Petrie, C. (2022). Every child to flourish in a post-COVID-19 world: Eight lessons and visions for the future, In Vincent-Lancrin, S., Romaní, C. C., & Reimers, M. F. (Eds.), *How learning continued during the COVID-19 pandemic: Global lessons from initiatives to support learners and teachers* (pp. 91-105). OECD Publishing. https://doi.org/10.1787/a6fcabbe-en

Potkonjak, V., Gardner, M., Callaghan, V., Mattila, P., Guetl, C., Petrovic, V. M., & Jovanovic, K. (2016). Virtual laboratories for education in science, technology, and engineering: A review. *Computers & Education, 95*, 309-327. https://doi.org/10.1016/j.compedu.2016.02.002

Psotka, J. (1995). Immersive training systems: Virtual reality and education and training. *Instructional Science, 23*, 405-431. https://doi.org/10.1007/BF00896880

Pulgar, J. (2021). Classroom creativity and students' social networks: Theoretical and practical implications. *Thinking Skills and Creativity, 42*, Article 100942. https://doi.org/10.1016/j.tsc.2021.100942

Ramakrishnan, S. K., Gokaslan, A., Wijmans, E., Maksymets, O., Clegg, A., Turner, J., Undersander, E., Galuba, W., Westbury, A., Chang, A.X., Savva, M., Zhao, Y., & Batra, D. (2021). Habitat-Matterport 3D dataset (HM3D): 1000 large-scale 3D environments for embodied AI. *ArXiv*, abs/2109.08238. https://doi.org/10.48550/arXiv.2109.08238

Rathore, M. M., Shah, S.A., Shukla, D., Bentafat, E., & Bakiras, S. (2021). The role of AI, machine learning, and big data in digital twinning: A systematic literature review, challenges, and opportunities. *IEEE Access, 9*, 32030-32052. https://doi.org/10.1109/ACCESS.2021.3060863

Reimers, M. F. (2022). Learning from the frontlines of educational innovation during a pandemic. In Vincent-Lancrin, S., Romani, C. C., & Reimers, F. M. (Eds.), *How learning continued during the COVID-19 pandemic: Global lessons from initiatives to support learners and teachers* (pp. 78-90). OECD Publishing. https://doi.org/10.1787/149b4e72-en

Rowe, S., & Humphries, S. (2004). The outdoor classroom. In Braund, M., & Michael, R. (Eds.), *Learning science outside classroom* (pp. 19-34). Routledge Flamer.

Sepasgozar, S.M. (2020). Digital twin and web-based virtual gaming technologies for online education: A case of construction management and engineering. *Applied Sciences, 10*, Article 4678. https://doi.org/10.3390/app10134678

Söderberg, R., Wärmefjord, K., Carlson, J.S., & Lindkvist, L. (2017). Toward a digital twin for real-time geometry assurance in individualized production. *Cirp Annals-manufacturing Technology, 66*, 137-140. https://doi.org/10.1016/J.CIRP.2017.04.038

Stokel-Walker, C. (2022). Welcome to the metaverse. *New Scientist, 253*, 39-43. https://doi.org/10.1016/s0262-4079%2822%2900018-5

Subramaniam, K., Asim, S., Lee, E.Y., & Koo, Y. (2018). Student teachers' images of science instruction in informal settings: A focus on field trip pedagogy. *Journal of Science Teacher Education, 29*, 307-325. https://doi.org/10.1080/1046560X.2018.1452531

Sulaiman, M.Z., Aziz, M., Bakar, M.H., Halili, N.A., & Azuddin, M.A. (2020). Matterport: Virtual tour as a new marketing approach in real estate business during pandemic COVID-19. *International Conference of Innovation in Media and Visual Design (IMDES 2020),* 221-226. https://doi.org/10.2991/assehr.k.201202.079

Suzuki, S. N., Kanematsu, H., Barry, D. M., Ogawa, N., Yajima, K., Nakahira, K. T., Shirai, T., Kawaguchi, M., Kobayashi, T., & Yoshitake, M. (2020). Virtual experiments in metaverse and their applications to collaborative projects: The framework and its significance. *Procedia Computer Science, 176*, 2125-2132. https://doi.org/10.1016/j.procs.2020.09.249


https://doi.org/10.33225/jbse/23.22.781

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Tao, F., & Zhang, M. (2017). Digital twin shop-floor: A new shop-floor paradigm towards smart manufacturing. *IEEE Access, 5*, 20418-20427. https://doi.org/10.1109/ACCESS.2017.2756069

Tao, F., Sui, F., Liu, A., Qi, Q., Zhang, M., Song, B., Guo, Z., Lu, S.C., & Nee, A.Y. (2019). Digital twin-driven product design framework. *International Journal of Production Research, 57*, 3935 – 3953. https://doi.org/10.1080/00207543.2018.1443229

Thelen, A., Zhang, X., Fink, O., Lu, Y., Ghosh, S., Youn, B.D., Todd, M.D., Mahadevan, S., Hu, C., & Hu, Z. (2022). A comprehensive review of digital twin-part 1: Modeling and twinning enabling technologies. *Structural and Multidisciplinary Optimization, 65*, 354. https://doi.org/10.1007/s00158-022-03425-4

Tilak, S., Glassman, M., Kuznetcova, I., Peri, J., Wang, Q., Wen, Z., & Walling, A. (2020). Multi-user virtual environments (MUVEs) as alternative lifeworlds: Transformative learning in cyberspace. *Journal of Transformative Education, 18*, 310-337. https://doi.org/10.1177/1541344620932224

Tuegel, E.J., Ingraffea, A.R., Eason, T., & Spottswood, S.M. (2011). Reengineering aircraft structural life prediction using a digital twin. *International Journal of Aerospace Engineering, 2011*, 1-14. https://doi.org/10.1155/2011/154798

van der Zanden, P. J. A. C., Meijer, P. C., & Beghetto, R. A. (2020). A review study about creativity in adolescence: Where is the social context? *Thinking Skills and Creativity, 38*, Article 100702. https://doi.org/10.1016/j.ts c.2020.100702

Vincent-Lancrin, S. (2022). Educational innovation and digitalisation during the COVID-19 crisis: Lessons for the future. In Vincent-Lancrin, S., Romaní, C. C., & Reimers, M. F. (Eds.), *How learning continued during the COVID-19 pandemic: Global lessons from initiatives to support learners and teachers* (pp. 21-47). OECD Publishing. https://doi.org/10.1787/93c3dc5e-en

Wang, Y., & Chiew, V. (2010). On the cognitive process of human problem solving. *Cognitive Systems Research, 11*, 81-92. https://doi.org/10.1016/j.cogsys.2008.08.003

Wells, N. M., Myers, B. M., Todd, L. E., Barale, K., Gaolach, B., Frenz, G., Aitken, M., Henderson, C. R., Tse, J. C., Pttison, K. O., Taylor, C., Connerly, L., Carson, J. B., Gensemer, A. Z., Franz, N. K., & Falk, E. (2015). The effects of school gardens on children's science knowledge: A randomized controlled trial of low-income elementary schools. *International Journal of Science Education, 37*, 2858-2878. https://doi.org/10.1080/09500693.2015.1112048

Yair, Y., Mintz, R., & Litvak, S. (2001). 3D-Virtual reality in science education: An implication for astronomy teaching. *Journal of Computers in Mathematics and Science Teaching, 20*, 293. https://link.gale.com/apps/doc/A80060971/AONE?u=anon~7eb5cf35&sid=googleScholar&xid=e79cb305

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