INVESTIGATION OF THE EFFECTIVENESS OF 3D CAPTURE AND VR AS LEARNING MATERIALS FOR BEGINNERS OF CIVIL ENGINEERING STRUCTURES

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A Virtual Reality (VR) educational material has been developed for beginners in civil engineering. The VR content consist of civil engineering structures captured in three dimensions using 3D Gaussian splatting. This educational material has three main objectives. First, users can become familiar with the names of structures in their environment by using familiar civil engineering structures as learning content, Second, learners can examine structures in more detail, through multi-perspective observation enabled by 3D capture technology. Third, the material allows learners to experience state-of-the-art technologies by incorporating VR and 3D Gaussian splatting. The target structures for this material are located on the campus of National Institute of Technology, Gunma College. A total of 16 civil engineering structures are captured in 3D and integrated into the VR-based learning system. In addition, the learners are able to view the names of these structures within the VR environment before starting the VR observation. To evaluate the effectiveness of this educational material, a survey is conducted with 28 students from National Institute of Technology, Gunma College. The survey assess the usefulness of using 3D models, the effectiveness of VR, and the benefits of focusing on the environment. Participants responded using a four-point Likert scale: "strongly agree", "somewhat agree", "neutral" and "somewhat disagree". The results showed that over 92.9% of students responded positively ('strongly agree' or 'somewhat agree') to all questions. In addition, participants were shown images of six civil engineering structures that they had observed in VR and were asked to categorize them into one of three options: "Can name the structure", "Probably can name the structure", or "Cannot name the structure". The cumulative response rate for "can name the structure" and "probably can name the structure" was over 85.7% for all structures. Open-ended responses included positive feedback such as "I was surprised by the number of civil engineering structures around me" and "VR helped me understand concepts that are difficult to understand in lectures in a more engaging way". However, a notable negative comment was the issue of motion sickness when experiencing VR. These findings suggest that a VR-based educational material using 3D Gaussian splatting can enhance civil engineering education by making structures more familiar and engaging to learners.

Keywords: *civil structure, learning material, digital twin, VR, 3D gaussian splatting*

Introduction

Civil engineering structures form the backbone of our daily lives. From commuting routes to the surroundings of schools and workplaces, various civil structures are present in our immediate environment. For instance, the National Institute of Technology, Gunma Collage (NITGC), where the authors are affiliated, contains numerous civil engineering structures, including those shown in Photo 1 and listed in Table 1. In this study, the definition of "civil engineering structure" follows the

Photo 1. Rivers and bridges on the NITGC campus

Table 1. Example of civil engineering structures on the NITGC (Nilim, 2025)

Concrete bridge	Asphalt pavement	River dike
Box culvert	Sluice gate	Fall barrier
L-shaped retaining wall	Masonry retaining wall	Concrete block retaining wall
Gravity retaining wall	Inclined retaining wall	Curb stone
Channel works	Grit chamber	Guard fence
U-shaped gutter	L-shaped gutter	Catch basin
Lighting pole foundation	Precast foundation block	Guard fence foundation

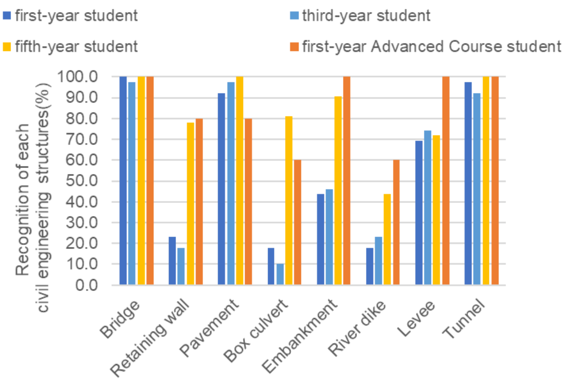

Figure 1. Results of survey on recognition of each civil structure (Watanabe & Takamizawa, 2025)

classification provided in the 2025 revised Construction Work Classification Tree issued by the National Institute for Land and Infrastructure Management (Nilim, 2025).

However, a survey conducted by Watanabe and Takamizawa (2025) targeting students in the Department of Environmental and Advanced Engineering at NITGC revealed that, especially among first- and third-year students, the recognition rate of specific civil engineering structures such as retaining walls, box culverts, and revetments were relatively low (10.0% to 24.0%) as shown in Figure 1. This suggests that such limited awareness is likely not unique to NITGC.

Professionals in civil engineering often notice structures during their travels and contemplate questions such as "Why is it located here?", "Why does it have this shape or structure?", and "What causes its deterioration?". Such reflection contributes to knowledge acquisition through direct observation of real-world structures. For beginners in civil engineering, recognizing various structures is the first critical step to gaining similar insights. While deeper understanding requires specialized knowledge, identifying and acknowledging the existence of these structures is a foundational learning step. Therefore, we emphasize the need for learning materials that help beginners learn the names and functions of civil engineering structures.

In addition, advancements in techniques like SfM-MVS analysis and laser scanning have made it easier to generate 3D point cloud and mesh data, accelerating the application of digital twins in civil engineering. Current studies utilize these technologies for modelling existing structures (Nakamizo and Nishio, 2022), infrastructure management (Otsuki, et al., 2022), and disaster recovery (Watanabe, et al., 2023). Moreover, the use of VR technology to present 3D data in immersive environments is gaining traction in disaster and safety education (Magara, 2019). Given the rapid evolution of digital tools, today's civil engineering students will soon be in positions requiring proficiency in such technologies. Early exposure is therefore essential.

Based on the above, we argue that civil engineering beginners should be provided opportunities to learn using digital twin and VR technologies. However, such learning materials remain scarce. To address this, our study aimed to (1) develop easy-to-understand instructional materials featuring civil engineering structures and (2) offer early exposure to digital twin and VR technologies. We created such materials and had students interact with them to collect feedback on their effectiveness.

Development Method of Learning Materials

This study developed instructional materials targeting structures on the NITGC campus. Table 1 lists the selected structures. As the intended users were NITGC students, we prioritized familiar, accessible structures. However, this method can be implemented elsewhere.

Figure 2 outlines the development process. We first listed relevant structures based on the 2024 Construction Work Classification Tree. The scanning application was scaniverse by Niantic, which supports both "Splat mode"

Identification and listing of civil engineering structures to be 3D captured

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3D scanning of various civil engineering structures using the scaniverse application

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Uploading of the 3D scan data onto a digital map using the built-in features of the scaniverse application (Figure. 3)

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Observation of the posted 3D captures on a digital map using individual smartphones or VR headsets (Photo. 2)

Figure 2. Flow of how to create learning materials

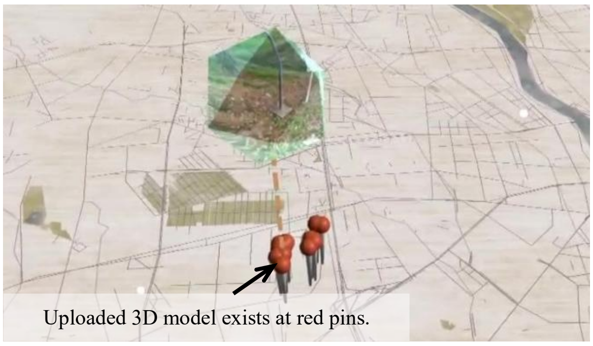


Figure 3. View of the arrangement of the 3D capture in the VR space

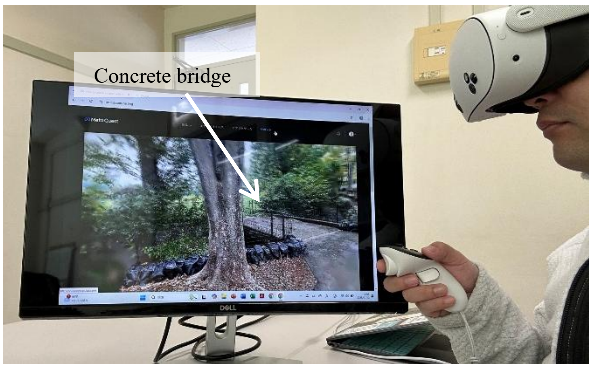


Photo 2. Observe uploaded 3D captures with VR

(using 3D Gaussian Splatting) and "Mesh mode" (combining LiDAR sensors and SfM-MVS). Splat-mode data can be uploaded to a digital map within the app, enabling users to view 3D data and location information on their smartphones.

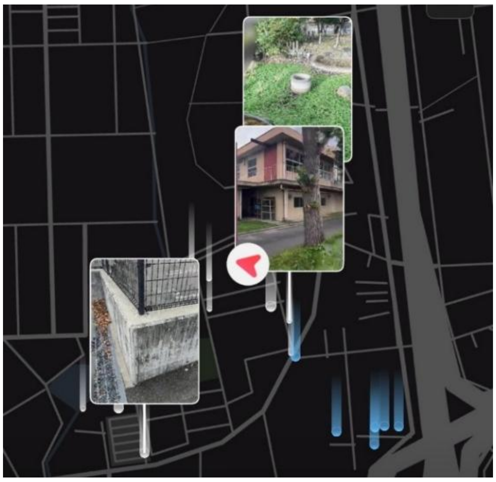
These uploaded 3D captures serve as digital twins, marked on a digital map with pins (Figure. 3). Clicking a pin displays the structure's name and entering the VR environment via the Meta Quest 3S headset allows immersive observation (Photo. 2).

Learning Materials for Beginners

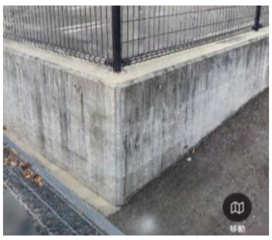
An example of the NITGC campus structure map and 3D captures is shown in Figure 4. We selected 16 structures from areas that are accessible and safe. Four student volunteers participated in the creation of these models, though any smartphone user can contribute. By scanning and uploading structures, students can learn scanning techniques and develop deeper interest in existing data.

Evaluation of Learning materials

We conducted a survey with 28 NITGC students (15 first years, 6 second years, and 7 third years) who used the Meta Quest 3S headset to observe 3D captures via Scaniverse. They evaluated the usefulness of 3D captures, VR technology, and familiar environments using a four-point Likert scale. Additionally, they were shown photos of the observed structures and asked to identify their names from three options: "can name", "probably can name", and "cannot name". A free-response section was also included; 18 students provided feedback. The survey explicitly stated the purpose and content of the study, as well as the privacy policy. Consent to participate in the study was considered to have been obtained upon submission of the completed questionnaire.



(a) Map of civil engineering structures on the NITGC



(b) 3D capture of gravity retaining wall

(c) 3D capture of concrete bridge

Figure 4. Learning materials for beginners of civil engineering structures

Figures 5 to 7 present the survey results, and Figure 8 shows comprehension levels. Table 2 summarizes free-text responses. For 3D capture usefulness, 89.3% answered "strongly agree" and 10.7% "agree", with a total of 100% positive feedback. Positive comments from free comments included the ability to observe structures from various angles. Some noted quality differences among models, suggesting further investigation into factors affecting model clarity (e.g., smartphone specs, scanning speed). For VR usefulness, 82.1% chose "strongly agree" and 14.3% "agree", though 3.6% responded "neutral". Some negative feedback mentioned 3D motion sickness and difficulty wearing the headset. However, many appreciated the engaging, memorable experience VR provided. Regarding the use of familiar environments as a target area, 75.0% responded "strongly agree" and 17.9% "agree". One student suggested expanding beyond the campus to unfamiliar structures. Conversely, others found the experience eye-opening, realizing the abundance of civil structures in their daily surroundings. The Free-text feedback indicate that incorporating emerging technologies such as 3D scanning and virtual reality into the learning process enhances the memorability of the educational experience.

Comprehension of structure names exceeded 85.7% for all cases when combining "can name" and "probably can name" responses. Notably, these students had not formally studied the names of these structures in class, indicating the educational value of the materials.

Conclusions

We develop VR-based instructional materials to teach civil engineering beginners about structural names and forms using real structures on the NITGC campus. The materials enable multi-angle observation through 3D scanning and immersive learning through VR. Surveys with 28 students reveale 100% positive responses for the usefulness of 3D captures, 96.4% for VR, and 92.9% for using familiar environments. Free-text feedback highlights the advantages of multi-perspective observation, immersive engagement, and newfound awareness of nearby structures. Some drawbacks included model quality inconsistency and 3D motion sickness. Comprehension surveys showed over 80% recognition rates for all structure names, confirming the material's educational effectiveness. The process of co-developing the materials with students also suggested potential applications in structure inspection and diagnosis. These materials demonstrate that civil structures in any location can be digitized and viewed in VR. By familiarizing novices with 3D scanning and VR,

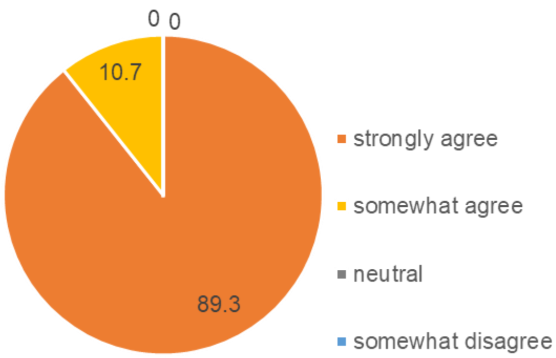


Figure 5. Usefulness of using 3D captures

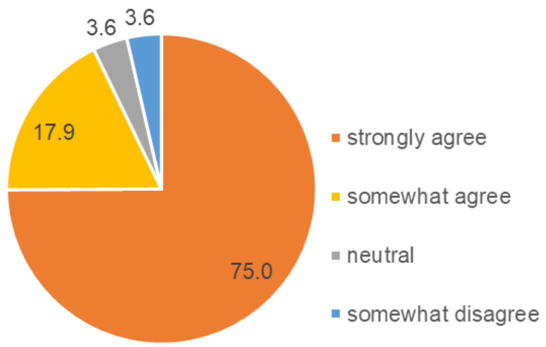


Figure 7. Usefulness of familiar environments

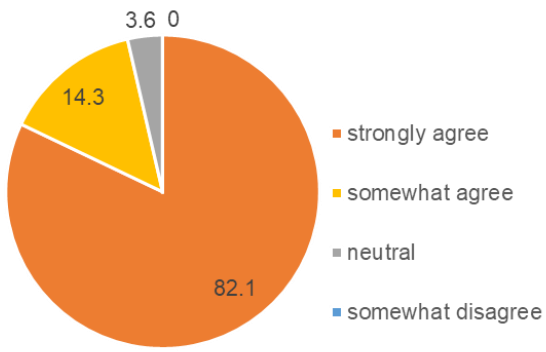


Figure 6. Usefulness of using the familiar environment as a target

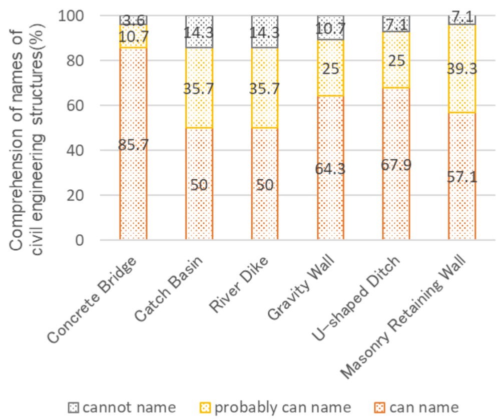


Figure 8. Recognition of each civil structure

Table 2. Free comment responses

No.	Free comment responses
1	I felt that 3D captures, which can be observed from various angles, can be used in various ways compared to photographs.
2	Some structures had blurred images or only a portion of the image was clearly visible, so I thought it was necessary to scan carefully.
3	I thought it was very easy to understand when I experienced it after learning in the classroom because I felt as if I was actually there. On the other hand, I thought it was an issue that some people get drunk and that it takes a little time to put on the goggles.
4	I had seen people using VR in game situations and thought it looked interesting, so I was very happy to be able to actually use it.
5	I was surprised that it was easier than I thought to observe my own model in VR.
6	I was amazed at how easily I could VR and experience the world around me. It was my first time wearing goggles and it was immersive.
7	It was very good to be able to see civil engineering structures from various perspectives that we cannot see in our daily lives, such as from inside a water catchment basin or from the sky. I also felt that it could be used effectively as a learning material, as it tickled the students' interest because they could learn while moving their bodies, unlike sitting down and looking at the material.
8	I was surprised that the scenery was projected more clearly than I had imagined. I thought it was an advantage to be able to see the local scenery without having to go there.
9	Using VR and 3D captures was fresh and interesting. I think it is good to show places inside the school, but I think it will deepen my understanding of the target structure if I can see places that are not often seen.
10	I thought it was good to be able to observe structures from various perspectives by using 3D captures. I was also a little surprised to realize that there are so many civil engineering structures in our everyday environment. I would like to look for them myself.

the program aims to further advance the use of the technology in civil engineering.

In this study, we utilize the 3D scanning and map-based uploading functions of an existing application, Scaniverse. Furthermore, we developed an educational material that integrates this application with a VR service. The primary focus of this material is to help students learn the names and shapes of civil engineering structures. Initially, the names of the structures are introduced through classroom instruction, with the functions of each structure being explained theoretically. However, we consider it more effective for students to deepen their understanding of these functions by viewing the 3D models in VR. Future improvements will aim to provide a more integrated learning experience combining both theoretical and VR-based instruction.

The services used in this study assume the public sharing of 3D models. For this project, a location-specific map focused exclusively on civil engineering structures However, when similar mapping and scanning activities are conducted for other purposes, there is a risk that all uploaded models may be displayed simultaneously on the same map. This could hinder users from efficiently locating the specific information they seek. Additionally, depending on the scanned object or location, some data may be unsuitable for public release due to privacy or security concerns. These issues suggest that, from a quality assurance standpoint, there will be cases where a closed-access version of the material is necessary.

Moreover, regarding the free responses in the questionnaire that addressed the quality of the 3D models, it is necessary to analyze the factors that influence model quality to ensure a minimum standard is met. Although this study is based on responses from 28 participants, future work will involve the accumulation and analysis of more data to obtain a more robust evaluation of the material.

Finally, although this study focused on beginner-level students in civil engineering at National Institute of Technology, Gunma College and utilized familiar, nearby structures as educational content, the free-response section of the survey highlighted that one of the advantages of digital materials is enabling observation of distant structures that are not easily accessible. While the current material was developed using a relatively simple method focusing on local civil infrastructure, we plan to expand its application to preserve and convey disaster-related information—such as damage caused by earthquakes or heavy rainfall—for future generations.

Acknowledgements

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References

Magara, T. (2019). Applications and Initiatives of VR/AR in the Construction Industry, *Journal of JCMA*, Vol. 71, No. 4, pp.62-66. (in Japanese)

Nilim, (2025), National Institute for Land and Infrastructure Management, Construction Type System Tree. Retrieved May 12, 2025, from https://www.nilim.go.jp/lab/pbg/theme/theme2/sekisan/tree/tree.htm

Nakamizo, T., Nishio, M. (2022). Finite Element Modelling with shell element from 3D point clouds of thin walled steel structural members, *Intelligence, Informatics and Infrastructure*, Vol. 3, No. J2, pp.786-794. (in Japanese)

Niantic scaniverse, Into The Scaniverse. Retrieved May 10, 2025, from https://scaniverse.com/quest

Meta. Retrieved May 10, 2025, from https://www.meta.com/jp/quest/quest-3s/

Otsuki, S., Imai, R., Tsukada, Y., Umehara, Y., Tanaka, S., Hirano, N. (2022). Research for utilizing product model using point cloud data in the maintenance of social infrastructure, *Intelligence, Informatics and Infrastructure*, Vol. 3, No. J2, pp.945-953. (in Japanese)

Watanabe, Y., Inoue, K., Ikeda, T., Kobayashi, M., Yokoyama, W. (2023). Investigation of the application of smartphone surveying for rapid shape determination of post-disaster slopes and design of countermeasure works, *Intelligence, Informatics and Infrastructure*, Vol. 4, No. 2, pp.73-83. (in Japanese)

Watanabe, Y., Takamizawa, T. (2025). Proposal for New Learning Materials Based on Questionnaire Survey on the Recognition of Civil Engineering Structures. *THE GUNMA-KOSEN REVIEW*, No.43, pp.39-44. (in Japanese)