

ISPRS Education and Capacity Building Initiatives 2024

Development of VR/AR applications to support geospatial education

Final Report August 2026

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2. Executive Summary

Immersive technologies, virtual reality (VR), augmented reality (AR), and mixed reality (MR), have advanced rapidly in recent years. The topic of how to integrate such technologies in geospatial education is becoming increasingly important. Immersive technologies can provide a number of solutions for many challenges in geospatial education, such as enhance and support remote learning, improve student preparedness for physical labs, simulate scenarios that are not possible in the physical world, enhance existing labs with augmented reality tools, and more. One of the biggest challenges for geospatial educators who want to get their hands on immersive technologies is that many existing immersive applications are not tailored to geospatial education. Therefore, educators need to spend extensive time on software and application development. Another challenge is related to the expensive hardware (computers and headsets) that is often needed with immersive technologies. This project will develop two immersive experiences (VR/AR/MR) relevant for geospatial education that can be used by instructors to enhance lab delivery. Furthermore, we often encounter a level of hesitation to learn and use immersive technologies from educators who have little or no experience with them. To address this challenge, we will develop sample learning material that educators can use to become familiar with the developed immersive technologies.

3. Project Outline

Aim: The role of immersive technologies in the geospatial world increases every year. Students and educators should become exposed to these technologies and embrace them in order to gain understanding and familiarity. The overall aim of this project is to support geospatial education with new pedagogical approaches and technological tools such as immersive technologies.

Objectives: (1) engage geospatial educators in identifying immersive experiences to support undergraduate education in geospatial sciences; (2) develop sample immersive experiences that educators can use in their classes to engage students with VR/AR/MR (we propose two experiences one in VR and one in AR/MR); (3) develop supporting material for geospatial educators in understanding immersive technologies.

Expected Outcomes: VR / AR / MR are new emerging technologies with many educators hesitating to get engaged with or even not having sufficient background to do so. The major outcome of this project is the development of sample immersive software experiences and learning materials that anyone can use to introduce these technologies to their students. With the new experiences gained, the educators can draw their own conclusions and decide the next steps of integrating immersive technologies in their courses. In addition, specific outcomes of this project will be:

- Support of geospatial education through innovative immersive technologies.
- Two immersive experiences, one in VR and one in AR/MR, that any educator will be able to use.
- Learning materials that educators can use to understand immersive technologies.
- One ISPRS conference paper and presentation.
- Undergraduate student inclusion in research activities.
- Collaboration with multiple faculty who are interested in immersive technologies.

4. Project Activities

4.1. Hardware and Software

The software is developed in Unity 3D Game Engine using C# due to our existing experience with the SurReal (surveying reality) virtual reality software that was developed by Dr. Bolkas and Mr. Chiampi at Penn State University. For the purposes of this project, 6 Meta Quest 3 VR headsets were purchased. The Meta headsets were selected because of our experience with the Meta VR ecosystem and their compatibility with existing software tools (SurReal). This allowed us to leverage and re-use parts of the existing project, 3D instrument models and developed code. In addition, Unity 3D has a more active development community, as it is the most popular game engine for educational and training VR applications.

4.2. Undergraduate students

Two undergraduate students majoring in computer science at Penn State University were hired to assist with software development. The two students are: Jason Herrera and Kyle Jason at Penn State University. Although familiar with VR, this was their first time working on software development for VR. The students spent most of the summer of 2024 familiarizing themselves with Unity, the Quest 3 hardware, and SurReal. The students continued working, and developing the two applications, until the end of the project in August of 2026.

4.3. Professional engagement

The research team prepared and distributed a questionnaire to professionals from academia and industry to understand their experience with immersive technologies, their attitude and beliefs towards immersive technologies, and to understand the potential benefits that immersive technologies can bring in education and industry. The online questionnaire was developed and distributed in collaboration with the FIG (International Federation of Surveyors) Commission 6 Working Group 3: Applications of Immersive Technologies in Engineering Geodesy. Through this collaboration the survey was distributed to attendees of the 2024 FIG Working Week in Ghana. The survey was distributed in the months of April and May, 2024.

Using the feedback received from the online survey along with available resources, team capabilities, and a team discussion, it was decided that the following two experiences would be developed:

- (1) Virtual reality: a topographic data collection simulation (GNSS instrument)
- (2) Augmented reality: Projecting geospatial points, lines, and objects, on the real world using a mobile tablet device interface.

The online survey results are shown below:

A total of 45 individuals completed the survey. The survey received responses from the following regions:

N. America: 12

Africa: 10

Europe: 10

Asia: 8

Australia: 1

Not disclosed: 4

The employment characteristics of the sample:

University: 19

Government agency: 5

Industry: 10

University Students: 7

Not disclosed: 4

Based on the survey results, 58% have used immersive technologies and 42% have not. 54% of the respondents said that they used immersive technologies for work related tasks, and another 42% that they used immersive technologies for both work and entertainment, only 4% said that they have used immersive technologies solely for entertainment. Of those using immersive technologies, about 46% responded that they use the technology once per month. Only 12% said that they use immersive technologies every day, and 23% said that they use immersive technologies every week. Another 19% said that they use immersive technologies every year.

When asked what technologies they have used, the responses showed that those engaged with immersive technologies have used more than one technology. Mixed reality and Augmented reality received the lowest score of 61%. Virtual reality received 74%, and 360° content received the

highest scores of 91%. On the other hand, asking the respondents why they have not used any of the immersive technologies, their responses revealed that the biggest barriers are the lack of commercial software or lack of development ability, cost, and IT support. This indicates a lack of maturity in the industry to develop the necessary commercial software that will spark widespread adoption. It also demonstrates the importance of this project to familiarize educators and professionals with the technology. Most of the respondents (90%) indicated that they have used immersive technologies to simply view 3D content. Another 55% indicated that they use immersive technology for education and training, and 55% of the participants said that they use immersive technologies for data interaction and analysis (e.g., building information modeling, digital twin), and another 25% for field data collection. These results reveal limited use of immersive technologies for analysis and field data collection. However, participants indicated a moderate to positive employer attitude towards adopting most of the existing immersive technologies, as scores ranged from 3.12 for mixed reality to 3.38 for virtual reality (with a max score of 5).

Despite the barriers, the majority of the participants believe that immersive technologies are going to become an important component of the geospatial industry (83% agreed, 17% said maybe, and 0% disagreed with this statement). Similarly, the majority of the participants believe that immersive technologies will become an important component of geospatial education (87% agreed, 13% said maybe, and 0% disagreed with this statement).

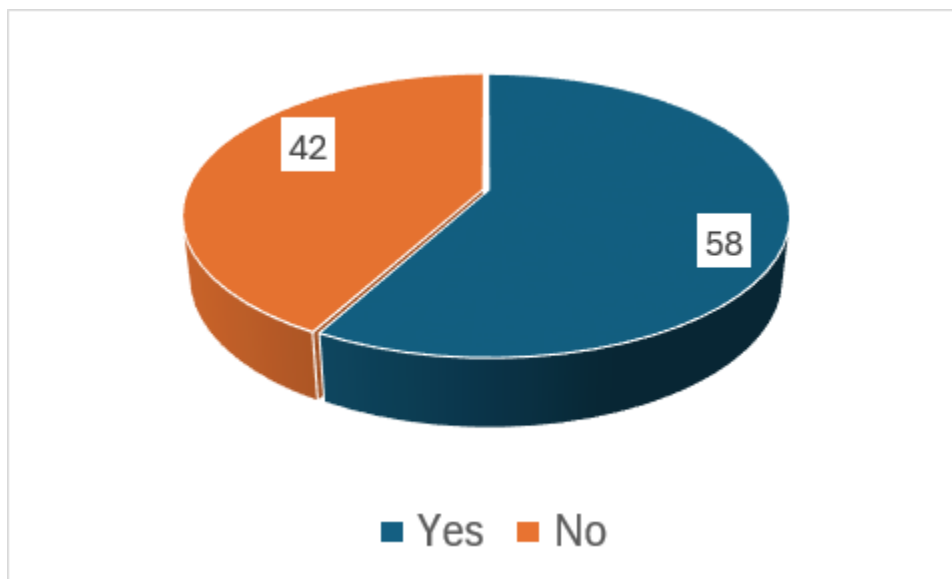


Figure 1: Have you used any immersive technologies (Virtual Reality, Augmented Reality, Mixed Reality, 360 Videos).

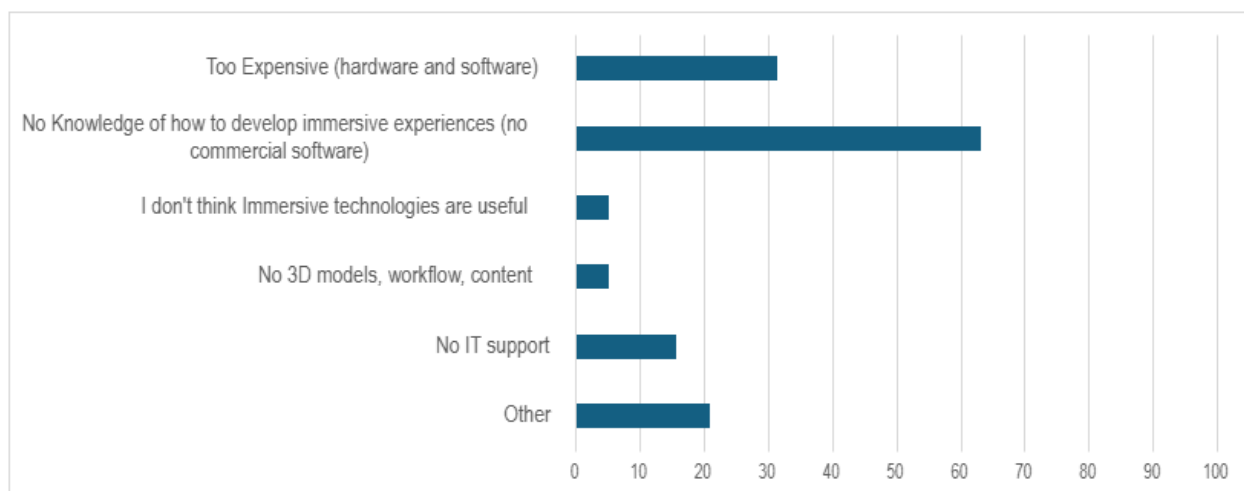


Figure 2: Why have you not used any immersive technologies so far?

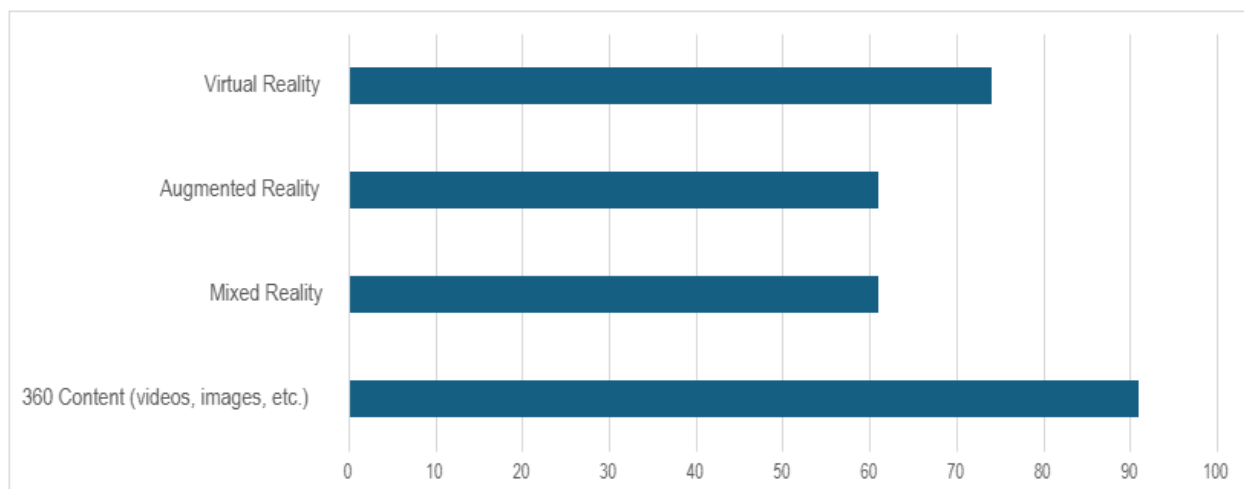


Figure 3: What technologies have you used?

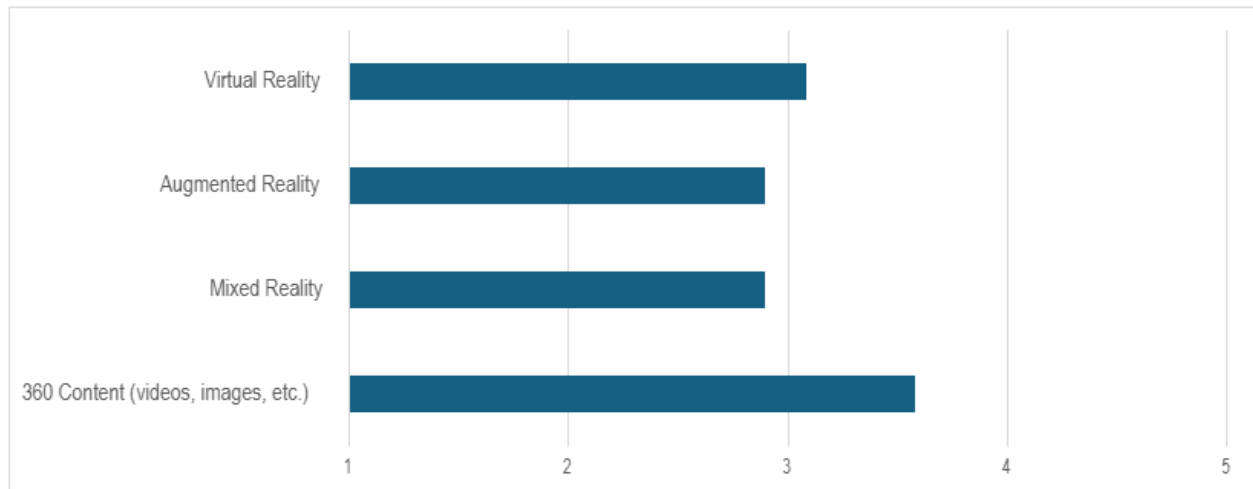


Figure 4: Rank your familiarity with each immersive technology.

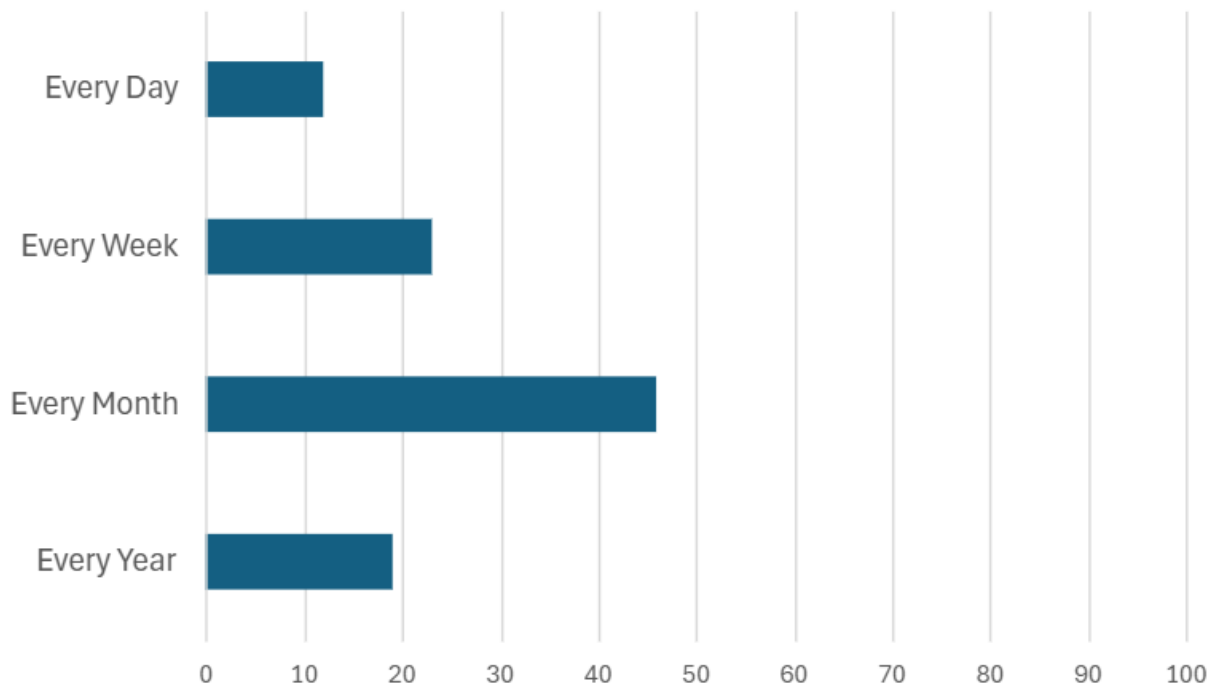


Figure 5: How often do you use immersive technologies?

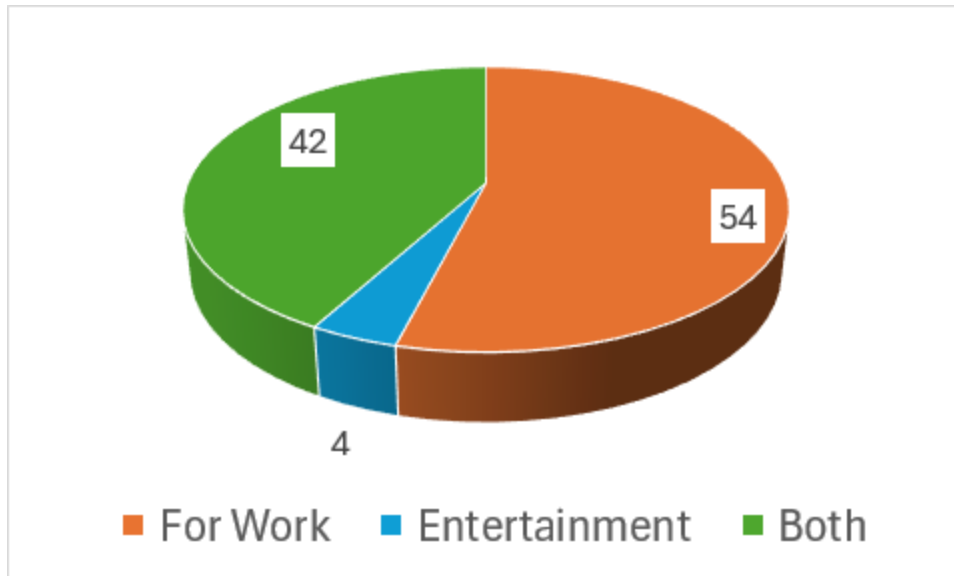


Figure 6: Why do you use immersive technologies.

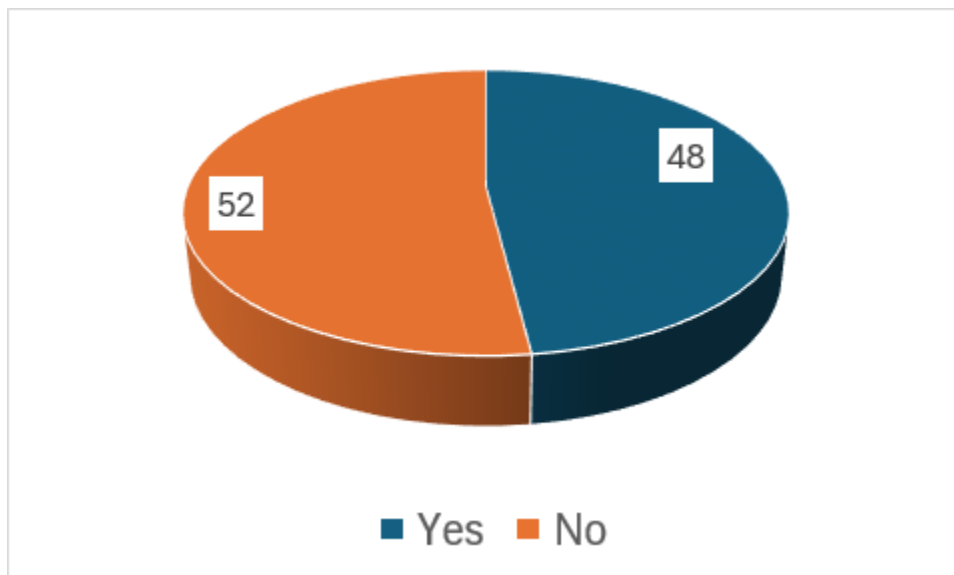


Figure 7: Do you have access to immersive technologies from your employer / company / university?

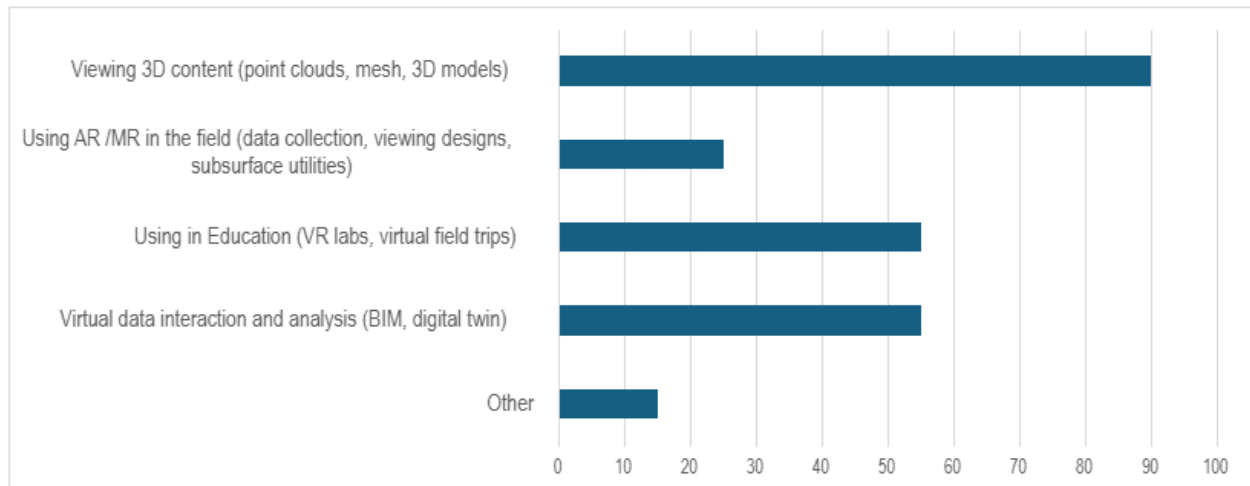


Figure 8: How does your employer / company / university use immersive technologies?

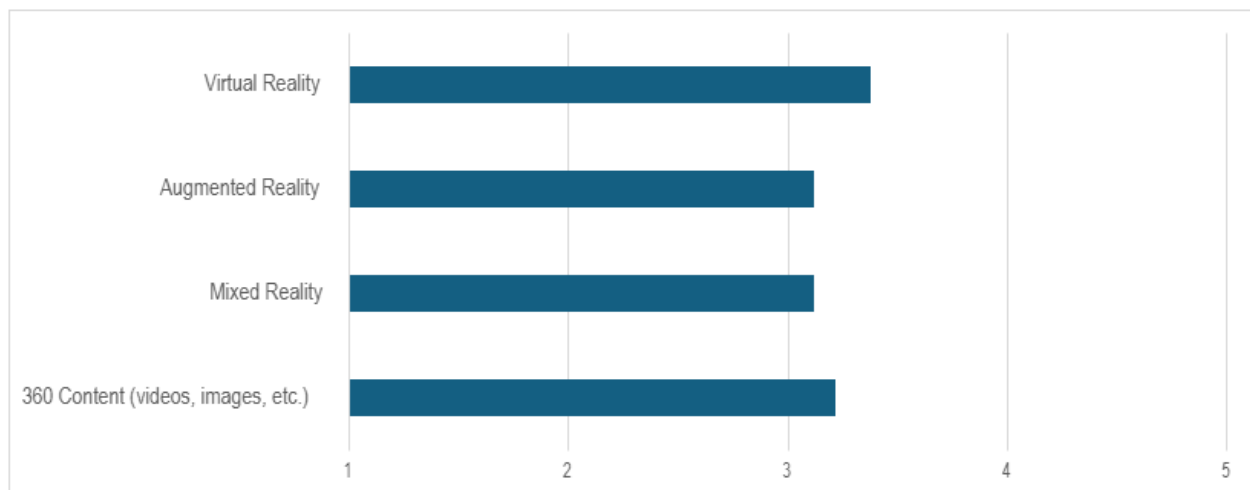


Figure 9: How motivated is your employer / company / university to use any immersive technologies?

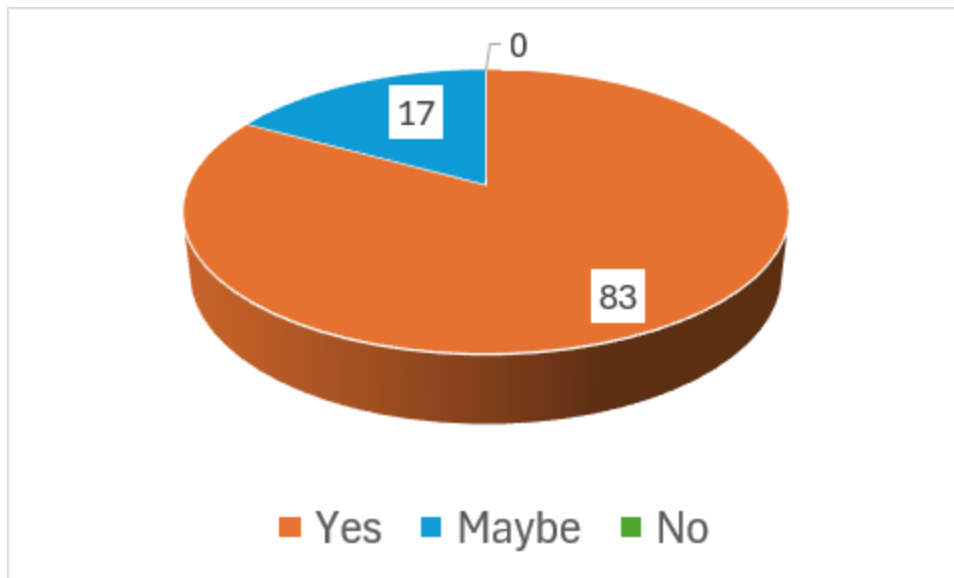


Figure 10: Do you think that immersive technologies are going to become an important component of the geospatial industry?

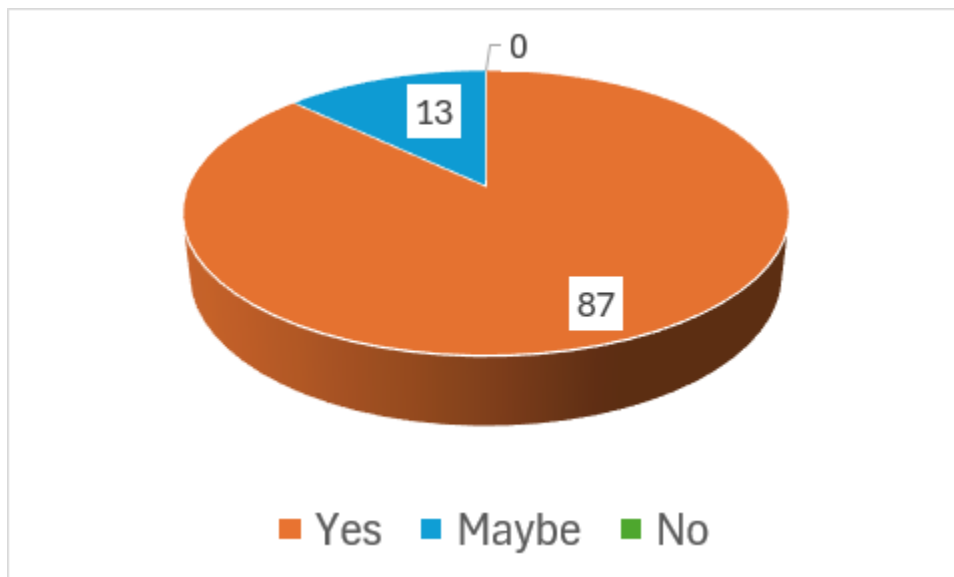


Figure 11: Do you think that immersive technologies are going to become an important component of geospatial education?

Figure 12: What are some of the industry problems that immersive technologies can address?
Figure generated with: <https://www.freewordcloudgenerator.com/generatewordcloud>



Figure 14: What kind of virtual reality experience would you like to see developed to support education and/or industry



Figure 15: What kind of Augmented Reality / Mixed Reality experience would you like to see developed to support education and/or industry

4.4. Software development

5.4.1 Experience 1: Virtual Reality (VR)

The VR experience is based on the existing SurReal software. This choice allowed us to accelerate development by using existing assets. Due to having new undergraduate students working on the project, most of Summer of 2024 was spent on familiarizing these students with Unity, the headsets, and the shared development environment. In addition, we decided to upgrade the software from Unity 2019 to Unity 2024. Upgrading the software package from the 2019 version to the 2024 was a crucial one. There was significant custom coding to develop features in the 2019 version that are now dealt with built-in function in the 2024 version. Upgrading the software package from the 2019 version took considerable time in the summer and fall of 2024, but it allowed us to deliver a product that is more efficient that interoperable with existing Unity functions, making future software development and integration of components easier.

There was considerable code development and improvements. Specific functions are summarized below:

- Selecting controls: The handling buttons were changed allowing more intuitive interactions with the virtual instrument and tablet (e.g., using the trigger for most meaningful interactions).
- Environment navigation: The ability to freely rotate the view was removed, because we found in previous studies that it would make users feel dizzy. For this version, the rotation left and right takes place in increments, which we found to provide a more stable navigation in the virtual environment.
- Terrain-instrument: The interaction of the instrument with the terrain when the user drops the GNSS instrument was upgraded to use the built-in Unity functions, allowing for faster and more efficient interaction of the instrument with the terrain.
- Manual instrument leveling: The instrument leveling tools were changed as well, with the sliders providing more dynamic changes to the instrument's position and allowing for faster leveling of the instrument.
- Auto instrument leveling: An automatic leveling option was added. In previous implementation we found that students complained that manual leveling was taking time. Students now have an option for automatic leveling of the instrument to save them time.
- Descriptions: A new description menu was created. The user now has the option to select any of the existing codes, but also has the option to add a custom code.
- Fieldbook: A new fieldbook was added; therefore, the user has access to two fieldbooks. The first fieldbook generic allows users to record generic notes. The second fieldbook records all the GNSS measurements and point descriptions. In addition, users have the ability to scroll up and down similar to an excel spreadsheet.

- Map view: We developed a map that shows the location of the points in the virtual environment as they are recorded to help students understand what features have been collected and what features still need to be collected.
- Viewing app in headset (Quest 3): The application was optimized and users can launch the app in the headset without needing a tethered connection to a computer. This considerably enhances the ability of users to use the developed app.

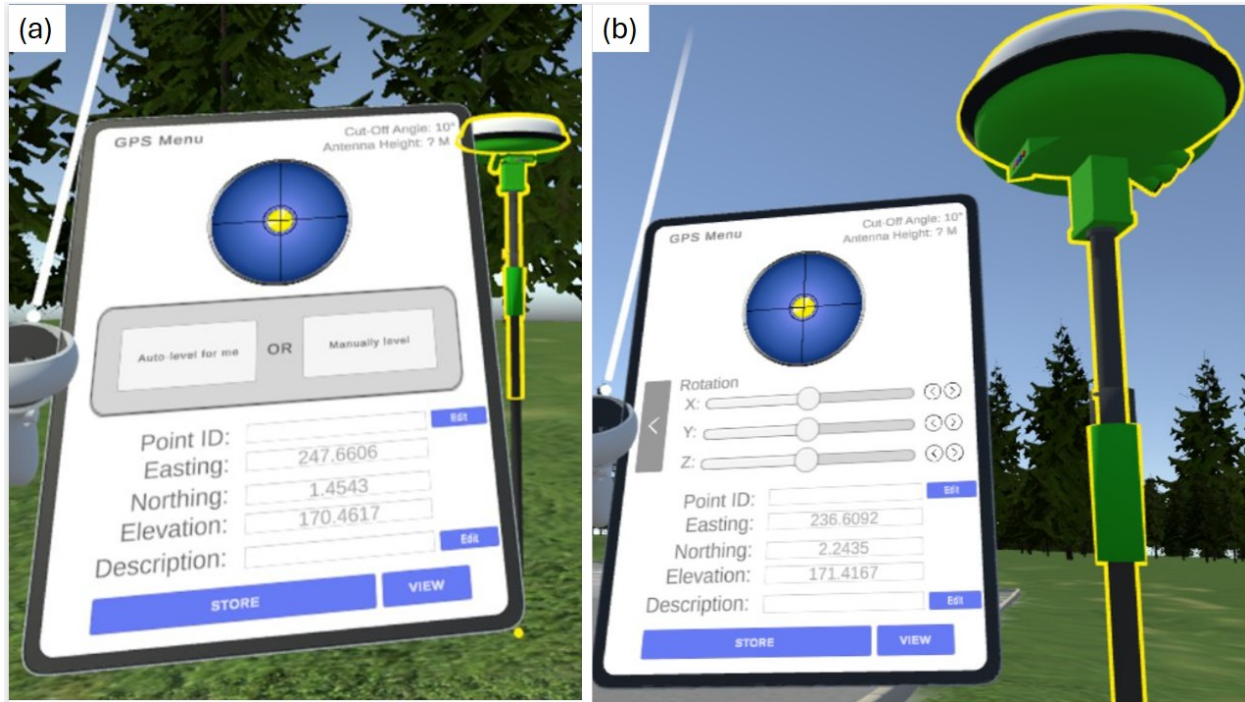


Figure 16. GNSS Auto level and Manual level (a) main menu option, (b) manual leveling menu

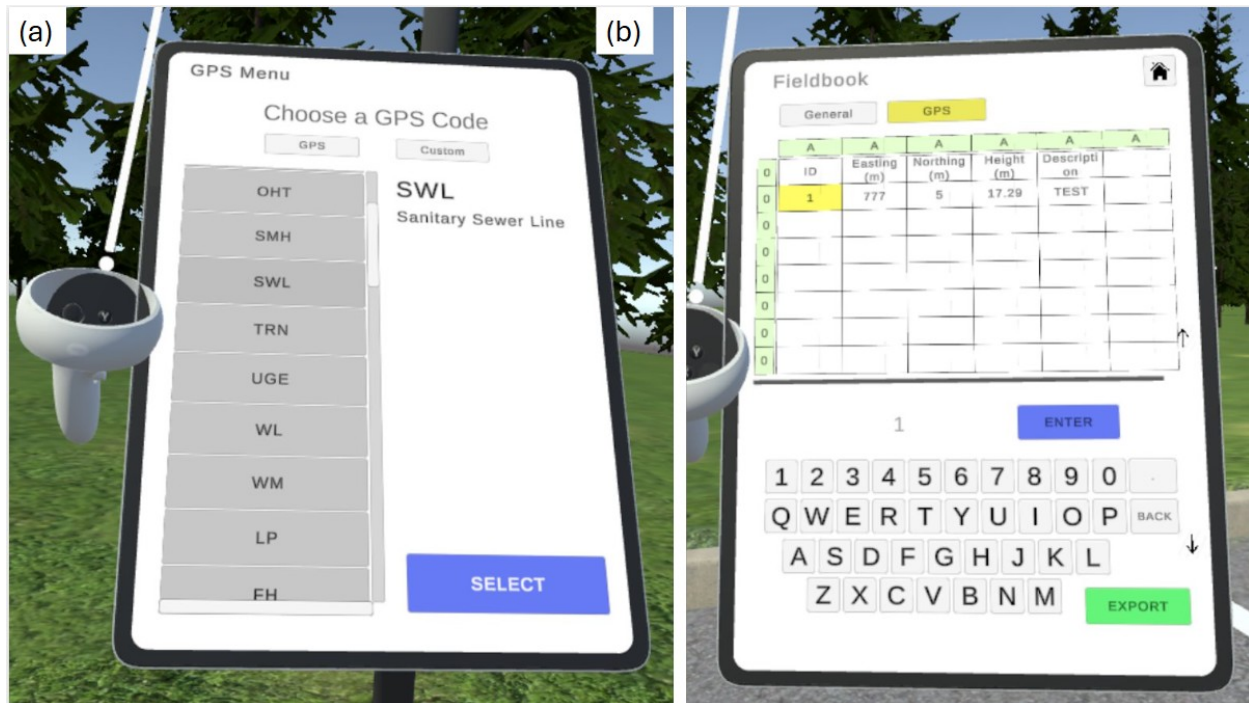


Figure 17. Descriptions and fieldbook. (a) User can select an existing point description or enter a custom description, (b) fieldbook showing a test point being recorded; the option of a generic or GPS fieldbook is also shown.

5.4.2 Experience 2: Augmented Reality (AR)

The AR experience will be viewed using mobile tablet devices to increase dissemination. The application can be used to capture geolocated points or load pre-existing points and 3D models and view them in real space in AR using a tablet interface. The application can be useful for geospatial programs who want to augment their courses with AR features. From an educational perspective, this application can support field-based learning, allowing students to better understand spatial relationships between digital models and the real environment. The application is intended to support educational activities in areas such field data collection and building information modeling.

Models can be loaded into the application in a .glb format. This format is one of the most common formats for sharing 3D models, and it was selected due to its ability to encapsulate geometry, textures, and associated assets within a single file. After development tests the team decided to develop the experience in android and Google's AR Core, as there were several issues with the React Native that delayed progress. Considerable software development took place to connect to a GNSS unit and be able to read coordinates directly. This creates the opportunity of more accurate positioning, as the application does not rely on the tablet's positioning information, but using the

GNSS information objects can be placed with cm-level accuracy. An Emlid Reach RS2+ was used for the development of this AR application, but users who want to use the developed application can use other GNSS units as long as there is connectivity via WiFi. Support for connecting to other GNSS units was not tested and is not given.

The main AR features are summarized as follows:

- Tablet-based implementation: The application can run on any Android tablet or smartphone.
- Interface: user-friendly interface with several settings for customization.
- Internal and External GNSS connectivity: Positioning is achieved through the tablet's internal GNSS unit. External GNSS connectivity is possible using an Emlid Reach RS2+ for capturing points with cm-level accuracy.
- External GNSS functions: The tablet supports several functions for the external GNSS unit such as setting data collection time when static (e.g., 5 seconds); setting accuracy levels (Fix or float); status displays (satellite geometry, signal strength, accuracy); and more.
- Visualization accuracy: Visualization depends on the tablet camera and currently is at the meter-level. Future work will test depth-enabled tablets to explore improving the visualization accuracy.
- Point visualization: Captured points can be visualized in 2D or 3D.
- Support of 3D models: 3D models in .glb format can be loaded and visualized in space, enabling applications related to building information modeling.
- Point loading: point coordinates can be loaded for visualization in WGS84 coordinates.
- Exporting: Captured points can be exported in CSV format.

The next steps that will follow will focus on optimizing the display of the 3D models and improving visualization using depth-enabled tablets, and evaluate the application in a classroom setting.

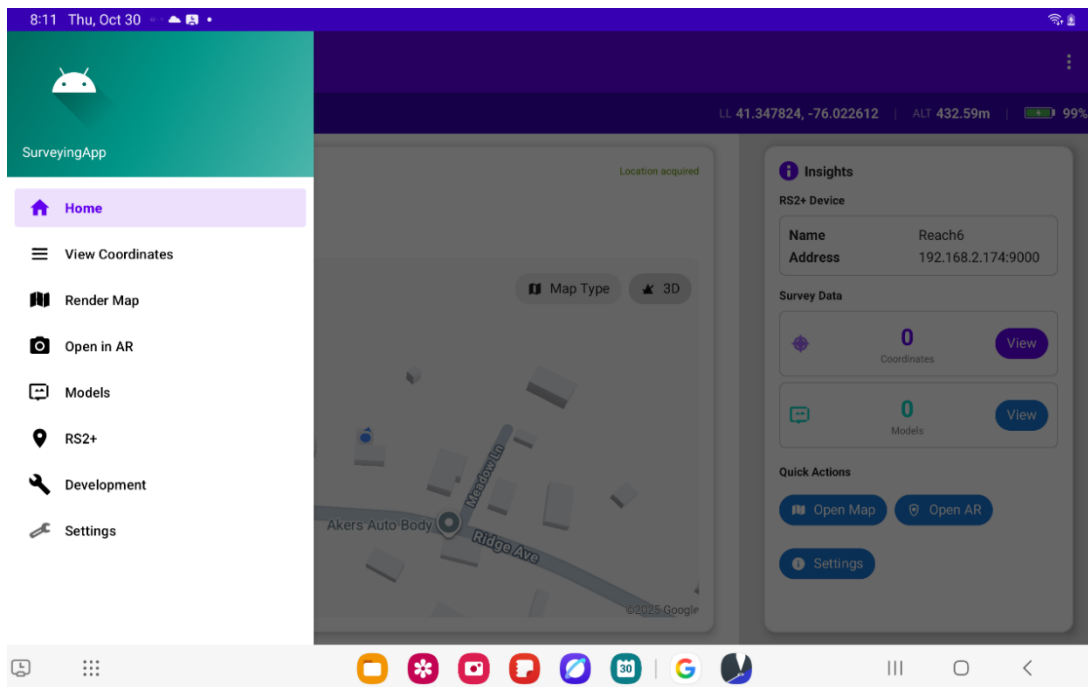


Figure 18. Main menu of the AR application.

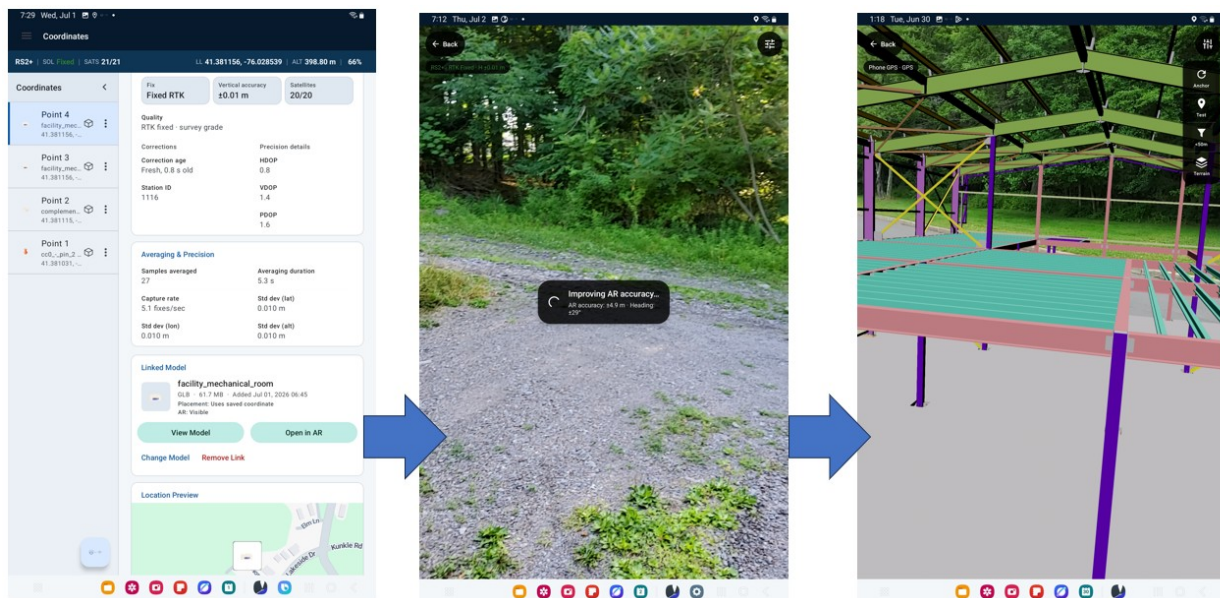


Figure 19. Point capturing and model linkage, and viewing 3D models in AR.

4.5. Implementation and testing

The application was tested in Fall of 2025 in a mapping course of the Surveying Engineering program at Penn State Wilkes-Barre with eight students participating. Although we planned for data collection at the US Military Academy at West Point in Fall 2025, this could not be completed due to the government shutdown. The team will make efforts to perform data collection at West Point in Spring of 2026, but this depends on course offerings with relevant content to the developed applications. The other option will be to perform data collection in Fall of 2026 after this program is over.

The Penn State Wilkes-Barre students completed the VR lab using Meta Quest 3 headsets connected to desktop computers. The VR lab took about 40 minutes to an hour to complete. Their feedback was positive overall. For example, students indicated that they found VR helpful in learning the course material (score of 4.5 / 5), it added to the fun of learning (score of 5/5), and helped them prepare for the real labs (score of 4/5). With all of them enjoying the virtual reality lab despite half of them feeling slightly nauseous.

Prior to conducting the VR lab, the students were given instructions about topographic mapping and how to properly collect planimetric features and ground shots for contours. They were then asked to collect data in the areas shown in Figure 20. After an initial demonstration of the VR application and its controls, the students spent about 10 minutes of becoming familiar with the VR application. They were asked to level the GNSS instrument and record a point to verify familiarity with the controls. Then the instructor asked each student to collect the features shown in Figure 20, and marked them if the points were collected in a correct or incorrect way (the correct way is shown on the second column of the evaluation table), and if they used the correct field code. This evaluation form will be distributed with the application, and it can be used by any university that will use the developed VR application.

The implementation results were recorded in our ISPRS Congress paper, and we refer readers in the said publication to avoid duplication of information. The main educational finding was that the VR lab helped students practice topographic data collection and revealed misconceptions (especially with ground-shot spacing, curb placement, and breakline identification) before the physical lab. Student feedback was generally positive, with high ratings for liking the VR lab, instrument handling, software interaction, and its usefulness as a training tool.



Evaluation

Feature	Requirement	Correct Code	Correct Placement	Incorrect Placement
Edge of Pavement	Single Shot			
Face of Curb	Single Shot			
Back of Curb	Single Shot			
Curb Curves	Three Shots (Min)			
Utility Poles	Single Shot (any side)			
Trees	Single Shot (any side)			
Signs	Single Shot			
Sanitary Manhole	Single Shot in Center			
Storm Inlet	Shot on (3) Corners			
Stone Wall	Face of Stone Wall			
Parking Paint Stripes	One Shot at Each End (Centered)			
Ground Shots	Spaced and Positioned Appropriately			
Breakline(s)	Clear Change in Topography			

Figure 20. Assessment tool for topographic mapping in VR.

4.6. ISPRS Congress

A conference paper was submitted to the 2026 ISPRS Congress in Toronto, Canada. The paper was published in the archives. The reference is: Bolkas, D., Chiampi, J., Herrera, J., Jones, K., Sharr, M., O'Banion, M., Parisi, E., and Detchev, I. (2026). Development of VR/AR applications to support geospatial education. ISPRS International Archives of Photogrammetry and Remote Sensing. Conference paper presented at the ISRS Congress, Toronto, Canada, 4-11 July.

The paper was presented at the ISPRS Congress on Saturday July 11 at the Open Source at the session: WG V/3: Open Source Promotion and Web-based Resource Sharing.

5. Repository

The applications along with supporting material can be downloaded from the following locations:

- VR application, one drive : https://pennstateoffice365-my.sharepoint.com/:f:/g/personal/dxb80_psu_edu/IgA1jD4zCOzmTqEgAvAx9kKXARepnsoRy3Zm3Y__8umaeU?e=4gU5ZO
- AR application, GitHub : <https://github.com/PennStateCS/GPS-App>

There users will find the applications and instructions on how to install and use the applications.

References

Bauer, P., Bolkas, D., O'Banion, M., Blut, C., Levin, E., Schotte, W., Staiger, S., Liu, R., Ng, A. and Jadidi, M., (2026). Virtual Reality and Digital Twins: A technological convergence. Conference paper presented at the FIG Working Week in Cape Town, South Africa, 24–29 May 2026.

Bauer, P., Bolkas, D., O'Banion, M., Blut, C., Lienhart, W., Schotte, W., Staiger, S. and Ng, A., (2025). Virtual Reality–“Just to be cool is not enough” An intermediate report of the FIG Working Group 6.3. Conference paper presented at the FIG Working Week Brisbane, Australia 6–10 April 2025.

Bolkas, D., Chiampi, J., Herrera, J., Jones, K., Sharr, M., O'Banion, M., Parisi, E., and Detchev, I. (2026). Development of VR/AR applications to support geospatial education. ISPRS International Archives of Photogrammetry and Remote Sensing. Conference paper presented at the ISRS Congress, Toronto, Canada, 4-11 July.