

Virtual Reality (VR) Assisted Geomatics lab Development

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ABSTRACT:

Virtual Reality (VR) lab components provide the opportunity to explore the efficacy of this technology on Geomatics education and lay the groundwork for the VR as an emerging education paradigm. Geomatics education at UF has been innovatively optimized towards a hybrid education system, with most of the curriculum taught using distance communication. Nevertheless, Geomatics teaching still involves intensive indoor and outdoor lab components. VR labs enable learning and practicing lab techniques as an alternative or supplement to live lab activities. These technically and physically demanding activities require intensive training on expensive lab equipment. The labs often go beyond allocated lab time and are susceptible to bad weather conditions. Using VR technology provides an integrated learning experience that mixes instructions with simulated physical activities, eliminating many limitations associated with lab instruction. In this study, we demonstrate the development of the total station device centring and levelling lab activity using the Meta Quest 2 Headset on the Unity Software Development Platform, as well as Unity's XR Interaction Toolkit. Development challenges related to different setup components (e.g., bubble-level setup, effective gravity for editing tripod placement, component intractability) are presented. Among multiple challenges of using Unity for the development of an educational VR application, adjusting the functions of the XR Toolkit in order to get the desired outcomes stands as one of the largest difficulties. Unity's physics is not intuitive for the intended purposes of this project, so multiple technical workarounds were required including the use of Unity's UI (User Interface) features.

1. INTRODUCTION

1.1 Background

Virtual Reality (VR) technologies are strongly emerging as a new transformative paradigm in human learning. Recent research on using VR in education highlights the advantages the students gain through the interactive integration of instructional and physical lab activities in the extended reality world (Guilbaud et al., 2021). VR labs enable learning and practicing lab techniques as an alternative or supplement to live lab activities. Extended reality effectively provides visualization and interaction with realistic digital and real objects that can enrich and facilitate the learning experience (Faridi, 2020; Alzahrani, 2020). It can provide a safe and cost-effective alternative to traditional physical labs, allowing students to conduct experiments and simulations without the need for expensive equipment or hazardous materials (Marchetti & Rossini, 2019). These technically and physically demanding activities require intensive training on expensive lab equipment. The labs often go beyond allocated lab time and are susceptible to bad weather conditions.

Lam et al. (2020) studied the effect of paper-based manual and stereoscopic-based mobile augmented reality and reported its advantages in both information retention and error avoidance. Another study conducted by Vate-U-Lan (2012) suggested that augmented reality capacity to facilitate the comprehension of instructional material while solving problems supported creative learning compared to traditional education methods. Elmunsyah et al. (2019) showed that increased interactivity, information accessibility, and learners' collaboration were associated with submersed reality learning. The studies emphasized the pedagogical advances of virtual reality labs in enhancing student learning.

Recently, efforts to develop augmented reality lab components to support Geomatics education have emerged (Weng et al., 2021; Bolkas et al., 2021). More recently, research by Bolkas et al. (2022) assessed the use of augmented reality in first-year Surveying Engineering education. The feedback provided by the students showed this technology was able to recreate surveying labs with a high level of fidelity. The students stated that "virtual reality gave them more incentives to learn, added to the fun of learning, and improved their overall learning experience". The students also indicated "that virtual reality labs helped them understand surveying procedures and the operation of instruments, and they considered virtual labs to be a useful tool for preparation for physical labs" (Bolkas et al. (2022). These efforts, however, are only available to the developers' team in private GitHub repositories.

1.2 Problem Statement

Integrating VR into the Geomatics education provides the opportunity to further explore the efficacy of this technology and potentially lay the groundwork for impacts on pedagogy and other research interests related to this new paradigm. Geomatics education at the University of Florida (Abd-Elrahman et al., 2019) has been innovatively optimized towards a hybrid education system with most of the curriculum taught using distance communication. Nevertheless, Geomatics teaching still involves intensive indoor and outdoor lab components. These activities are technically and physically demanding, requiring intensive training on expensive lab equipment. The labs often go beyond allocated lab time and are susceptible to bad weather conditions. Equipment availability and the need for frequent upgrading to adopt the latest technologies are limitations to current lab teaching.

Geomatics lab instructions are typically done in three phases: pre-lab preparation, actual data collection, and post-lab computations. This multi-step pedagogy often reduces students'

ability to comprehend and master the material. Using VR technology provides an integrated learning experience that mixes instructions with simulated physical activities, eliminating many limitations associated with lab instruction. For example, VR allows supplemental repetition and additional practice to hands-on components that are often challenging for students to master in the limited time available during in person labs, and other logistical concerns, such as the student numbers, equipment battery life limitations, and weather conditions in outdoor setups. This technology enables learning and practicing lab techniques as an alternative or supplement to live lab activities. We expect the introduction of VR activities in Geomatics education to: (1) overcome many of the obstacles in Geomatics lab pedagogy, (2) optimize time and equipment use of live lab components, (3) increase Geomatics education resilience in emergencies such as COVID19 closure, (4) increase program visibility, and (5) improve Geomatics recruitment, especially among young Gen-Z students. The knowledge gained through this study's development of VR-based education material is a great asset for expanding the utilization of this technology into other Geomatics and other instructional activities across the Geomatics program.

In this study we demonstrated the development of a full total station device setup procedure using VR technology. Total station setup is required for surveying field observations. It represents a fundamental skill for ground-based surveying involving total station use. This process is typically taught and used in multiple labs during the first semester of college-level surveying education curriculum. Figure 1 shows snapshots of the total station setup steps within the developed VR application. Figure 2 shows a Meta Quest 2 user utilizing the developed.

The process can be used fully or partially used for other equipment setup procedures such as Global Navigation Satellite System (GNSS) antenna or spirit level setups. In the following section, the hardware and software development kits used to develop the application and the total station adjustment steps implemented in the application are introduced in the Methods section. The results of the developed implementation, challenges related to different setup components, and key lessons are introduced in the following Results, Discussion, and Conclusion sections.

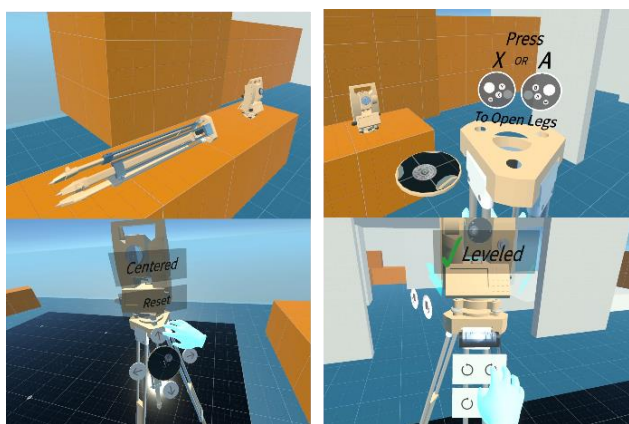


Figure 1. Screen snapshots of student total station adjustment work within the VR application.



Figure 2. User wearing the Oculus Quest 2 device.

2. METHODS

2.1 Material

We developed Virtual Reality (VR) lab components to support Geomatics education. We adopted a generic 3D total station device model uploaded to the 3dWarehouse Sketchup online site (Henry, 2023). The Unity Software Editor Development Platform v 3.30 and the Unity's XR Interaction Toolkit were used to develop the application on a Meta Quest2 headset in an indoor setup. The total station 3D model was reviewed and edited to ensure the model had the correct individual components, such as the multi-piece tripod, total station base, and base screws needed to accurately represent the movement and usage of individual parts. The editing of the 3D model involved separating the mesh where necessary in Maya 2023. For many issues confronted in the technical development of the application, Unity's XR Input Manual and the Unity Forum provided useful references.

2.2 Procedure

Total station accurate adjustment and multi-step setup is crucial before collecting observations. The entire workflow is implemented by a user wearing the Meta Quest2 headset and holding the two Meta Quest controllers by both the left and right hands. Various controller buttons are used to grab and release tripod and total station components, and pointing with the controllers is used to interact with buttons which guide the setup process, all in a virtual environment. Several consecutive setup steps were implemented, starting from carrying the tripod, opening the legs, and mounting the tripod on a ground marker. The user then carries the total station and mounts it on the tripod with an instruction to tighten the mounting screw. Several steps follow to adjust the total station mounting using a ground-looking (centring) scope. Then, the user adjusts the circular level by adjusting individual leg heights. Once the circular bubble level is adjusted, total station levelling is adjusted using the long bubble level. Finally, the user is instructed to shift the

total station position on the tripod base to ensure accurate centering over the ground mark.

The total station setup process was divided into six steps, outlined as follows supported by illustrative graphics. After each step the user responds virtually by clicking a button to continue to the next step.

Step 1. Tripod setup

In this step, the user wearing the Meta Quest2 headset sees the tripod and total station laid on a bench. The user approaches the total station in a virtual environment by moving the joysticks on the controllers, reaches out to the tripod's upper leg, and press and hold the trigger button on the grip of the controller to carry the tripod. The user then moves while carrying the tripod to one of six control point markers represented as disks and nails on the ground. The user then presses the A or X button on the controller to open the tripod legs and position the tripod directly on the control point (ground marker). This process is aided by a simulated optical telescope to the left of the tripod which shows the ground under the tripod to the user. The final outcome of this step is to have the tripod placed correctly above the control point.

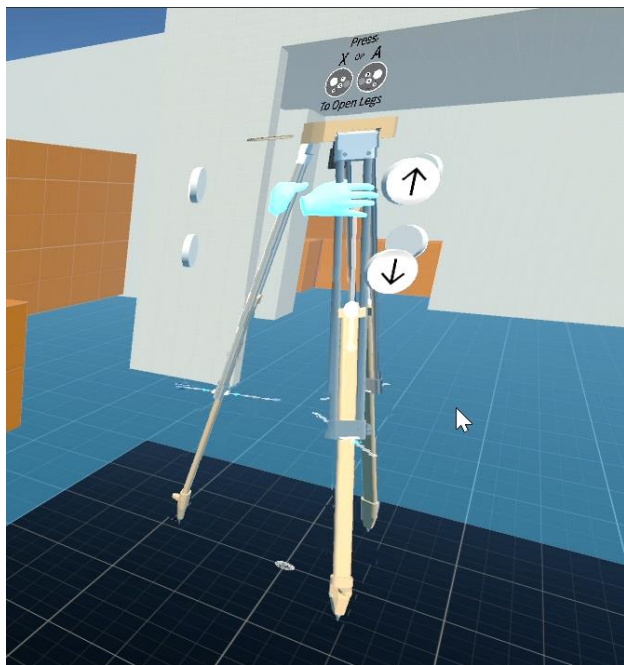


Figure 3. The tripod is being held by the user's press and hold of the grip trigger button on the controller. The user has opened the legs by pressing the corresponding button, allowing the tripod to be placed on the ground above the control point.

Step 2. Total station mounting

The joysticks on the controller is used to move the operator virtually to the bench. The user then carries the total station from the top handler by pressing and holding the controller's grip trigger button and moves back to the tripod location to mount the total station on the tripod. This step requires the user to place the total station on the tripod correctly in order to move to the next step. The user is prompted by a virtual button to tighten the total station mounting screw. This step is essential for total station mounting safety, which is an important lesson for the students. The use of a button in virtual reality takes the

place of difficult mechanics that are needed to virtually simulate this screw tightening successfully. At the end of this step, the total station is mounted firmly on top of the tripod base.



Figure 4. The total station being held by the user (left). The user pointing at the virtual user interface button in order to simulate the screw tightening step (right).

Step 3. Centring using leg pivoting

This step is difficult to implement given the current VR technology limitations due to the complicated nature of grabbing objects with two hands and synchronizing their move. A simpler implementation was adopted where the user is prompted to identify a pivot leg. Once the pivot leg is selected, 4 buttons (left, right, up, and down) are activated in between the two legs opposite the leg which has been selected for pivoting. This allows the user to move these two legs left and right and front and back, simulating a pivoted swinging motion. The process is guided by a simulated optical telescope showing the control point on the ground with a cross hair. The process can be repeated by changing the pivot leg until the cross hair is overlaid perfectly on the control point mark on the ground. Finishing this process indicates that the vertical axis of the total station passes by the ground control point mark on the ground.

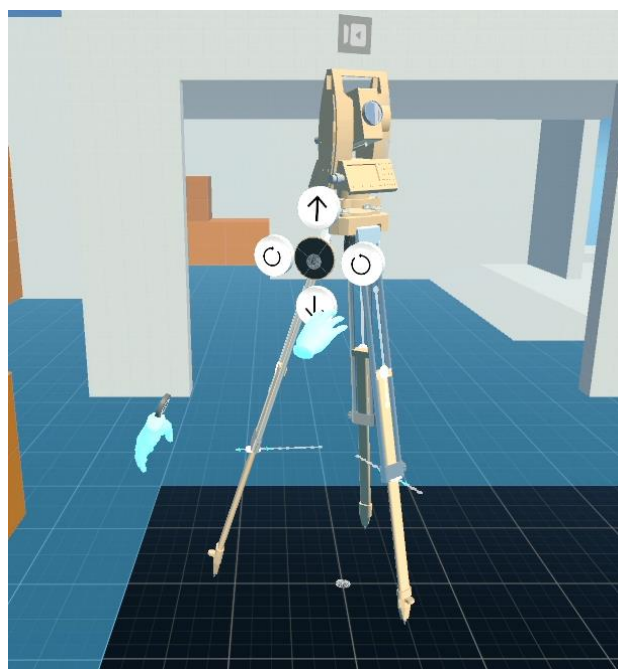


Figure 5. The user interacts with buttons that control the position and rotation of the tripod and total station in order to

get the total station cantered above the control point mark on the ground.

Step 4. Levelling using the circular level bubble

Adjustment of surveying equipment levelling using a circular bubble level is essential not only for total station setup, but also for adjusting other surveying equipment such as the spirit level device. In this step the user is allowed to raise and lower each of the tripod legs using their hands to touch a virtual button which controls the movement of the leg's heights. This interaction can be seen in Figure 6. The user watches the bubble moves based on the change of the leg height. The user should change the height of the leg to which the bubble is leaning towards or away from. Once the bubble is shifted in the direction of another leg, the leg lowering or raising actions are repeated using the other leg. The process is iterated until the bubble is perfectly cantered, indicating the total station is levelled.

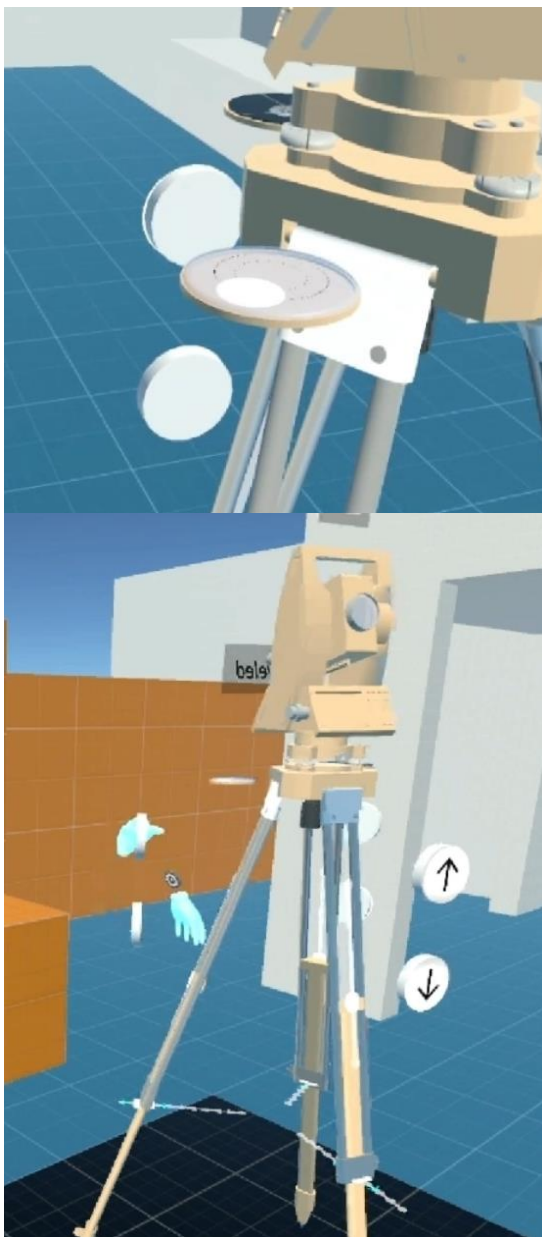


Figure 6. Circular level (top) is adjusted by changing leg heights (bottom) repeatedly and referencing the current position

of the circular level's bubble to determine which leg height(s) are appropriate to alter.

Step 5. Levelling using the long (plate) level bubble

Accurate levelling of the total station is adjusted using the three base screws and the long plate level bubble. In this step, the user rotates the total station so that the plate level is parallel to two of the base screws. The user interacts with a virtual button which rotates the two screws together inward or outward to adjust the plate level. The user can then rotate the total station 90 degrees towards the third screw. This enables buttons which allow the rotating of the third screw to adjust the plate level in this perpendicular direction. This step ensures accurate levelling of the total station. A visualization of these steps can be seen below in Figure 7.

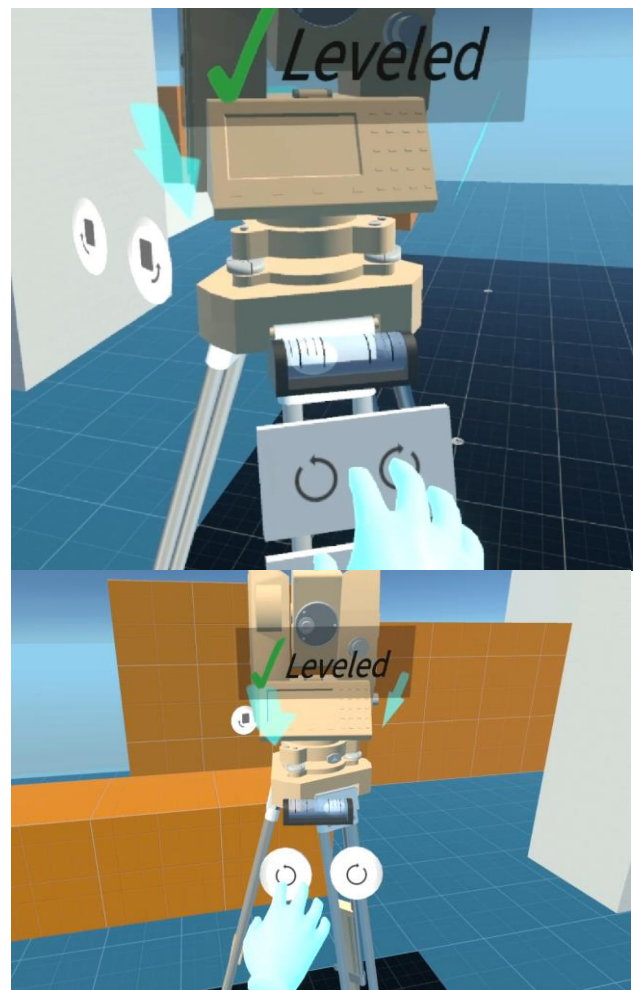


Figure 7. The user is interacting with virtual buttons allowing the change in total station orientation by rotating two screws at a time, either both towards the inward direction, or both towards the outward direction (top). Additionally, the user is seen interacting with virtual buttons in order to rotate the total station – using only one screw – and centre the plate level (bottom).

Step 6. Final centring by total station shift

This final step takes care of any misalignment from the control point mark resulting from the base screw rotations in the previous step. This misalignment is typically small, and only a small shift of the total station on the top tripod base can fix the

centring again. The user interacts with arrow buttons to shift the total station on the base in 4 directions to adjust the centring, while looking at a simulated telescope showing the control mark on the ground. If this process requires significant shift of the total station that brings it outside the base, the user is prompted to restart the setup process.

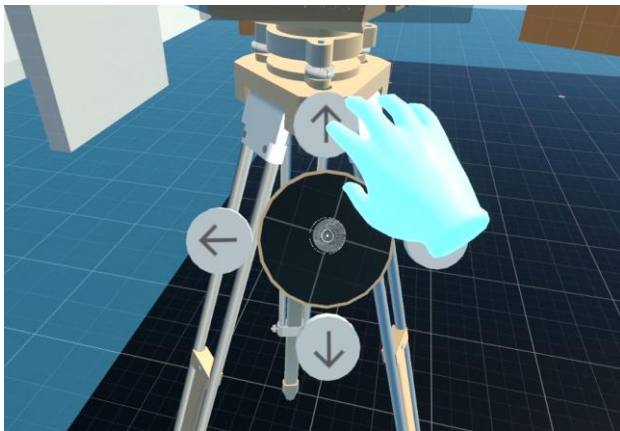


Figure 8. User touching the virtual buttons with controllers to shift the total station as needed on the tripod.

3. RESULTS AND DISCUSSION

A video demonstrating the detailed VR implementation can be accessed in (School of Forest Fisheries and Geomatics Sciences Youtube Channel, 2023). The application includes the option to display video clips which demonstrate the real-life implementation of each step as well as corresponding clips showing the same steps in the VR environment. These videos assist the VR user's learning experience emphasizing the real world steps and contrasting these steps with the VR implementation. The team is in the process of narrating the videos in Spanish to reach out to a wider user groups. First classroom deployment is planned in the fall of 2023.

This implementation is confined to setting the tripod on a rigid surface (e.g., concrete or asphalt floor). For future work, a branch for soft soil setup needs to be introduced. The additional step involves stepping on the leg foots to push the legs down into the ground in case of a softer ground material such as dirt or grass soils. The total station base screws will need to be used to adjust the total station tilt so that the vertical access passes through the ground mark. The technical components needed to add this step are already available in the current implementation, which minimizes the additional efforts.

Among the multiple challenges of using Unity for the development of an educational VR application, adjusting the functions of the XR Toolkit in order to get the desired outcomes stands as one of the most significant difficulties. Unity's physics is not intuitive for the intended purposes of this project, so multiple technical workarounds were required, including the use of Unity's UI features and incorporating inquiries supported by visual cues. Examples of additional features would be incorporating extended reality features, where real world environment is integrated in the immersed environment and providing more setup challenges to assess students' task understanding within the VR practice environment.

Further developments are needed to build more intuitive interactions within the VR environment and to develop more

VR labs to augment physical lab activities across the Geomatics curriculum. These further developments may include more robust tripod physics interactions, improving the spirit levels within the application by adding precise calculation to determine the bubble's position. Introducing more direct user interaction, by grabbing, in place of the current Unity UI components is also desirable. Our next Geomatics lab will include a telescope pointing and measurement reading lab that helps the students master this process in an extended reality setup.

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REFERENCES

- Abd-Elrahman, A., Barnes, G., Benjamin, A., Britt, K., Dewitt, B., Hochmair, H. H., ... & Wilkinson, B. (2019). Geomatics education at the University of Florida: A case study of challenges and adaptation. *Surveying and Land Information Science*, 78(1), 5-16.
- Alzahrani, N. M. (2020). Augmented reality: A systematic review of its benefits and challenges in e-learning contexts. *Applied Sciences*, 10(16), 5660.
- Bolkas, D., Chiampi, J. D., Fiotti, J., & Gaffney, D. (2022). First Assessment Results of Surveying Engineering Labs in *Immersive and Interactive Virtual Reality*. *Journal of Surveying Engineering*, 148(1), 04021028.
- Bolkas, D., Chiampi, J., Fiotti, J., & Gaffney, D. (2021). Surveying Reality (SurReal): Software to Simulate Surveying in Virtual Reality. *ISPRS International Journal of Geo-Information*, 10(5), 296.
- Demitriadou, E., Stavroulia, K. E., & Lanitis, A. (2020). Comparative evaluation of virtual and augmented reality for teaching mathematics in primary education. *Education and Information Technologies*, 25(1), 381-401.
- Elmunyah, H., Hidayat, W. N., & Asfani, K. (2019, April). Interactive learning media innovation: utilization of augmented reality and pop-up book to improve user's learning autonomy. *In Journal of Physics: Conference Series* (Vol. 1193, No. 1, p. 012031). IOP Publishing.
- Faridi, H., Tuli, N., Mantri, A., Singh, G., & Gargrish, S. (2021). A framework utilizing augmented reality to improve critical thinking ability and learning gain of the students in Physics. *Computer Applications in Engineering Education*, 29(1), 258-273.
- Guilbaud, P., Guilbaud, T. C., & Jennings, D. (2021, July). Extended Reality, Pedagogy, and Career Readiness: A Review of Literature. *International Conference on Human-Computer Interaction* (pp. 595-613). Springer, Cham.
- Henry, A., 2023. 3D Warehouse Sketchup Total Station Model. Retrieved June 19, 2023, from <https://3dwarehouse.sketchup.com/model/87802247-e83e-4bc9-bf6c-fc22eb1f4b4e/Total-Station-with-Tripod?hl=en&login=true>
- Lam, M. C., Sadik, M. J., & Elias, N. F. (2021). The effect of paper-based manual and stereoscopic-based mobile augmented

reality systems on knowledge retention. *Virtual Reality*, 25, 217-232.

Marchetti, E., & Rossini, M. (2019). Virtual Reality in Education: A Tool for Learning in the Experience Age. *Journal of e-Learning and Knowledge Society*, 15(2), 145-157.

School of Forest Fisheries and Geomatics Sciences YouTube Channel (2023, May 19). Virtual Reality (VR) Total Station Playlist [Video]. *YouTube Virtual Reality (VR) Total Station Playlist*.

<https://www.youtube.com/playlist?list=PLr5M0QvUoAelz-hsIn-eBSf4I2E-s6mBV>

Vate-U-Lan, P. (2012, July). An augmented reality 3d pop-up book: the development of a multimedia project for English language teaching. In *2012 IEEE International Conference on Multimedia and Expo* (pp. 890-895). IEEE.

Weng, C., Puspitasari, D., Tran, K. N. P., Feng, P. J., Awuor, N. O., & Matere, I. M. (2021). The effect of using theodolite 3D AR in teaching measurement error on learning outcomes and satisfaction of civil engineering students with different spatial ability. *Interactive Learning Environments*, 1-15.