Pilot Desktop and Immersive Virtual Reality Field Trip Study of Coastal Maine Indicates Equivalent Student Learning Outcomes and High Engagement

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Abstract

There is an increased interest in geoscience virtual field trips (VFTs) coinciding with an expansion of online learning and growing concerns about the lack of diversity, inclusion, and equity in many STEM fields. Motivated by this interest, we built a VFT of Coastal Maine using Unity software, traditionally a game development platform, and piloted a web-based desktop VR (dVR) and headset immersive VR (iVR) version of the VFT in an introductory physical geology class (total n=25, dVR=14, iVR=11) at a small liberal arts college in spring 2021. Our primary goals of the pilot study were to assess if students would demonstrate (1) learning outcomes within an accessible virtual environment as they would in a real-world geology field site lab experience and (2) equivalent proficiency in lab goals in dVR and iVR conditions as measured by response accuracy. Within the VFT, participants were shown a series of overview maps across several spatial scales to help them geolocate the field site. They were then placed in the model at ground level and asked to perform several tasks to learn to navigate the environment and use the compass for orientation and spatial reasoning tasks. Participants observed prompted geologic features and answered multiple choice and short answer questions with the aid of augmented information (i.e., real-world site images, photomicrographs) embedded within the VFT. There was no statistically significant difference in response accuracy between the dVR and iVR conditions, which suggests the potential for VFT access and scalability without requiring iVR equipment. However, there was a marked decrease in accuracy on lab responses (i.e., identifying rocks, assessing rock orientation, and interpreting collision processes) when compared to previous in-person field experiences. We hypothesize higher resolution images and more realistic field site rendering could address this issue in the future. Encouragingly, when compared to in-person field experiences, we qualitatively observed an increase in independent exploration and reasoning and an increase in student comfort using the augmented compass within the VFT environment. Student feedback was overwhelmingly positive regardless of VFT condition and 100% of participants indicated they wanted access to more VFT experiences.

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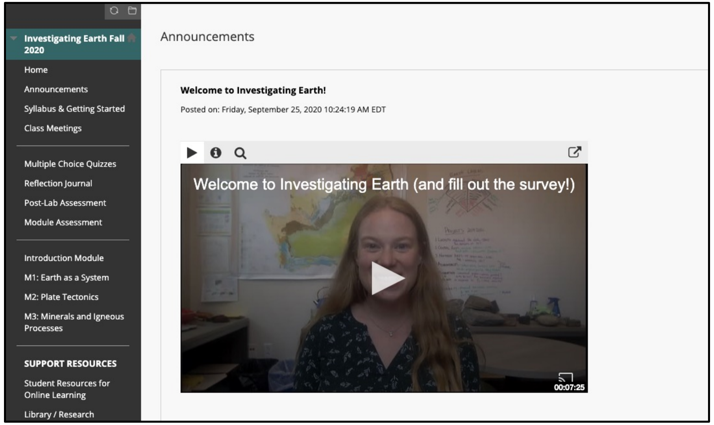
Motivation – 1

1. Create an accessible geoscience field experience for:
   - Students with mobility constraints
   - Large format classes
   - Remote learners



Blackboard Course Page for Intro Geology Fall 2020

Introductory Physical Geology Class at Giant's Stairs, Maine

Alroyfonseca - Public Domain, https://commons.wikimedia.org/w/index.php?curid=5559428

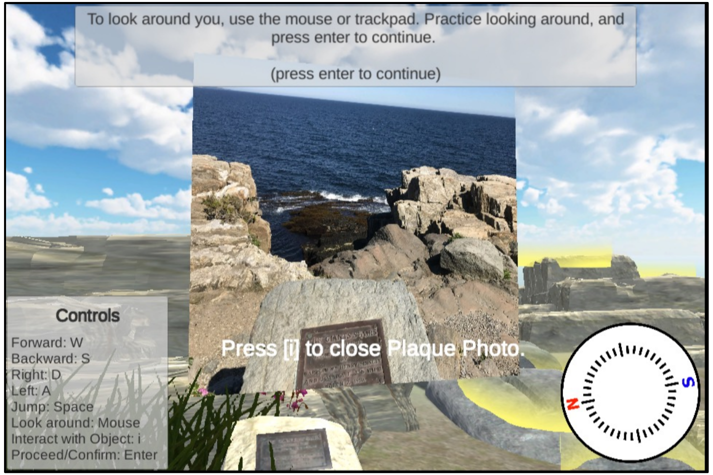
Motivation – 2

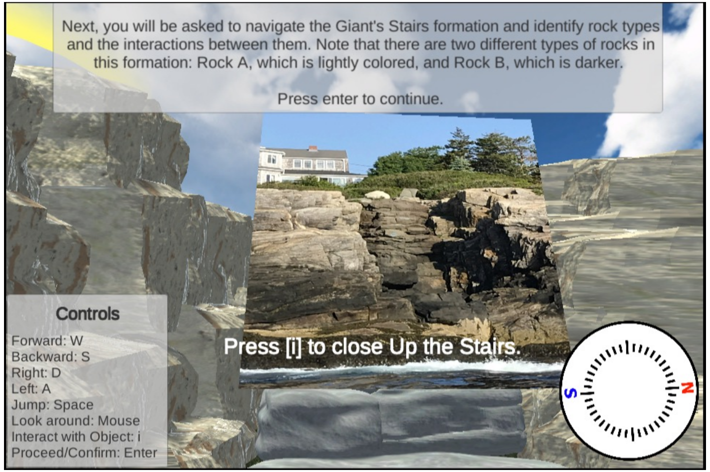
2. Create a tool to enhance spatial reasoning required to solve complex geoscience questions

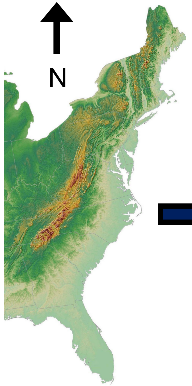
Real-world images of the Giant's Stairs embedded within the virtual environment

Right: View east, down the stairs

Bottom Right: View west, up the stairs.

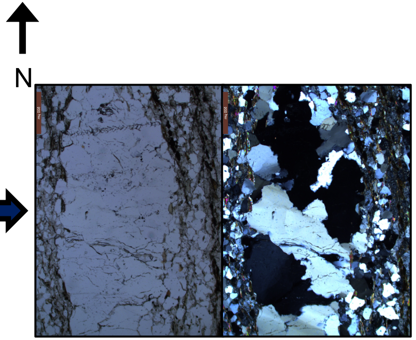






Orogen Scale: Appalachian Mountain Range

Outcrop Scale: Schist at Giant's Stairs, Maine



Microscopic Scale: Plane- and cross-polarized photomicrographs

Research Questions

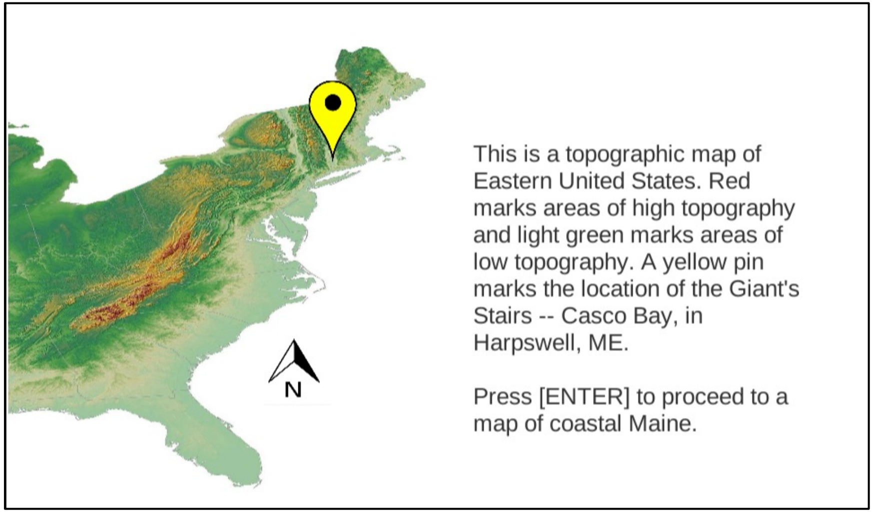
1. Are students able to demonstrate domain specific learning outcomes within an accessible virtual environment as they would in a real-world geology field site lab experience?

2. Will students in the desktop VR (dVR) and immersive VR (iVR) conditions demonstrate equivalent proficiency in lab goals as measured by selected response accuracy?

Virtual Field Trip Design and Protocol - 1

Part I: Map/Geolocation Phase

- Overview maps show the field site at several spatial scales to **orient** the student to the location of the field site.



Orogen-scale map

Local-scale map

Virtual Field Trip Design and Protocol - 2

Part 2: Training

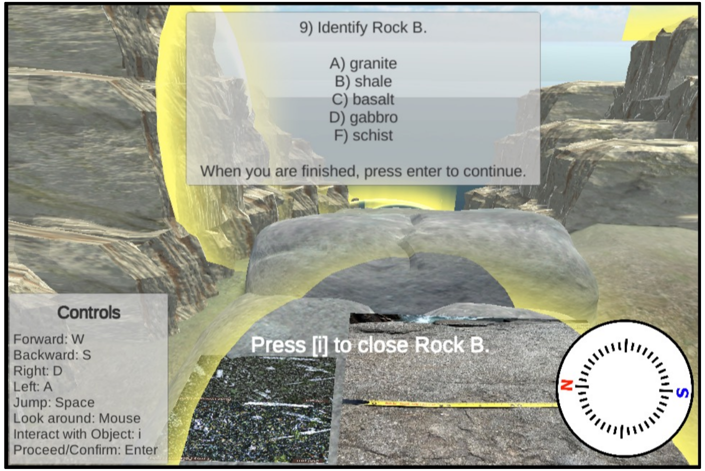
- Students are placed into the model at ground level and asked to perform several tasks to learn how to navigate and use the virtual compass for orientation and spatial reasoning tasks.

Right: Welcome prompt in the virtual environment

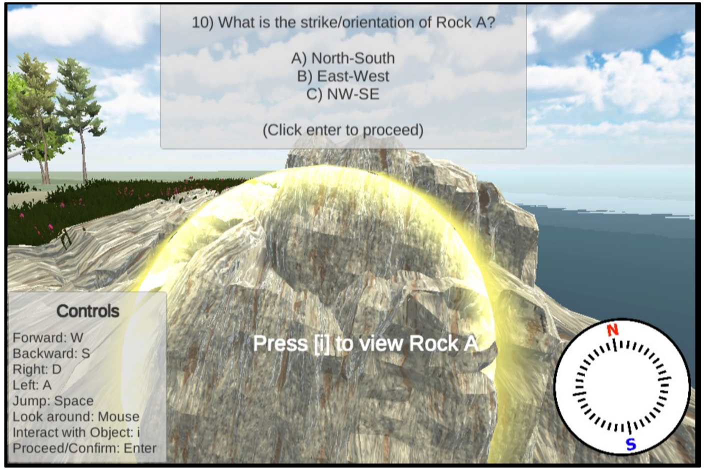
Virtual Field Trip Design and Protocol - 3

Part 3: Geoscience Lab

- Students navigate through prompts to features in the environment. They observe the feature and answer questions with the aid of augmented information embedded in the model.



Rock identification question and embedded real world images within the virtual environment

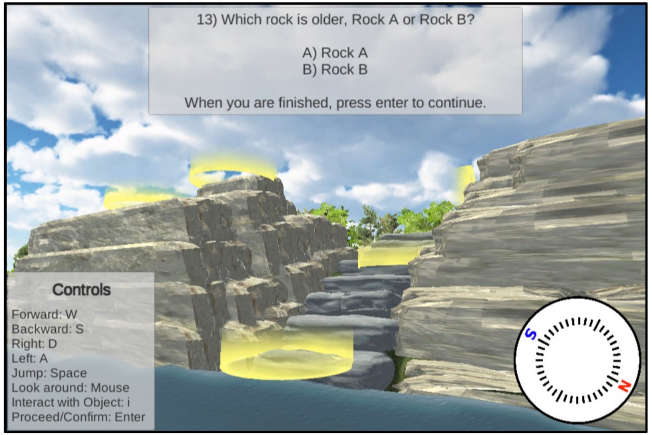


Rock orientation question and embedded real world images within the virtual environment

Virtual Field Trip Design and Protocol - 3

Part 3: Geoscience Lab

- Students navigate through prompts to features in the environment. They observe the feature and answer questions with the aid of augmented information embedded in the model.



Left: Temporal question based on cross-cutting relationships

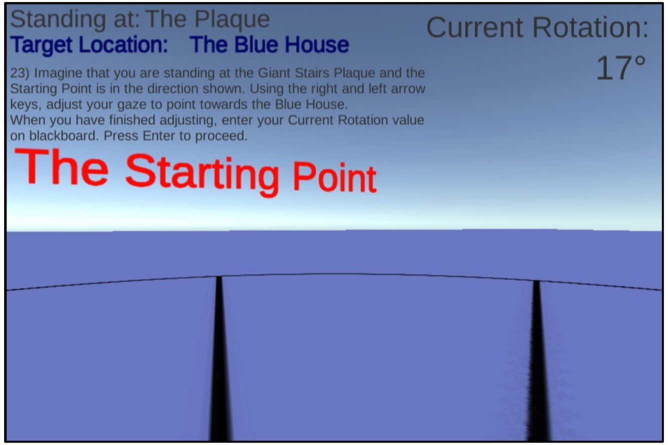
Lab Task	Question
Rock ID	Q7, Q9
Orientation	Q10, Q11, Q12
Spatio-Temporal Processes/Events	Q13, Q25
Collision	Q15, Q17, Q19
Spatial Reasoning	Q22, Q23, Q24

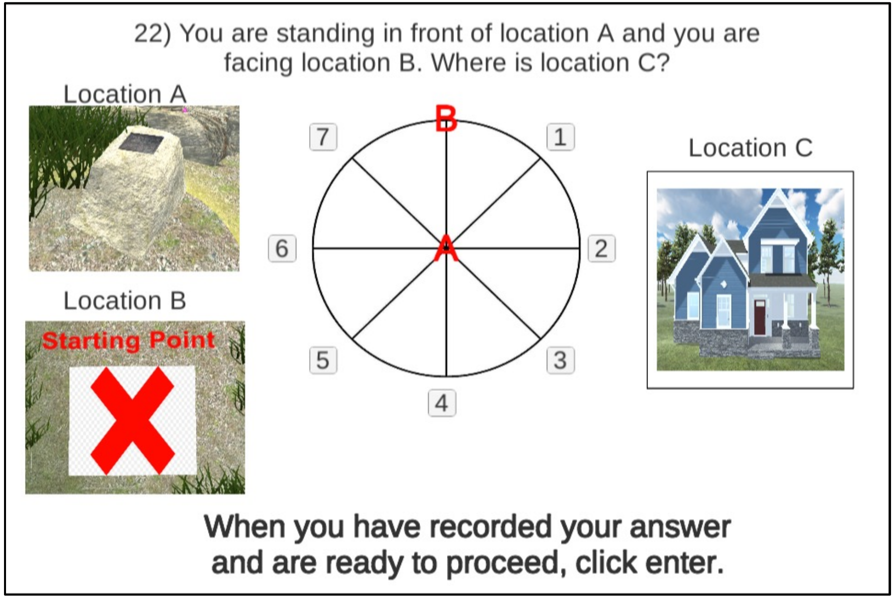
Table 1. Geoscience Lab Assessment Concepts

Virtual Field Trip Design and Protocol - 4

Part 4: Spatial Reasoning

- Students complete spatial reasoning tasks about the orientation and relationship between model features.





Left and above: post lab questions exploring spatial reasoning and retention

Participants

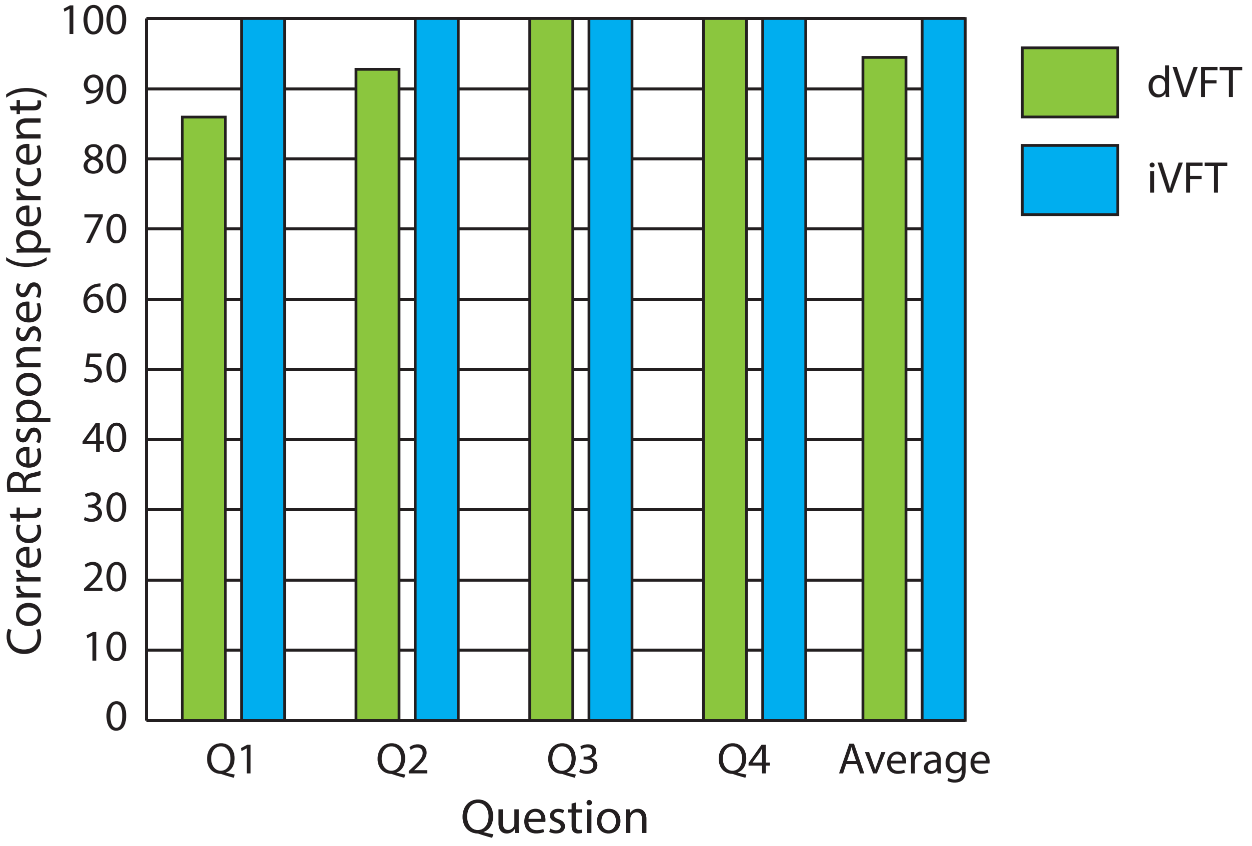
- Intro geology students at a small, liberal arts college (n=25).
- Self-perception of spatial reasoning skills not statistically different between dVR and iVR groups

Condition	Range	Mean	St. Dev.
dVR	48-89	67.86	11.86
iVR	44-68	62.36	9.55

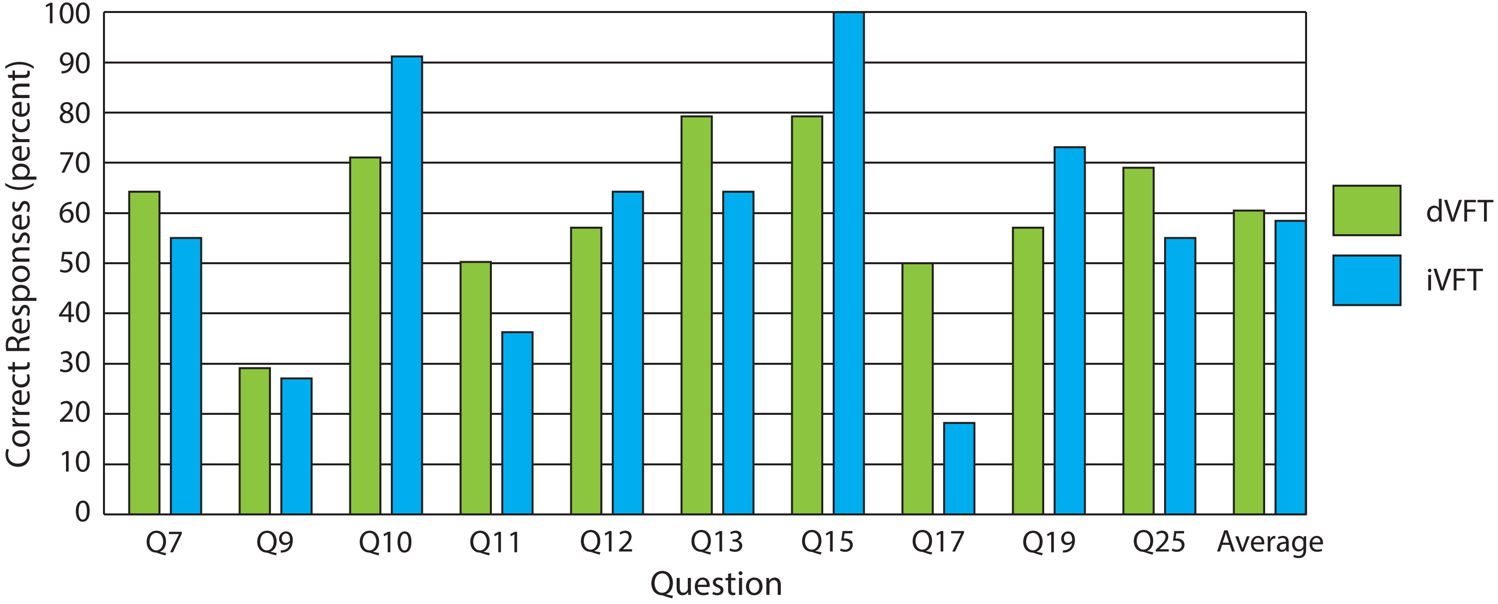
Table 2. Santa Barbara Sense of Direction Survey – standardized self-reporting assessment of student spatial reasoning skills

Training Results

- Highly accurate in both conditions
- Indicates quick and proficient navigation of the environment and initial spatial orientation

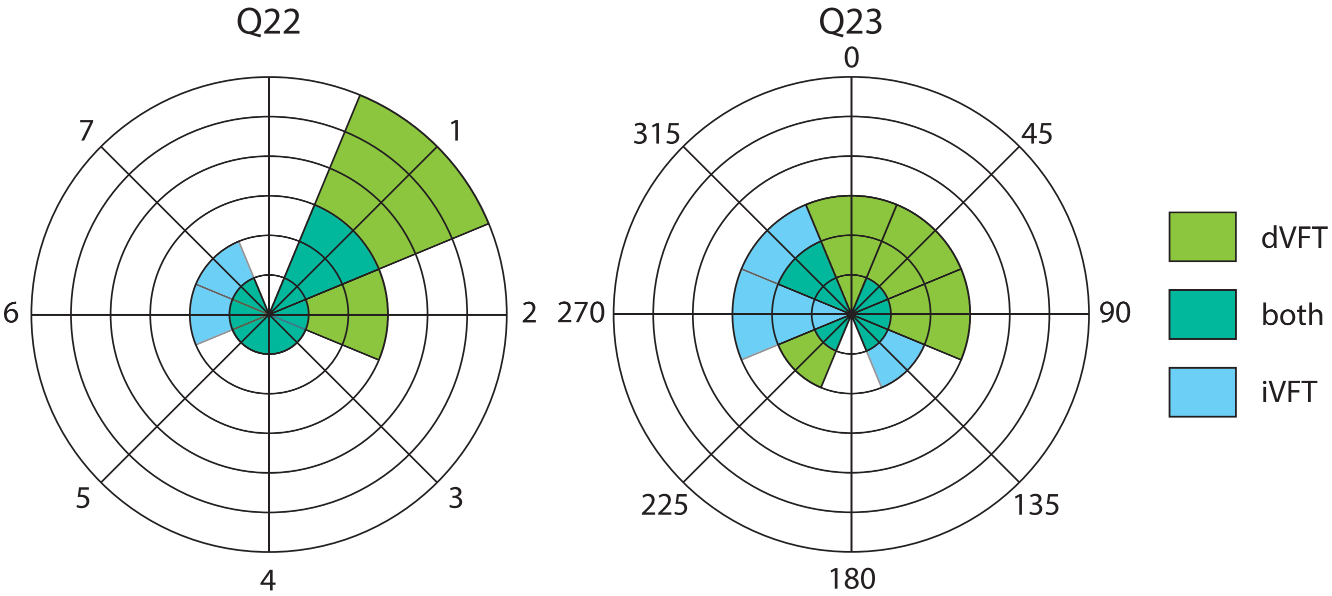


Geoscience Lab Results



- Decrease in accuracy in both conditions compared to in-person experience
- Functional equivalency in accuracy between dVFT and iVFT experiences
- $t(25) = 0.17$ $p = .86$ iVR ($M = 60$, $SD = 19.4$) dVR ($M = 58$, $SD = 29.08$)

Spatial Orientation and Reasoning



- Better results in feature orientation recall accuracy in the dVFT condition
- Both groups found the 360° absolute frame of reference (FoR) to be more difficult

Discussion – Lab Learning Objectives

Mixed Results on Lab Learning Objectives

- Research Question 1: Are students able to demonstrate domain specific learning outcomes within an accessible virtual environment as they would in a real-world geology field site lab experience?
  - Decrease in accuracy on geology lab responses as compared to in-person field site: identifying rocks, assessing rock orientation, and collision processes.
  - Observed increase in spatial reasoning using augmented compass as compared to in-person field skills.
  - Observed increase in independent exploration and reasoning as compared to relying on classmate/instructor assistance.

- Research Question 2: Will students in the desktop VR (dVR) and immersive VR (iVR) conditions demonstrate equivalent proficiency in lab goals as measured by selected response accuracy?
  - Functional equivalency in response accuracy suggests potential for VFT access/scalability without need for iVFT equipment.

Discussion – Student Engagement Survey

Condition	Positive Sentiments	Negative Sentiments
dVFT	• Accessibility • Autonomy of movement • Engagement/Gamification • Augmented information • Immersion in VFT	• Rock images not clear • Computer lab • Answering in L.M.S. • Some trouble with navigation/perspective
iVFT	• Accessibility • Novelty of HMD/VR gear • Engagement/Fun • Augmented information • Immersion in VFT	• Fogging in HMD • Text instructions blurry • Unstable image • Headache

Table 3. Emergent sentiment themes from the desktop (d) and immersive (i) virtual field trip (VFT) experiences.

- Students cited increased accessibility as top benefit
- High engagement results with no statistically significant difference between groups
- 100% of students indicated they wanted access to more VFT experiences
- Students cited VFT experiences as way to pre-train/review spatial reasoning skills and geology concepts

Thank You

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