Teaching and Learning Biochemistry in Virtual Reality

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October 8, 2021

Future of Technology in Higher Education Summit

A terrific team from across the university has made it possible to explore using VR for teaching

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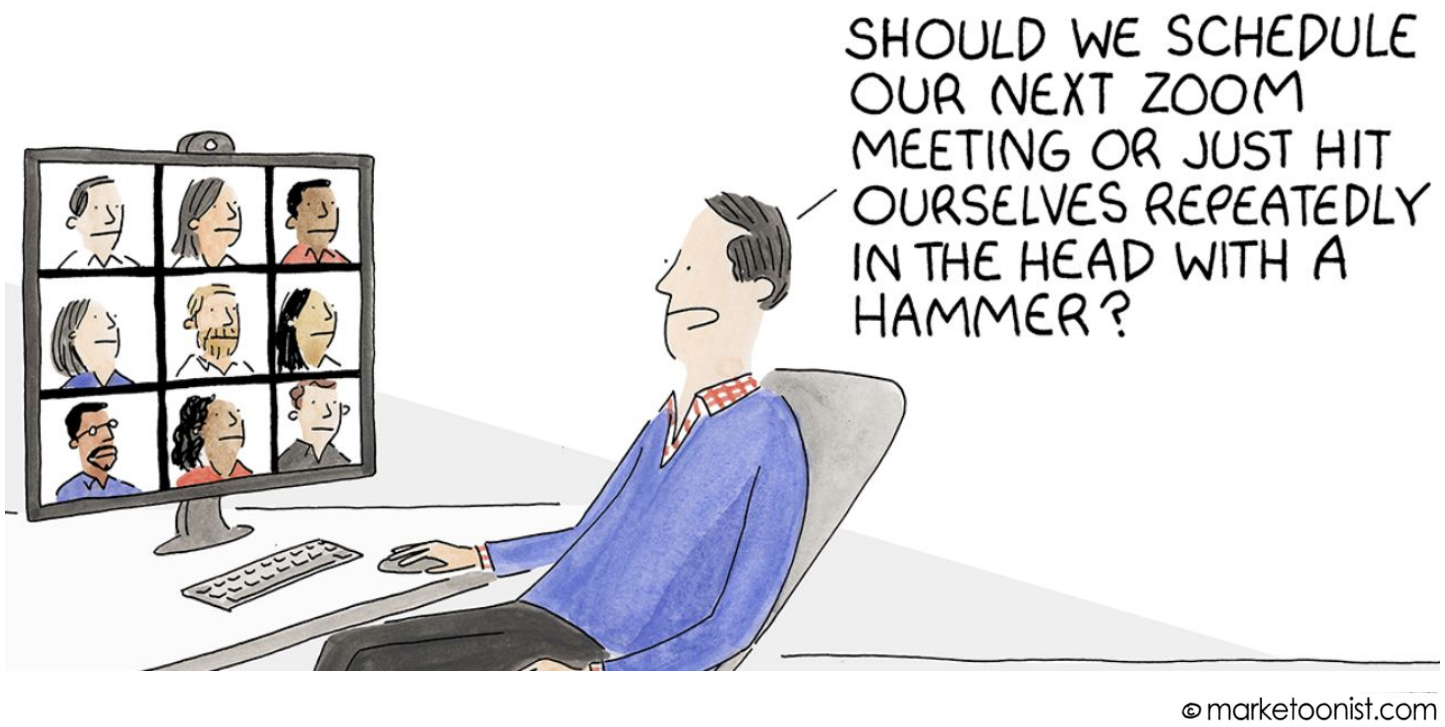
Thanks to the Emerging Technologies Consortium, the Provost's office, SOLER, and HP and AMD for funding!

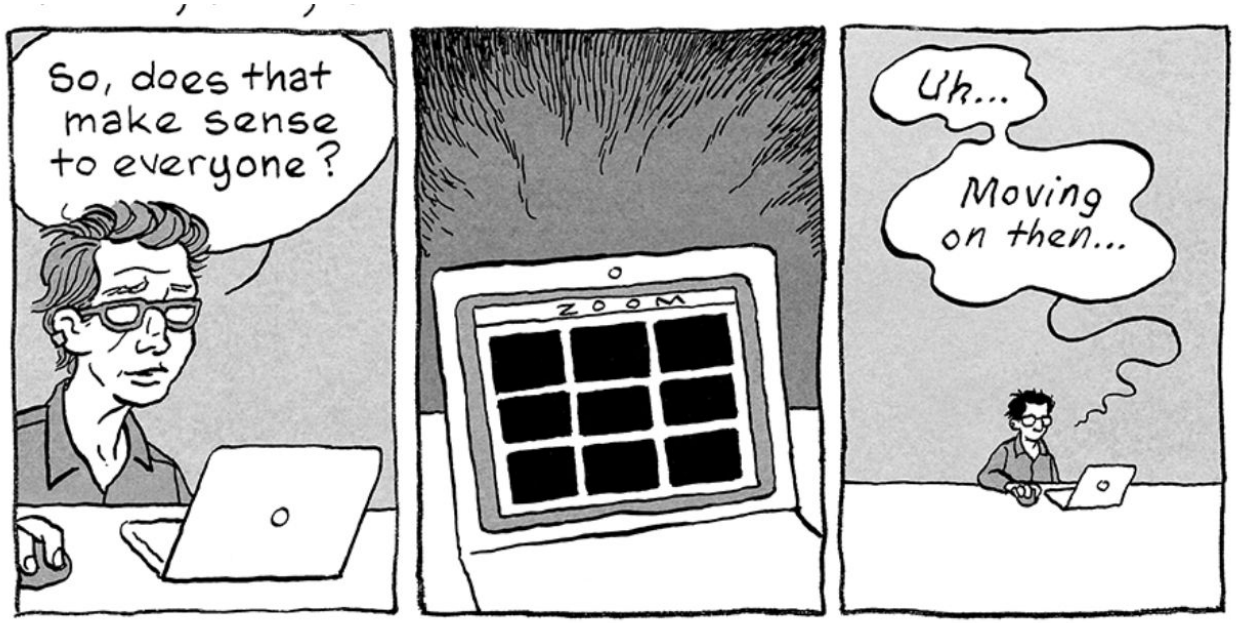
Teaching online in Zoom has some advantages

- **Advantages**
  - Can see other participants
  - Can view documents together
  - Can be recorded
  - Can do breakout rooms for group work



Teaching online in Zoom has critical limitations

- **Disadvantages**
  - Distractions/multitasking
  - Zoom/Eye fatigue
  - Health issues of extended sitting
  - Camera on or off dilemma
  - Less interactive



Extended use of smartphones and computers is associated with eye strain due to:

- eye muscle strain of focusing on close objects
- reduced blinking
- Excessive eye contact
- Staring at yourself

Teaching in person has some advantages

- **Advantages**
  - Better ability to read non-verbal cues
  - Can have informal interactions before, during, and after class
  - Added benefit of being on campus

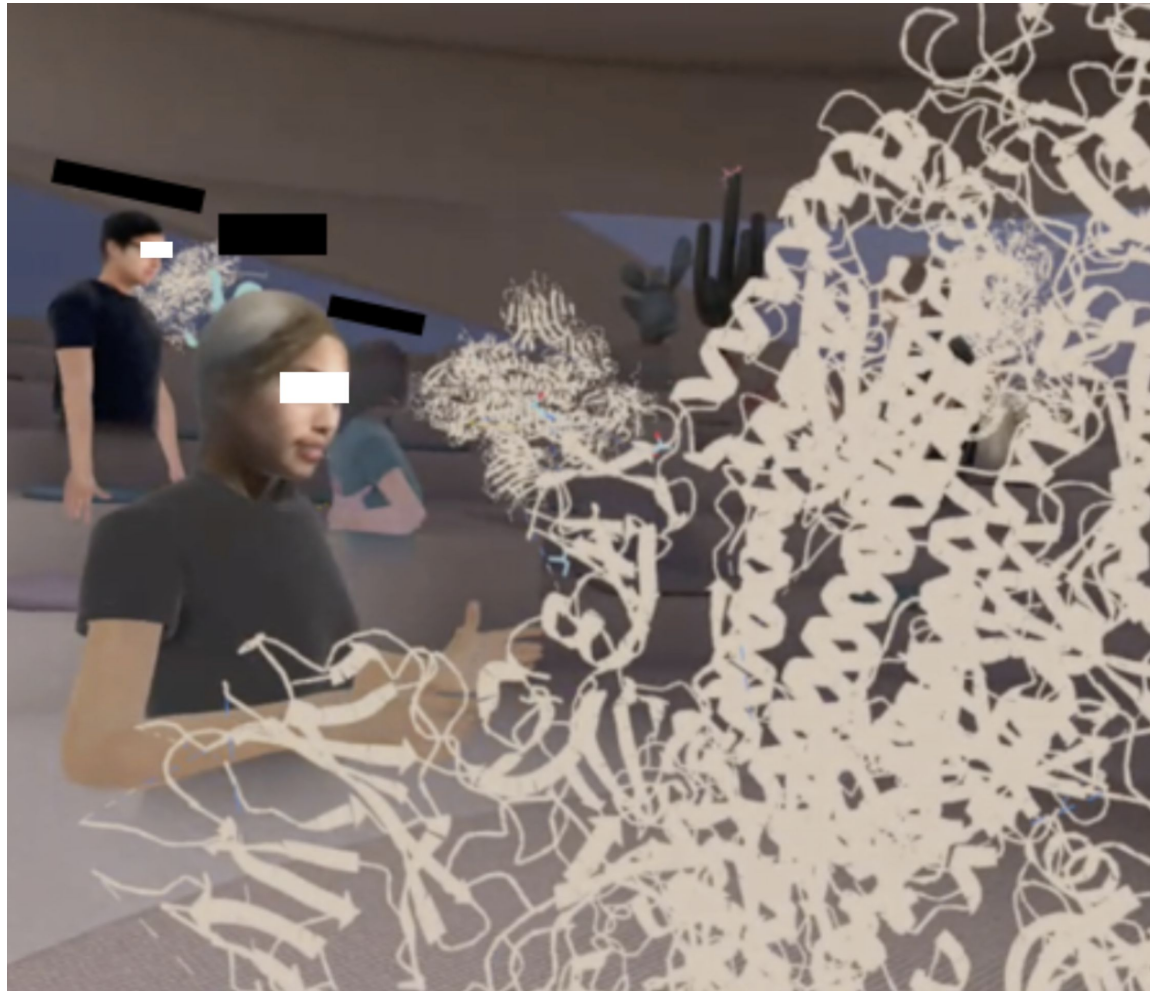
Teaching in person has limitations

Disadvantages

- Difficult to know students' names for large groups
- Potential health/COVID issues
- Limited space on campus / breakout rooms
- Harder to record
- Distractions—phones, computers, other students

Virtual reality offers distinct benefits compared to Zoom and in person teaching

- Some limitations of teaching on Zoom and in person are reduced in VR

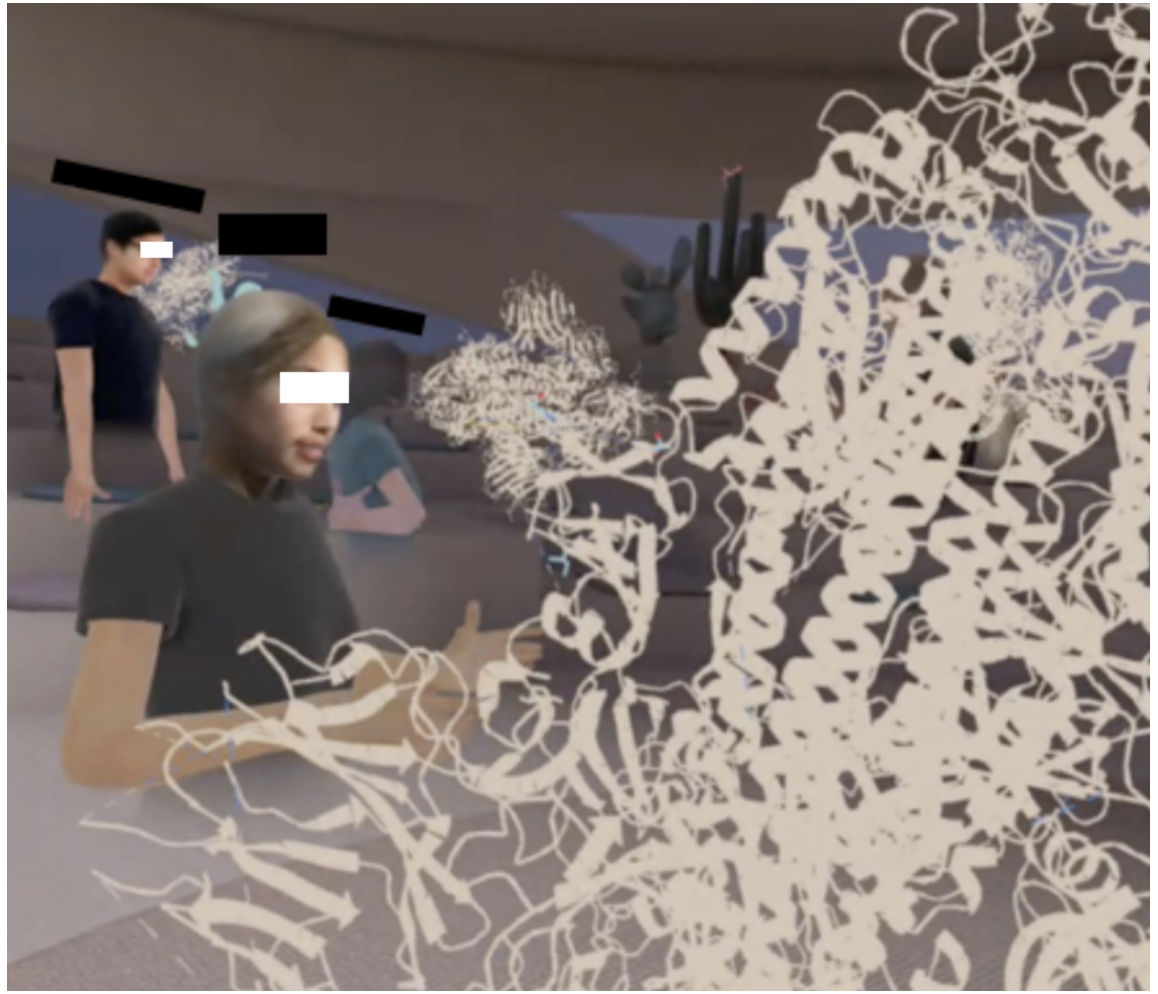


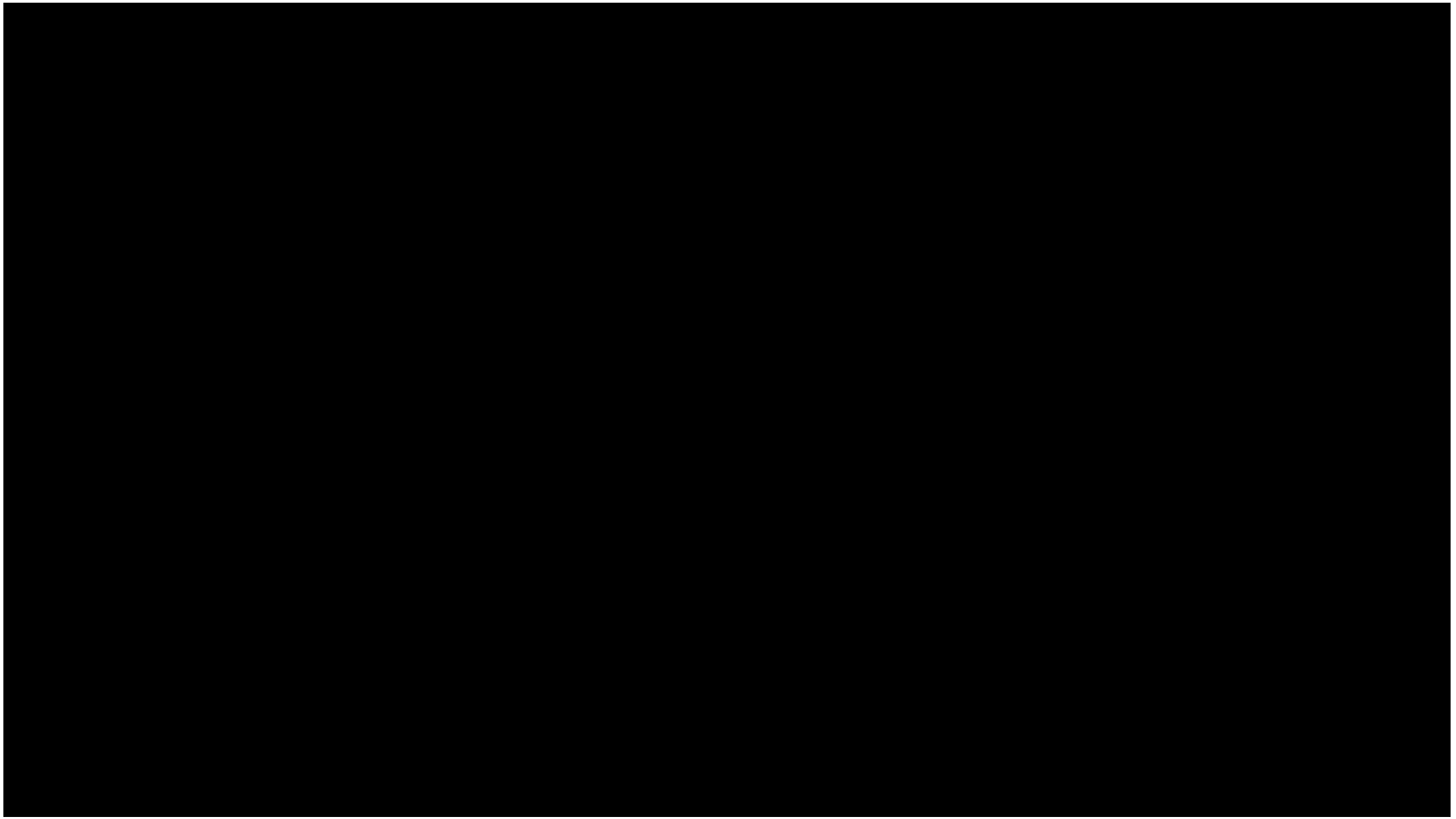
Exp Optom 2019 Jan;102(1):18-29. doi: 10.1111/cxo.12798. Epub 2018 May 23.

Bailenson et al. 2021, Nonverbal Overload: A Theoretical Argument for the Causes of Zoom Fatigue. Technology, Mind and Behavior, 1 (3), DOI: 10.1037/tmb0000030

Virtual reality offers distinct benefits compared to Zoom and hybrid teaching

- Often standing/moving in VR, reducing extended sitting
- Immersive -- creates a sense of being present with others in a distinct environment
- Can discuss and interact with 3D objects





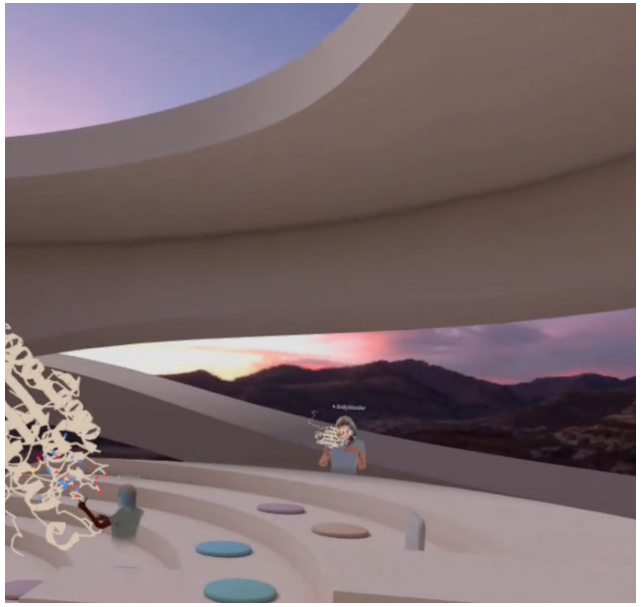
Discussions in VR have some advantages

- Fewer distractions—you are immersed in an environment without email, texts, computer, etc
- Avoids issue with camera on vs off – everyone is present as an avatar, no need to adjust lighting, worry about how you look, the quality of your room, etc
- Can’t generally see yourself while you talk
- Names are displayed over avatars
- Can record sessions

VR allows you to meet with students in diverse environments

Island beach in Glue

Conference Center / Resort in Glue

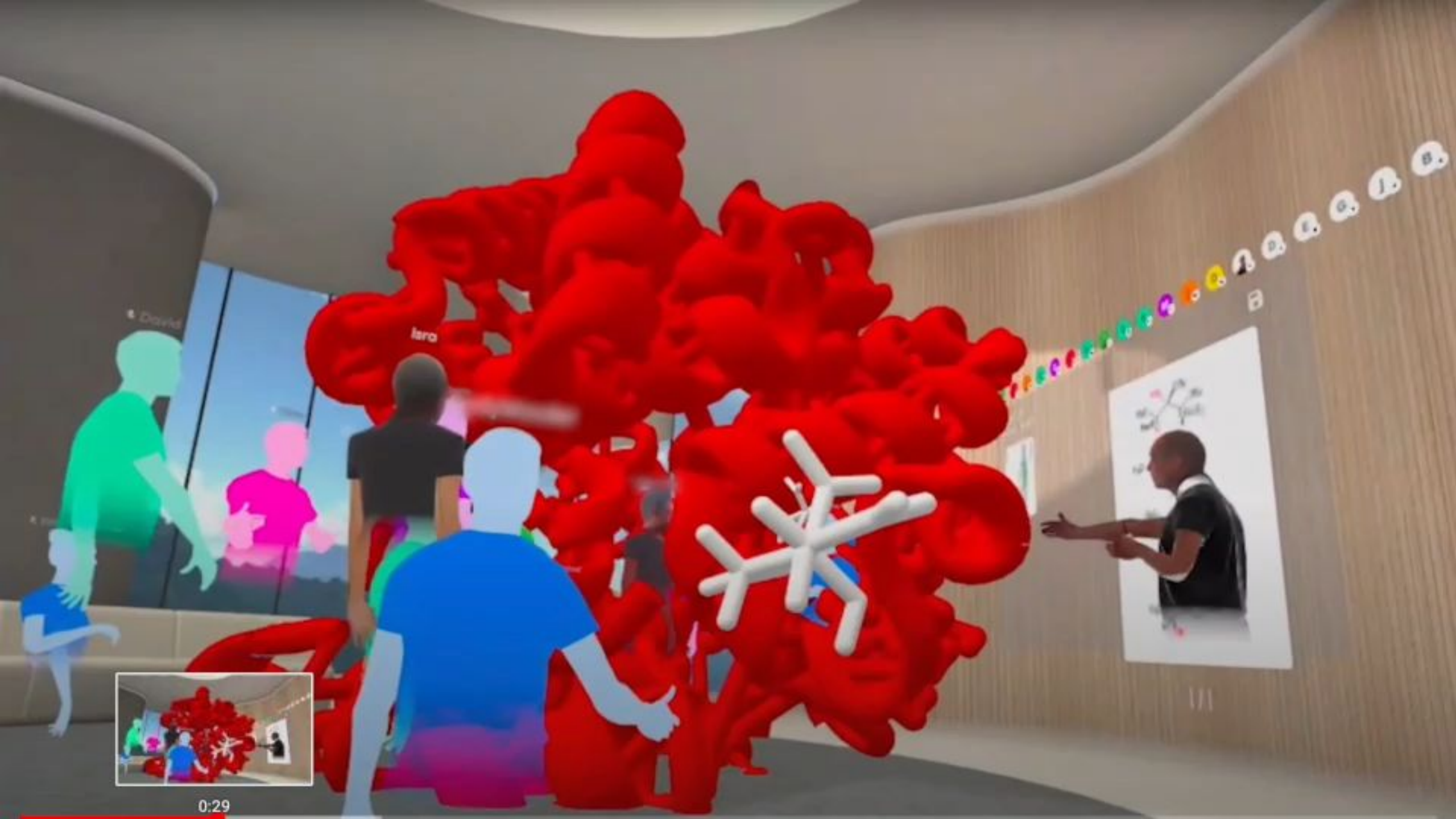


Desert Amphitheater in Spatial

Animated avatars create a sense of presence

VR allows you to interact with 3D objects

- Difficult to recreate in person or on Zoom


David
Isra
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Our experience: Iteration 1

- Provided students with Oculus Quest 1; used Spatial VR platform
- 3D drawings with Google Tilt Brush, imported into Spatial
- Converted molecules from Chemdraw in 3D models for Spatial
- Imported protein structures into 3D models for Spatial
- Compared vs meeting with students in Zoom

- **Most impactful: protein structure 3D models**

"It was helpful that we could each have our own molecule to look at and manipulate...Prof. Stockwell could point to exactly where in space a reaction occurred."

"The ability to visualize complex molecules and look at the arrow pushing mechanisms is so helpful to understanding how particular reactions work."

It is difficult for students to take notes in VR

Solution: near the end of the session, have students leave VR, and capture all things they remember, leveraging the recall effect for learning/memory

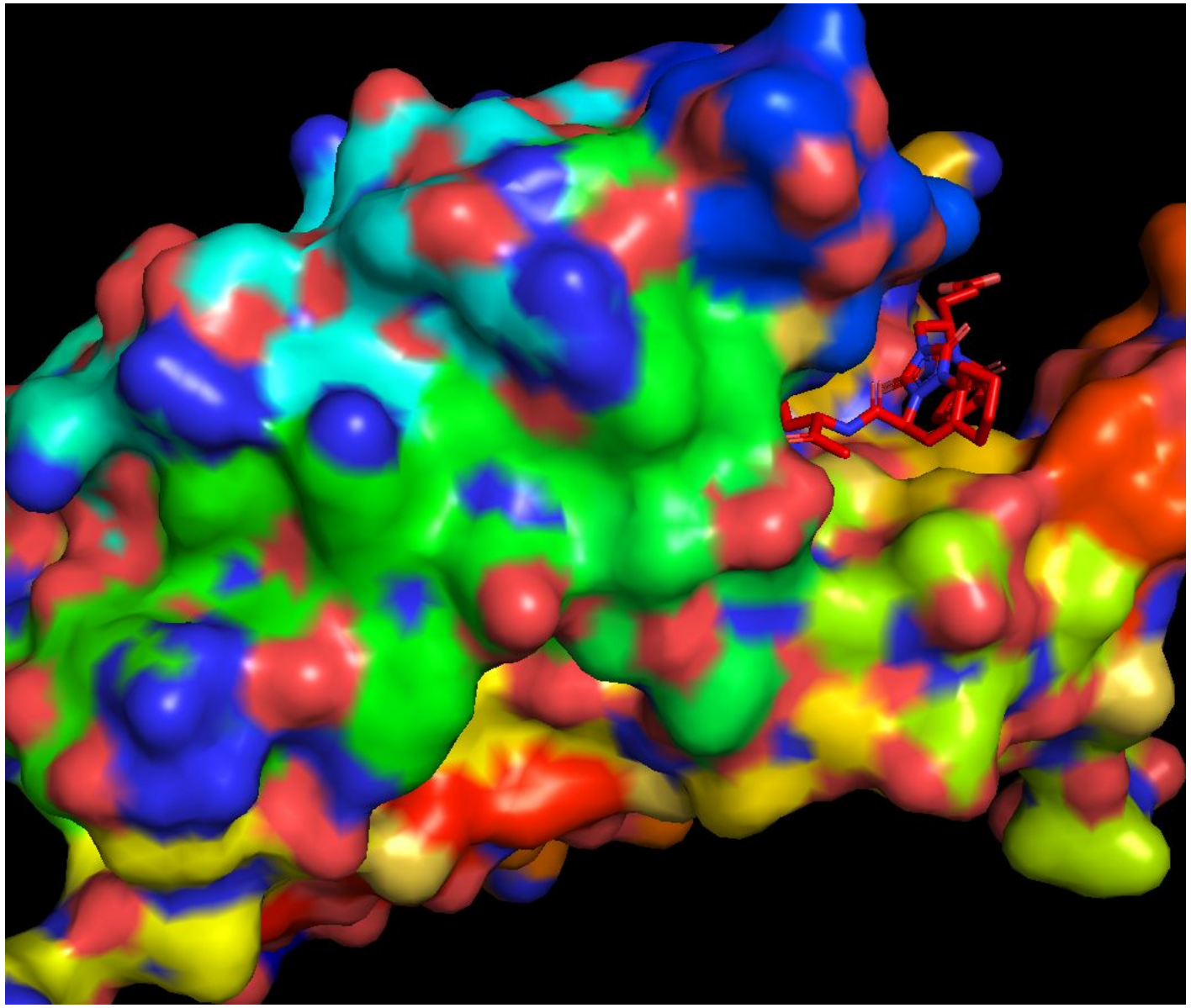
- Record in a shared PADLET doc set up in advance
- In addition, students can record the session to review it later

Key questions to ask about teaching in VR

- What three-dimensional aspects of your subject are difficult to master in 2D formats?
  - Molecular conformations in biochemistry
  - Multidimensional data sets
  - 3d organs
  - Instrumentation training

First attempt: Lessons learned

- 3D aspects of protein function are most impactful in VR
- Students needs training in VR tools
- Students need a way to take notes

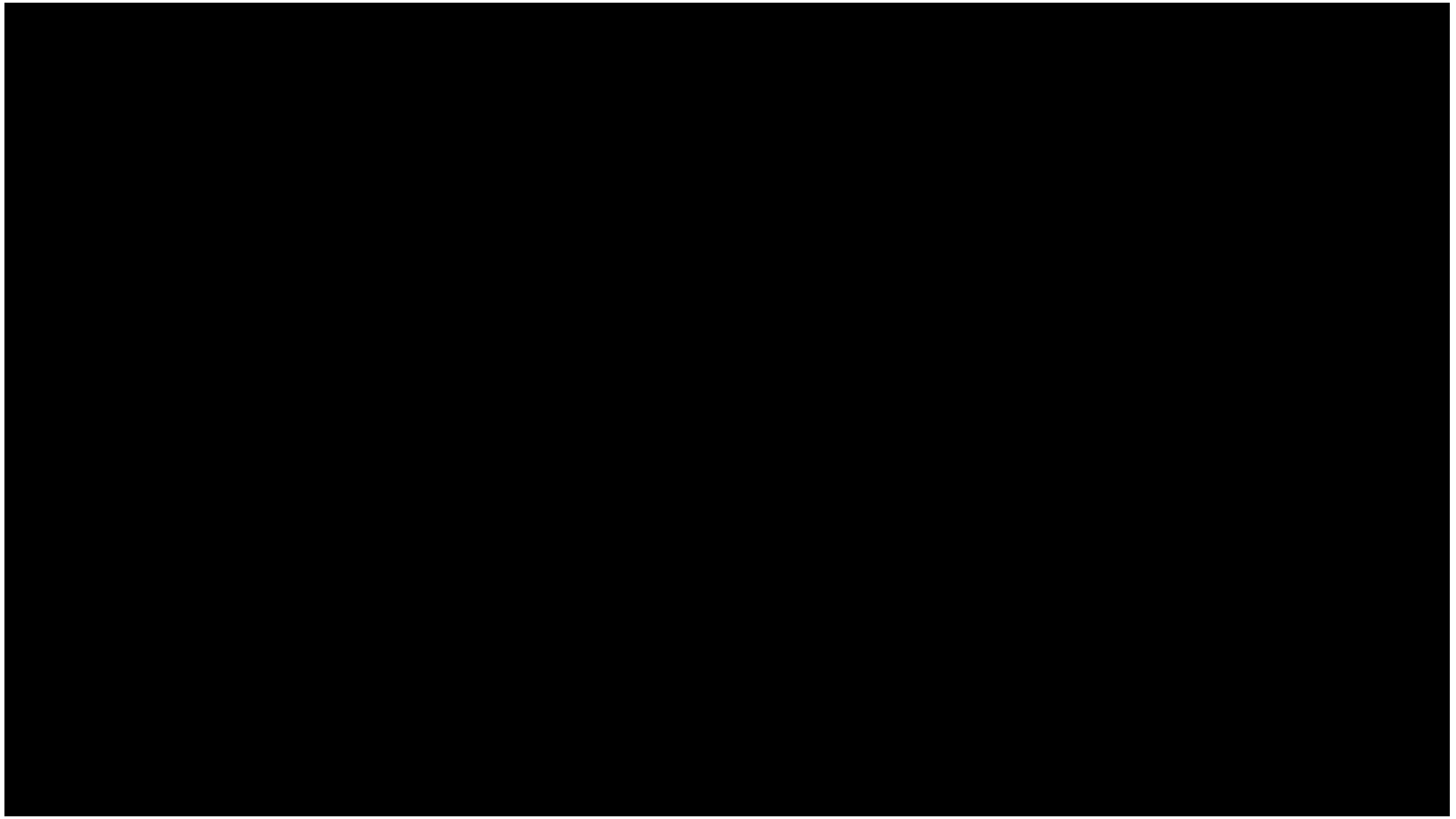


Second iteration of teaching in VR: Summer 2021

- Our structure from this summer:
  - Oculus Quest 2 Headsets
  - Glue meeting platform
  - Voxvote for polling
  - Shared Padlet doc for notetaking
  - Extensive training sessions in LMS for students in VR hardware/software

- Students could enroll in VR or Zoom recitation
  - Not a RCT: a pilot to evaluate methods and possible impact

3D protein models can be used to teach biochemistry in VR



Evaluated impact of VR vs Zoom

- Enrolled students in IRB protocol
- Evaluated impact in pilot for students in Zoom vs VR recitations
  - Exam performance
  - Survey about usability of the technology
  - Survey about engagement
  - Voluntary quiz regarding 3D spatial aspects of biochemistry

No basal difference in students in different groups based on midterm exam performance

- First part of VR recitation was focused on distributing headsets, training students in using Quest 2 and VR platform, introducing 3D models, and learning how to work together in VR
- Midterm exam performance:
  - VR recitation: 96.0 +/- 1.1
  - Zoom recitation: 96.4 +/- 3.4
  - P-value ns

Students in VR recitation had improved final exam performance in the course

Final exam performance

VR recitation mean	92.7
Zoom recitation mean	89.7
P-value	0.03
95% CI for difference	0.31-5.69

Technology usability survey showed perceived advantages of VR by students

The technology used during my small group discussions would be a positive addition for biochemistry students (rate on a 1 to 5 scale where 5 = strongly agree / 1 = strongly disagree)

VR recitation	4.60
Zoom recitation	3.66

P-value 0.006

95% CI for difference = 0.29 – 1.60

Technology usability survey showed advantages of VR

The technology used during my small group discussions is useful for learning biochemistry

VR recitation:	4.70
Zoom recitation:	3.69
P-value	0.003
95% CI for difference	0.36 – 1.66

Technology usability survey showed advantages of VR

I am better able to learn biochemistry with the technology used in my small group discussions

VR recitation:	4.20
Zoom recitation:	3.45
P-value	0.031
95% CI for difference	0.74 – 1.43

VR student comments in surveys

The analysis of the molecules in 3D virtual reality made it easy to see the bonding interactions and understand many of the topics we were tested on (e.g. proteases, caspases, Mpro in SARS-2-COV, etc.)

VR student comments in surveys

I liked that in the VR you could have conversations in small groups, but switch who you talk with naturally based on location in the room.

VR student comments in surveys

Being able to see the proteins in VR was very key in my understanding of the amino acid side chain reactions. I was not able to properly visualize them until my first small group discussion in VR.

VR improved performance on a difficult voluntary quiz on 3D aspects of biochemistry

- **Tested the ability of students to extrapolate to new contexts involving 3D features of molecules**

VR recitation: 3.0/7.0
Zoom recitation: 2.2/7.0

P-value 0.05

Students in the VR group felt less of a need to be entirely in person to learn

If you could customize your daily academic interaction to be divided among IN-PERSON, ZOOM-BASED, and VR-BASED experiences, what percentage would you allocate to each category?

VR recitation median in person: 57%

Zoom recitation median in person: 75%

*ns

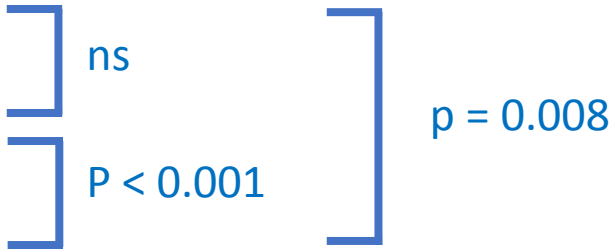
Students in the VR group felt more engaged in their learning

Rate the level of engagement you typically feel during your academic experiences with ZOOM, IN-PERSON, or VR-BASED instruction. We analyzed the percent of students that rated themselves highly engaged in each modality.

VR recitation: 87%

In person 82%

Zoom recitation: 33%



Technical aspects of 3D model preparation

- Downloaded protein structure models from the PDB
- Imported into PyMol
- Rendered as desired, exported as GLB files
  - Important to only render relevant portions and to highlight key amino acids, active sites, interactions, etc
- Imported into blender to reduce polygon count and to color atoms
- Exported as FBX file
  - Glue requirements: < 50K polygons, simple textures

Summary

- VR can improve learning of biochemistry
- VR is more engaging than Zoom
- Generating useful models is time-consuming
- Most impactful with well-chosen and simple 3D models
- Interactive nature and presence is valued by students ("being together")

Next steps for teaching in VR

- Train TAs in VR instruction so we can have more VR recitations
- Develop more advanced 3D models of proteins and protein-ligand complexes
  - Need to become a 3D artist!
  - Better tools for generating 3D models
- Develop animated FBX files to show motion of molecules
- Explore additional VR platforms, hardware
  - Better avatars, better performance w/ many models