Undergraduate Student Learning and Perceptions of a Virtual Reality Chemistry Activity

FRESNO STATE

Dr. Dermot F. Donnelly-Hermosillo

ddonnelly@csufresno.edu; @dfdonn (Twitter)

Chemistry and Biochemistry Department

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Virtual Reality Research

- A need for more research, alongside learning theory, on VR learning outcomes.

(Coban et al., 2022; Cromley et al., 2023; Luo et al., 2021; Matovu et al., 2022; Villena-Taranilla et al., 2022)

- Medium-effect of VR instruction on student learning outcomes (**g = 0.723**, SE = 0.181, CI = [0.367, 1.079], p = 0.000; 22/149 VR articles; 2000-2019; 17 effect sizes for K-12 and 19 from university studies)

(Luo et al., 2021; Other VR meta-analyzes (above) report small to medium effect sizes)

- Several studies impacted by physical discomfort, technical glitches, etc.

(Luo et al., 2021)

Virtual Reality Research

- Larger effect sizes typically align with active learning techniques, iterative research design, and specific subjects such as science/engineering.

(Cromley et al., 2023; Luo et al., 2021; Wu et al., 2020)

- Value in VR of stereoscopic visuals and wider fields of visual displays, but VR education apps commonly lack narrative and social features.

(Cummings & Bailenson, 2016; Matovu et al., 2022)

- Students impacted in terms of engagement and motivation, related to sensory and actional features of VR.

(Cromley et al., 2023; Matovu et al., 2022)

1st and 2nd Order Barriers to Tech. Integration

First Order – External To User

- Lack of **access** to computers, software, etc.
- Inadequate technical and administrative **support**.
- Insufficient time for **planning** instruction.

Second Order – Internal To User

- Beliefs about **technology**.
- Beliefs about **teaching and learning**.
- Established **classroom practices**.

(Ertmer, 1999; Ertmer et al., 2012)

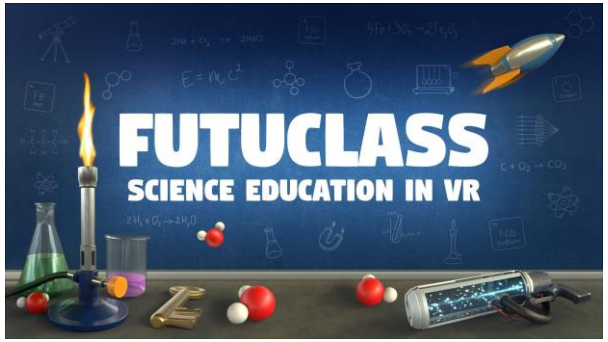
Research Questions

1. How does a virtual reality activity impact **student chemistry learning**, specifically naming elements and compounds, identifying atomic properties of elements (protons, neutrons, electrons), and balancing chemical equations?

2. What are **first and second order barriers** to using virtual reality in classrooms for future elementary school teachers?

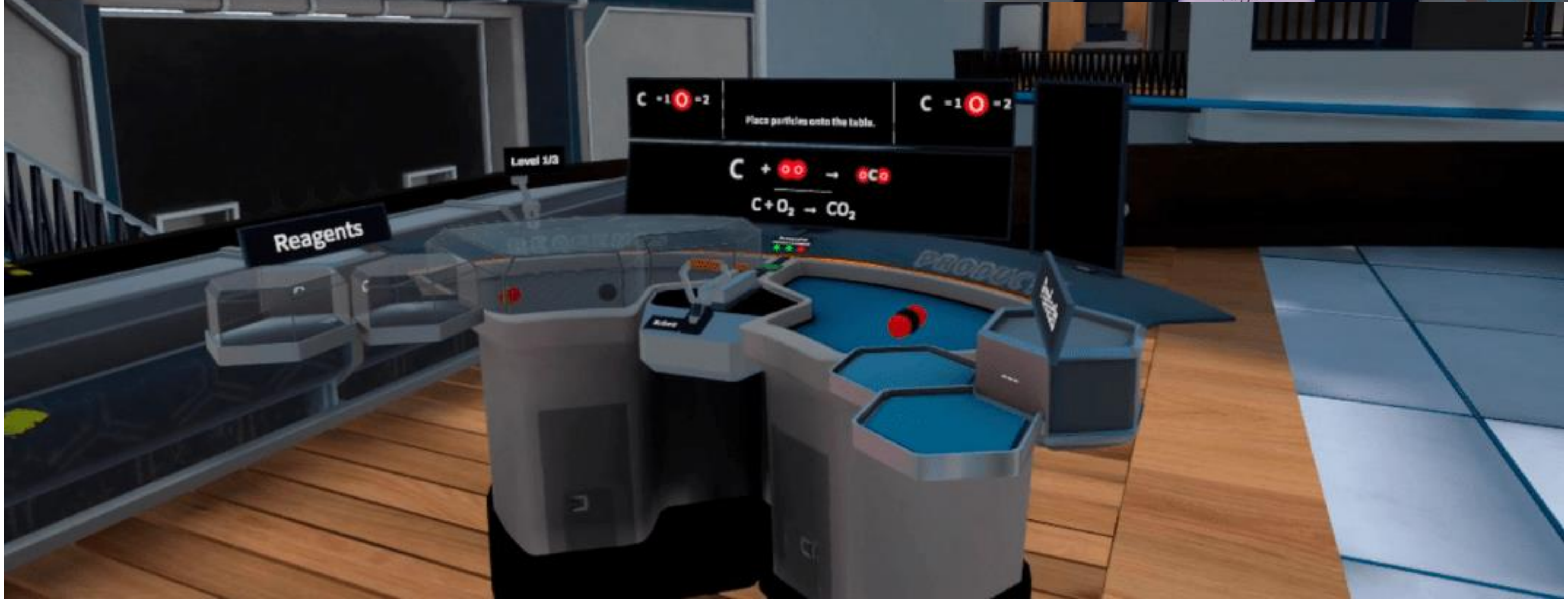
Method

- **Learning theory:** Embodied cognition (Varela et al., 1999; Wilson, 2002)
- **Research design:** Design study. Students completed VR activity in a VR Center outside of class time. First time use of VR with students and smaller sample of students.
- **VR headsets:** Oculus Quest 2
- **VR App:** FutuClass
- **Assessment (RQ1):** 12 open response items directly before and after the VR activity administered via a Google Forms.
- **Assessment (RQs 1 & 2):** 500-word reflection from students with 9 written-prompts plus facilitator interview.



- **Participants:** 35 Preservice Elementary Teachers
- **Gender:** 26 Female (74%)
- **Race:** 29 Hispanic (83%)

FutuClass VR App



Some Examples of Test Items (RQ1)

- What element is represented by the letters **Cl**?
  (Elements and Compounds; Recall)

- How many **protons** are in **carbon**?
  (Atomic Theory; Identification)

- Balance the following reaction:
  $Na + Cl_2$ -> NaCl
  (Chemical Equations; Problem-Solving)

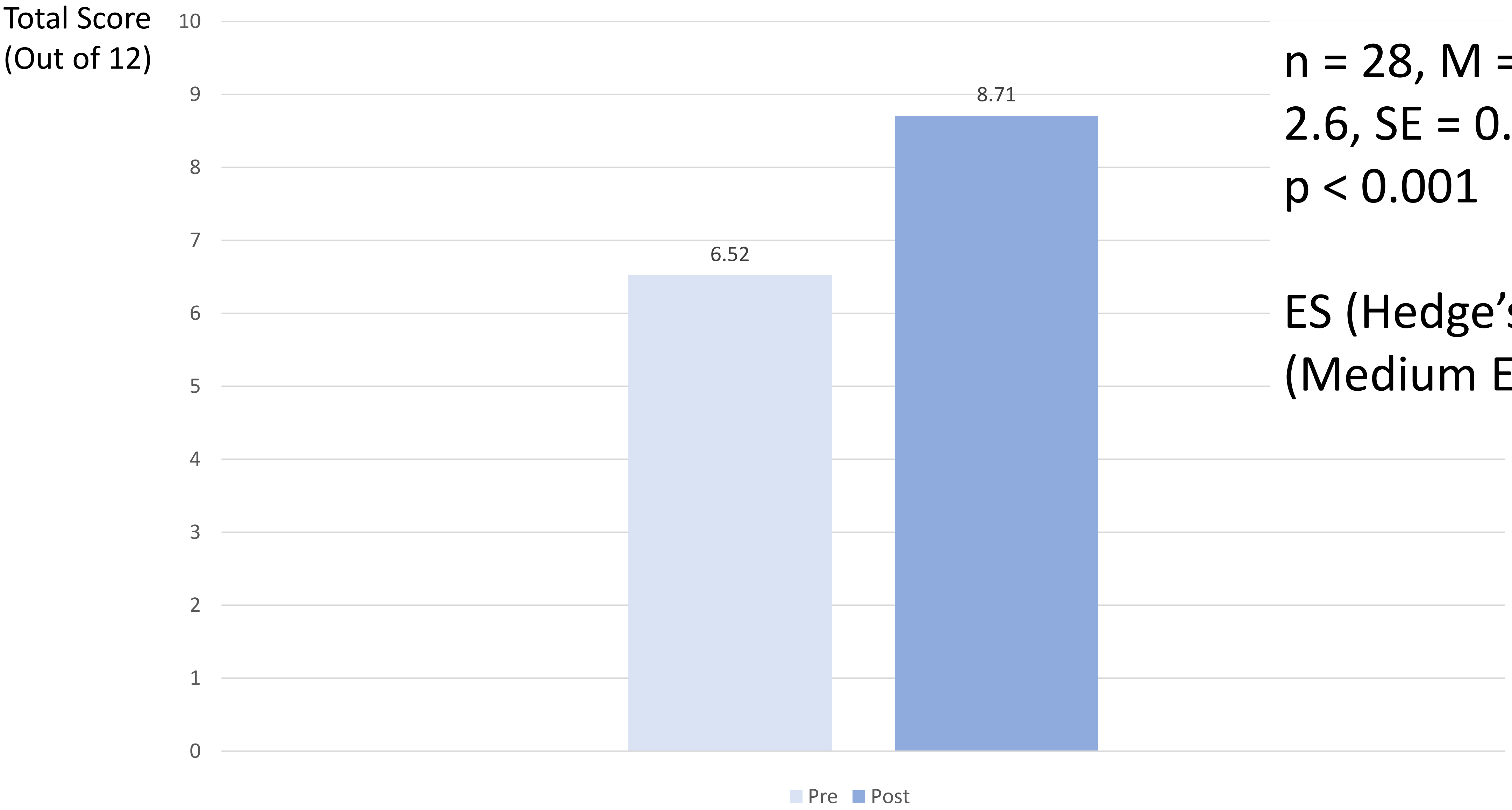
Some Examples of Reflection Prompts (RQ2)

- Did you find the VR activities in FutuClass **helpful for your learning of Chemistry concepts**? Please explain with an example.

- Would you consider using FutuClass with your **future students**? Please explain.

- Thinking more broadly, what are your perspectives on **using VR as a future teacher**? Please explain.

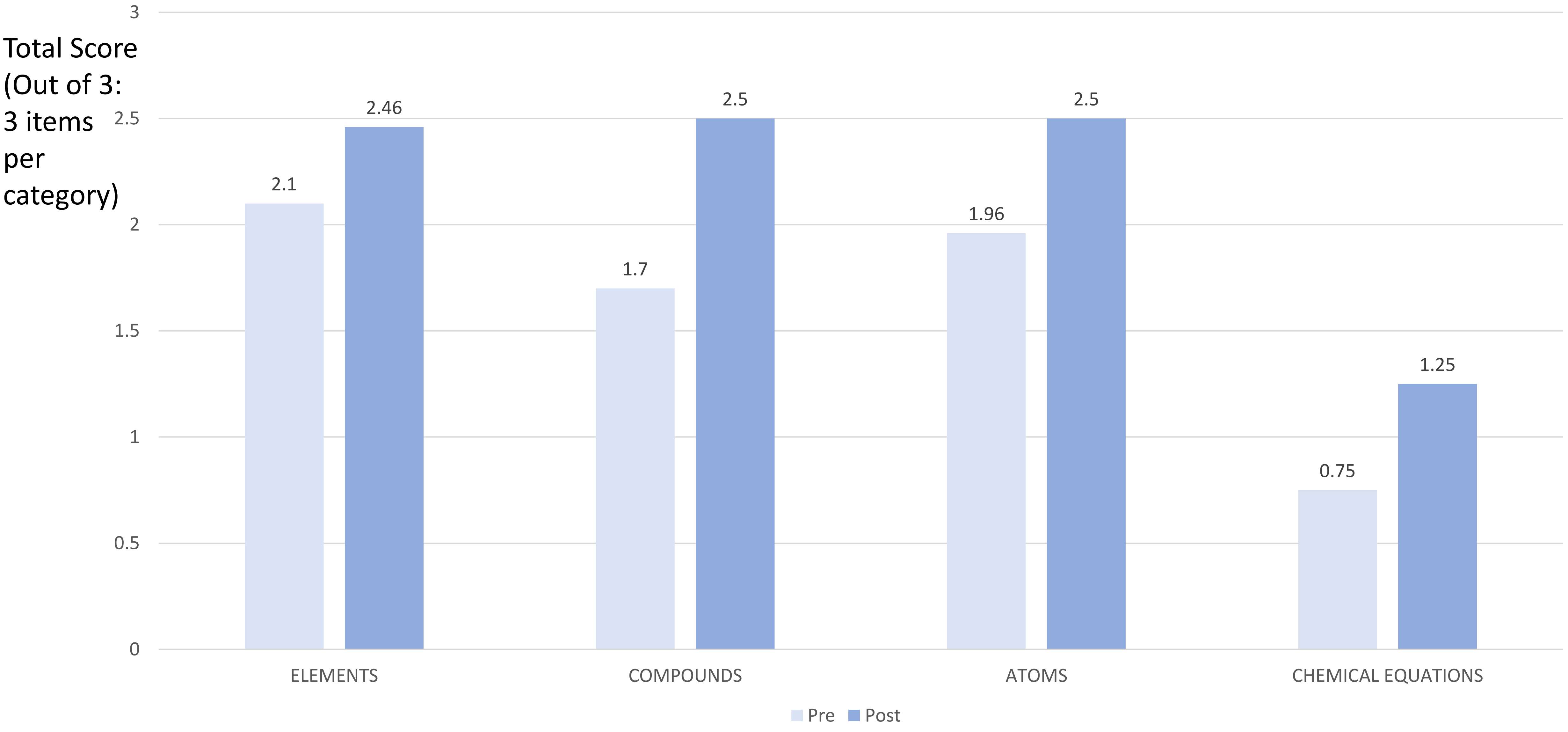
Findings - Learning Outcomes (RQ1): 12 items



n = 28, M = 2.2, SD = 2.6, SE = 0.5, t = 4.5, p < 0.001

ES (Hedge's g) = 0.78 (Medium Effect Size)

Findings - Learning Outcomes (RQ1)



Embodied Cognition – Grab, Pick Up, See, etc.

- *"I understood balancing bonds so much better like when **I got to grab the bonds and place them** where they needed to be."*

  Hispanic Female Student (#7)

- *"It showed so many visuals to what I've learned in past chemistry classes. It made so much more sense to me once I got to **physically see things like atoms and molecules** etc. being made in front of me!"*

  Hispanic Female Student (#33)

- "It is very intuitive to be able to **"pick them up" and move them [atoms] in a 3D space**. Balancing the equations is easier when the objects are able to float and aren't restricted to the physics of the real world."

  Male White Student (#6; Didn't complete pre/post test)

Findings – First Order Barriers (RQ2)

1. Access to Technology

"Personally I think it will cost a lot of money many schools will not be open minded to, but I think it will be a great investment even if they are only allowed to use this technology once a week to be made available to other students."

Hispanic Female Student (#5)

"I don't believe it is realistic for an elementary school to have VR sets simply because kids will break the equipment too fast or the price."

Hispanic Female Student (#35)

Findings – First Order Barriers (RQ2)

2. Support to Use Technology
10/28 first time users

*"This was my first time using an oculus device or going into VR. I was a bit nervous that it would take me a long time to learn how to use it, but **it wasn't difficult to get it**."*

Female Hispanic Student (#3)

*"The VR headset was **fairly easy to use** despite it being my first time using it…I was confused in some area but quickly got the hang of the task given and completed the activities with ease."*

Male Hispanic Student (#4)

Findings – First Order Barriers (RQ2)

3. Support for Instructional Planning

"maybe it would be cool to have a virtual classroom and try to lesson plan virtually."

Hispanic Female Student (#7)

"I think that it would be fun to incorporate science lessons with VR headsets because it is a way for students to have fun while learning about science concepts. I do think it can be challenging to show students how to use the headsets and focus on the activity."

Hispanic Female Student (#26)

Findings – Second Order Barriers (RQ2)

1. **Beliefs about teaching and learning**

"kids learn better when they are having fun and are more likely to recall material than if I gave them a dry lecture that would probably bore them to death. I have an optimistic outlook on the usage of virtual reality in education in the future. "

Female Hispanic Student (#29; Did not complete pre/post test)

"I think vr is great for someone in engineering or construction management because they have to create models and the vr can show how it would look. I don't think it's necessary to teach younger grades in school."

White Female Student (#15)

Findings – Second Order Barriers (RQ2)

2. Beliefs about technology

“Some may say that using VR in a classroom is bad because it makes students dependable on technology for their knowledge, but I disagree. This is because I believe that as years go by, technology is gonna get more advanced and there is no way to escape it in teaching. It does more good than harm.”

Hispanic Female Student (#18)

“with how quickly times are changing and how technology is advancing even faster, it’ll only be normal to have some sort of virtual reality device being incorporated into classrooms.”

Hispanic Male Student (#19; Did not conduct pre/post test)

Findings – Second Order Barriers (RQ2)

3. Established Classroom Practices

- *"I would either only give it to students who need the extra support, or those who want extra experience with chemistry."*

Asian Male Student (#16)

- *"For this kind of activity to work in a real classroom setting with young kids, it would have to be done in very small groups. I would consider using this during center time where students can rotate around to different centers in small groups, one of them being the VR center."*

White Female Student (#25)

Discussion

- RQ1: Learning outcomes at larger end of those reported in the VR literature (small to medium).

  (Coban et al., 2022; Cromley et al., 2023; Luo et al., 2021; Matovu et al., 2022; Villena-Taranilla et al., 2022)

- RQ2: Most future elementary teachers see potential value in VR (second-order), but have concerns with cost and breakages (first-order).

- Embodied cognition is a potential insightful learning theory to explain the value-added components of VR for science education.

Future Work

- Focus exclusively on Chemical Equations – biggest area for growth for these students.

- Comparison Study with larger class – Our introductory chemistry course typically has 400-500 students (25 students per lab section).

- FutuClass readily applicable in middle/high school classes so another opportunity for research.

Acknowledgements

- Participating Students

- Research Assistant

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Thank you. Go raibh maith agaibh.

- Questions?
- Comments?
- Concerns?

References

- Coban, M., Bolat, Y. I., & Goksu, I. (2022). The potential of immersive virtual reality to enhance learning: A meta-analysis. *Educational Research Review*, *36*, 100452. https://doi.org/https://doi.org/10.1016/j.edurev.2022.100452
- Cummings, J. J., & Bailenson, J. N. (2016). How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. *Media Psychology*, *19*(2), 272–309. https://doi.org/10.1080/15213269.2015.1015740
- Ertmer, P. (1999). Addressing first- and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development*, *47*(4), 47–61. http://dx.doi.org/10.1007/BF02299597
- Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education*, *59*(2), 423–435. http://www.sciencedirect.com/science/article/pii/S0360131512000437
- Luo, H., Li, G., Feng, Q., Yang, Y., & Zuo, M. (2021). Virtual reality in K-12 and higher education: A systematic review of the literature from 2000 to 2019. *Journal of Computer Assisted Learning*, *37*(3), 887–901. https://doi.org/10.1111/jcal.12538
- Matovu, H., Ungu, D. A. K., Won, M., Tsai, C.-C., Treagust, D. F., Mocerino, M., & Tasker, R. (2022). Immersive virtual reality for science learning: Design, implementation, and evaluation. *Studies in Science Education*, 1–40. https://doi.org/10.1080/03057267.2022.2082680
- Varela, F., Thompson, E., and Rosch, E. (1991). *The Embodied Mind: Cognitive Science and Human Experience*. Cambridge, MA: MIT Press.
- Villena-Taranilla, R., Tirado-Olivares, S., Cózar-Gutiérrez, R., & González-Calero, J. A. (2022). Effects of virtual reality on learning outcomes in K-6 education: A meta-analysis. *Educational Research Review*, *35*, 100434. https://doi.org/10.1016/j.edurev.2022.100434
- Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review*, *9*(4), 625–636. https://doi.org/10.3758/BF03196322
- Wu, B., Yu, X., & Gu, X. (2020). Effectiveness of immersive virtual reality using head-mounted displays on learning performance: A meta-analysis. *British Journal of Educational Technology*, *51*(6), 1991–2005. https://doi.org/https://doi.org/10.1111/bjet.13023