Shrink or grow the kids? Scale cognition in an immersive virtual environment for K-12 summer camp

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Figure 1. Overview of Scale Worlds. Left: children exploring Scale Worlds. Middle: main user interface. Right: Earth, Jupiter, and Sun.

ABSTRACT

Virtual reality (VR) has been widely used for education and affords embodied learning experiences. Here we describe: Scale Worlds (SW), an immersive virtual environment to allow users to shrink or grow by powers of ten (10^X) and experience entities from molecular to astronomical levels; and students' impressions and outcomes from experiencing SW in a CAVE (Figure 1) during experiential summer outreach sessions. Data collected from post-visit surveys of 69 students, and field observations, revealed that VR technologies: enabled interactive learning experiences; encouraged active engagement and discussions among participating students; enhanced the understanding of size and scale; and increased interest in STEM careers.

Keywords: virtual reality, scale cognition, education application.

Index Terms: CAVE--Virtual reality (VR)--User experience

1 INTRODUCTION

VR applications turn abstract concepts into sensory phenomena and present exciting opportunities to transform science education and public outreach practices [1]. An important aspect of science education is outlined in the Next Generation Science Standards, where "scale, proportion, and quantity" is a crosscutting concept that pervades science and can aid students in making connections across disciplines [2]. VR affords embodied learning experiences, which enables students to physically engage in learning activities with rich information [3], [4]. The use of VR for science education has revealed learning gains relative to traditional instruction [3].

Our multidisciplinary research team—design, education, and engineering—has developed a virtual learning environment named Scale Worlds (SW) to address challenges in the conceptualization of size and scale through embodied cognition in VR. In SW, users can interact with exponents and decimal points to apparently shrink or grow as they travel to different "scale worlds" to visualize scientific entities of a wide range of sizes (Figure 2) and are able to experience entities at five powers of ten simultaneously [5].

The potential of VR technologies to engage the public and groups of non-academic users to learn about science, technology, engineering, and mathematics (STEM) is largely unexplored [1]. The work presented here is part of a larger project, Virtual Reality to Improve Students' Understanding of the Extremes of Scale in STEM, which aims to investigate how students' understanding of scale and number sense (numeracy) can be improved using VR. Our objective here is to explore public outreach practices with science education through the use of VR and disseminate work to non-academics, where we describe SW and the students' impressions and outcomes from experiencing SW in a CAVE during a summer camp of elementary and middle school students.

2 METHODS

Participants in the SW experiential summer outreach were attendees of a larger summer camp program led by The Science House, an organization within North Carolina State University that offers STEM experiences to underserved and historically underrepresented students. Sixty-nine participating students (41 elementary and 28 middle school students) visited the research facility to experience SW and other technologies. While experiencing SW in the CAVE, one student at a time wore the

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tracked active shutter 3D glasses, while approximately three other students wore the non-tracked 3D glasses and stayed near the main viewer; students took turns using tracked glasses.

To assess the impact of the outreach experience and inform future outreach initiatives, we created a survey consisted of four 5-point Likert-like scale questions, a multiple-choice question, and four short-response questions to understand student's scale cognition and situational interest (Table 2).

Table 2. Survey questions administered to students.

For questions Q1–Q4, please indicate your level of agreement with the given statements (*Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree*)
(Q1) I enjoyed my visit to CAVE today.
(Q2) I learned something during my visit to CAVE today.
(Q3) I think that using virtual reality is an effective way to learn about scale.
(Q4) I have a better understanding of scale than I did prior to my visit to CAVE.
(Q5) Scale Worlds was made by STEM researchers to help prepare students for STEM careers. STEM includes science, technology and design, engineering, and math. Did Scale Worlds make you more interested in a STEM career? A. I am more interested in a STEM career. B. No change in my interest in a STEM career. C. I am less interested in a STEM career.
(Q6) Which aspect of Scale Worlds made you interested in STEM?
(Q7) Did you experience feelings of **awe** (amazement, astonishment, or wonder) during your Scale Worlds experience? If so, what caused those feelings? Please describe.
(Q8) Did you feel like YOU were growing or shrinking, or did you feel like you remained the same and the objects in CAVE were growing or shrinking? Explain.
(Q9) Describe something you learned about the size of one object during your CAVE visit.

3 Results

All 69 students responded to the quantitative section of the survey after experiencing SW in the CAVE. Of the 69 students, 67 (97%) agreed or strongly agreed that they enjoyed the visit to CAVE, 53 (77%) agreed or strongly agreed that they learned something during the visit to CAVE, 60 (87%) agreed that using VR is an effective way to learn about scale, and 50 (73%) agreed that they had a better understanding of scale after visiting the CAVE. Finally, 48 students (70%) stated that SW made them more interested in a STEM career.

Qualitative analysis focuses on Q6–Q9 (Table 2). When students were asked about STEM interest (Q6), 38 of 69 (55%) indicated an enjoyable experience in SW. Of those 38, 12 (32%) identified either the experience of encountering different scales of objects or general immersion as the aspect of SW that made them more interested in STEM. A relatively high percentage of students (55%) identifying these aspects suggests that experience-driven, as opposed to knowledge-driven, gains from SW contributed to STEM interest.

When asked about awe (Table 2, Q7), 62 students (91%) indicated that they experienced feelings of awe. The top two reasons for feeling awe were related to either experiencing different scales of objects, or general immersion.

When students were asked about their subjective sense of scaling (Q8), forty-nine (72%) indicated a feeling that they were changing size themselves, suggesting that SW effectively provided an experience of scale change. 22% felt the objects around them were shrinking or growing.

Students were also asked to describe something they learned about the size of one entity ("object") during the CAVE visit.

Figure 2. A user in the CAVE. The wand's virtual magenta ray activates interactive 3D user interface elements.

COVID-19 and the solar system were each mentioned more than twice as often as other objects. Therefore, these two entities seem to be of particular interest to SW users, though the solar system was not presented as a single entity, but rather elements of it appeared in their respective scale worlds. Approximately half of the respondents (51%) indicated that they learned about size on a relative, as opposed to simply absolute, scale.

4 Conclusion and Future Work

Our results indicate that the CAVE-based SW was an interactive and engaging approach for elementary and middle school students to experience dramatic size differences and learn about the crosscutting concept of scale, proportion, and quantity. The CAVE is a novel and practical tool for education outreach, and SW increased students' interest in STEM. Our experience also suggests an urgency to update VR technologies and content for children, in order to facilitate educational experiences.

In the future, we will use the feedback reported here to inform the next iteration of SW. All the verbal comments from students during the visit and data from the post-visit survey provided insight for us to form a clear direction of the design and development of SW and make accommodations for facilitators (e.g., instructors) and non-adult users.

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References

[1] M. Kersting, R. Steier, and G. Venville, "Exploring participant engagement during an astrophysics virtual reality experience at a science festival," *Int. J. Sci. Educ. Part B Commun. Public Engagem.*, vol. 11, no. 1, pp. 17–34, 2021, doi: 10.1080/21548455.2020.1857458.

[2] National Research Council, *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* 2022.

[3] M. C. Johnson-Glenberg, D. A. Birchfield, L. Tolentino, and T. Koziupa, "Collaborative embodied learning in mixed reality motion-capture environments: Two science studies," *J. Educ. Psychol.*, vol. 106, no. 1, pp. 86–104, 2014, doi: 10.1037/a0034008.

[4] B. Dalgarno and M. J. W. Lee, "What are the learning affordances of 3-D virtual environments?," *Br. J. Educ. Technol.*, vol. 41, no. 1, pp. 10–32, 2010, doi: 10.1111/j.1467-8535.2009.01038.x.

[5] L. Wu, B. Sekelsky, M. Peterson, T. Gampp, C. Delgado, and K. B. Chen, "Immersive virtual environment for scale cognition and learning: Expert-based evaluation for balancing usability versus cognitive theories," *Proc. Hum. Factors Ergon. Soc. Annu. Meet.*, vol. 66, no. 1, pp. 1972–1976, 2022, doi: 10.1177/1071181322661094.