From Immersion to Behavioral Intentions: Virtual Reality and Advanced Water Purification

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Environmental Communication Immersive Learning Virtual Reality

This study examines the relationship between immersive Virtual Reality (VR) and behavioral intentions related to Advanced Purified Water (APW). Using a quasi-experimental pre-test/post-test design, the study compares participants' willingness and comfort using APW before and after engagement with an educational VR simulation of the water purification process. Statistical tests (Chi-square, Fisher's Exact, and Mann–Whitney U) were used to compare pre- and post-test responses. Results show that overall participants' willingness and comfort with using APW were higher following the VR experience, suggesting an association between immersive educational VR and increased acceptance of emerging water technologies.

Introduction

Virtual reality (VR) is rapidly emerging as a transformative tool for science and environmental communication because of its ability to generate deep psychological engagement and behavioral change (Behm-Morawitz & Shin, 2024; Fauville et al., 2020; Breves, 2020). Drawing from the Theory of Planned Behavior (Ajzen, 1985), which posits that attitudes and perceived control predict intentions and subsequent actions, VR uniquely influences both cognitive and affective components of behavior. Immersion creates a powerful sense of presence, enabling audiences to experience scientific phenomena rather than merely observe them (Behm-Morawitz & Shin, 2024; Breves, 2020). This presence enhances message credibility, emotional connection, and empathy, producing persuasive effects (Breves & Schramm, 2021; Ahn et al., 2014). These mechanisms allow VR to bridge the gap between abstract information and lived experience, engaging both emotional and rational pathways that underlie behavioral intention (Behm-Morawitz & Shin, 2024; Ahn et al., 2014; Breves, 2020; Markowitz & Bailenson, 2021; Fauville et al., 2020).

A growing body of research demonstrates that VR-based experiences can enhance environmental learning, emotional engagement, and pro-environmental behavioral intentions. Studies show that immersive simulations reduce psychological distance and help participants visualize the tangible impacts of environmental issues, thereby strengthening concern and action tendencies (Markowitz & Bailenson, 2021; Luzzati et al., 2025). For example, Luzzati et al. (2025) found that participants who explored a climate-change scenario in VR reported greater perceived urgency and stronger intentions to adopt sustainable behaviors than those receiving text-based information. Similarly, Ahn et al. (2014) showed that embodiment in virtual environments increased participants' environmental locus of control, translating awareness into behavioral intentions. Experiments using 360° and embodied simulations report comparable effects: Fauville et al. (2020) demonstrated that participants who experienced ocean acidification through VR exhibited higher environmental concern than control groups viewing the same content in 2D, and Shin and Lee (2024) found that immersive campaign videos prompted deeper cognitive elaboration and alignment with pro-environmental messaging. Meta-analytic studies also substantiate these findings. Villena-Taranilla et al. (2022) synthesized 54 studies and identified a large effect of VR on motivation and learning outcomes, while Zhang and Bowman (2022) confirmed that interactive storytelling in VR enhanced both engagement and content retention. Overall, these studies establish VR as a powerful experiential medium that can influence cognition, emotion, and behavior in sustainability contexts. Furthermore, ethical design frameworks further emphasize that persuasive effectiveness depends on user agency, narrative coherence, and representational transparency (Lambrecht et al., 2024, 2025).

While VR's potential to change attitudes and behaviors is well established in environmental and educational contexts, little research has explored how it might help the public understand and accept specific sustainability technologies they are being asked to adopt. To address this gap, the current study examines how immersive VR relates to public acceptance and behavioral intentions toward AWP. Although APW systems have been proven safe and environmentally beneficial, messaging from municipalities has failed to account for residents' cognitive and affective barriers and has thus failed to convince a skeptical public that returning recycled wastewater directly back to the public drinking system is safe (Annin, 2024; Dolnicar et al., 2011). Phrases like, "toilet to tap," for instance, have historically hindered AWP development (Annin, 2024). This makes AWP a high-risk sustainability issue because despite it being a "viable near-term solution" for water security in Arizona, perceptual barriers remain and could reduce public acceptance. The psychological and perceptual hurdles that prevent people from feeling comfortable adopting a new sustainability technology like Advanced Purified Water is just the sort of visceral challenge that the embodied nature of VR may help overcome. By bringing people directly into the water-purification processes to demonstrate its safety, VR can reduce perceived risk, foster understanding, and strengthen acceptance. Therefore, this study asks whether participants' engagement with a VR exploration of an APW system is associated with differences in behavioral intentions, which, according to the Theory of Planned Behavior (Ajzen, 1985), is operationalized in this study through self-reported comfort and willingness. These measures function as theoretically informed indicators of attitudinal evaluation and perceived behavioral control shaping intention, consistent with established TPB measurement practices.

Methods

Research Design

Guided by a Learning Engineering framework, this study employs a human-centered, evidence-driven approach to evaluate an immersive VR learning intervention (Goodell et al., 2023). The research design represents a focused evaluation cycle embedded within a broader design effort, consistent with nested Learning Engineering methodologies (Craig et al., 2025). The study used a quasi-experimental pre-test/post-test design to examine differences in participants' willingness and comfort using APW between pre- and post-VR groups. Participants played Flow Forward, a 15-minute VR game created by members of the Arizona Water Innovation Initiative and students in ASU's MESH Lab ("ASU Mesh Labs," 2025). In the game, players learn about advanced water purification, then pilot a nanosubmarine through ozonation, ultrafiltration, reverse osmosis, and UV filtration to remove contaminants and complete the process. Participants completed a brief online survey before (pre-test) and after (post-test) engaging in a VR experience illustrating the Advanced Water Purification process. Since individual participants' pre- and post-test responses could not be matched, pre- and post-test scores were treated as independent samples for analysis.

Data Collection and Analysis

Researchers obtained IRB approval to work with high school students (IRB STUDY #00018372). Participants were recruited through a convenience sample consisting of two sections of AP Environmental Science during the spring semester of 2025. This population was particularly relevant because students were concurrently learning about water systems and environmental sustainability, making Advanced Water Purification a familiar and meaningful topic of study. After entering the classrooms, the project lead explained the study and administered the online pre-survey. The pre-survey defined APW as a process "to recycle and treat wastewater so that it is clean enough to drink" and asked students to specify, on a four-point scale from extremely uncomfortable to extremely comfortable, the extent to which they would feel comfortable drinking APW water or using it for a variety of other purposes (see Table 2). The development lead then provided a short walkthrough of the headset and general flow of the game before students used MetaQuest headsets to play the game from start to finish. When done, students filled out the post-survey where they were, once again, asked to what extent they would feel comfortable drinking APW and using it for other domestic purposes, before taking part in brief, informal group debriefs about their experiences. Out of 32 students, two students opted not to fully participate. All other students completed the pre-survey, gameplay, and post-survey.

Data analysis followed a structured process to address the three research questions. For RQ1, a Chi-square test of independence and Fisher's Exact Test were conducted to assess differences in willingness to drink APW between pre- and post-test groups, with Cramer's V reported as an effect size. For RQ2, independent-samples Mann–Whitney U tests were conducted to compare comfort ratings across the five APW uses, with effect sizes (r) calculated as $Z/\sqrt{N}$. For RQ3, effect sizes across uses were compared to determine which APW use showed the largest change in comfort. All analyses emphasized effect sizes and trends rather than significance alone, given the small sample size.

Results

Willingness to Drink Advanced Purified Water (RQ 1)

A cross-tabulation examined whether exposure to the VR experience exposure to an immersive VR experience was associated with greater willingness to drink APW. In the pre-test group, 26 of 30 participants (86.7%) reported 'Yes' while four (13.3%) said 'Maybe'. In the post-test group, all 30 participants (100%) reported 'Yes'. A Chi-square test of independence indicated a statistically significant association between group (pre vs. post) and willingness to drink APW, $\chi^2(1, N = 60) = 4.29$, $p = .038$, with a moderate effect size, Cramer's $V = .27$. Because 50% of the cells had expected counts less than five, Fisher's Exact Test was examined as a more conservative test. Fisher's test was not significant on the two-sided comparison ($p = .112$) but approached significance on the one-sided test (p = .056). Overall, these results suggest a positive trend toward greater willingness to drink APW following the VR experience (see Table 1).

Table 1.

Willingness to Drink Advanced Purified Water (Pre vs. Post VR)

Group	Yes	Maybe	No	Total (n)
Pre-test	26 (86.7%)	4 (13.3%)	0 (0%)	30
Post-test	30 (100%)	0 (0%)	0 (0%)	30
Statistical Test: $\chi^2(1, N = 60) = 4.29$, p = .038; Fisher's Exact (two-sided) = .112, one-sided = .056 Effect Size: Cramer's V = .27				

Comfort Using Advanced Purified Water (RQ 2)

Descriptive statistics and Mann–Whitney U tests were used to examine differences in comfort using APW between pre- and post-VR groups across five household purposes. Median comfort ratings were high for both groups, generally ranging between 3 and 4 on a 4-point scale. A significant difference was found for drinking, U = 586.50, Z = 2.19, p = .028, r = .28, indicating greater comfort after the VR experience. No significant differences were found for cooking (p = .422), showering (p = .137), laundry (p = .679), or gardening (p = .920). The moderate effect for drinking indicates greater comfort with the most personal use of APW in the post-VR group compared to the pre-VR group (see Table 2).

Table 2.

Comfort with Using Advanced Purified Water Across Purposes (Pre vs. Post VR)

Purpose	Pre Median	Post Median	U	Z	p (2-tailed)	r
Drinking	3	4	586.50	2.19	.028	.28
Cooking	4	4	496.00	0.80	.422	.10
Showering	4	4	534.00	1.49	.137	.19
Laundry	4	4	473.00	0.41	.679	.05
Gardening	4	4	445.00	-0.10	.920	.01

Change in Comfort After the VR Experience by APW Use (RQ 3)

Effect size comparisons showed that comfort for drinking exhibited the largest difference between pre- and post-VR groups (r = .28), followed by a smaller difference for showering (r = .19). Comfort for cooking, laundry, and gardening showed negligible differences (r < .10). Overall, these patterns suggest that differences in comfort were greatest for direct, personal uses of APW, supporting the potential of immersive educational tools to promote behavioral change toward water reuse.

Discussion

This study demonstrates how VR can make complex sustainability processes like APW production understandable and engaging. The findings suggest that comfort and willingness to incorporate APW in daily life tend to increase after the VR experience. In particular, there was a greater willingness to drink APW (RQ 1), with fewer participants being less uncertain about their willingness following the VR experience. Comfort using APW (RQ 2) increased, but only for drinking purposes (RQ 3), as using APW across other purposes was already largely accepted and thus did not change following the VR experience.

By combining immersion with narrative-driven interaction, the experience helped participants connect large-scale issues such as water scarcity and climate change to their own lives (Petersen et al., 2020; Lambrecht et al., 2025). Positioning users to “battle” contaminants through each purification stage shows potential to reduce psychological distance and foster active engagement, echoing findings from Markowitz and Bailenson (2021). Future work will extend this research by systematically isolating and examining specific VR design features to better understand their individual and combined effects on participant outcomes. Additional variables, including emotional engagement, sense of presence, empathy, perceived agency, memorable moments, and participant reflections, can be incorporated to clarify the mechanisms through which immersive VR may shape behavioral intentions.

Limitations

This study provides early evidence of how immersive VR can shape public perceptions, but several limitations should be noted: (1) because individual pre- and post-test responses could not be linked, the analysis focused on group-level trends rather than participant-specific changes; (2) the sample consisted solely of high school students from similar educational backgrounds, limiting the generalizability of findings to broader populations.

Conclusion

Findings from this study suggest that immersive, narrative-based VR experiences have potential to positively influence behavioral intentions related to sustainable technologies. By situating this evaluation within a Learning Engineering framework, the study demonstrates how iterative, human-centered design and empirical testing can inform the development of effective immersive learning interventions for real-world sustainability challenges. Future research will extend this work by examining participants’ learning, engagement, and perceptions within the same VR environment.

Acknowledgments

The authors would like to thank ASU’s MESH Lab for developing the Flow Forward VR experience. This work was supported by Arizona State University’s Arizona Water Innovation Initiative and the Impact Water—Arizona program, courtesy of the State of Arizona and the Virginia G. Piper Charitable Trust. Additional support was provided by the National Science Foundation (Grant Number 2314259).

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