xWe Can’t Just Go Shooting Asteroids Like Space Cowboys: The Role of Narrative in Immersive, Interactive Simulations for Learning

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Abstract: The purpose of this study is to explore how merging narrative, role-play, and immersive, interactive technology can support learners to participate in designerly STEM practices (e.g., posing questions, designing investigations, modeling data). Set in university pre-service teacher education courses, we contrast two problem-based units incorporating immersive, interactive projection. Elementary pre-service teachers (n=9) completed a three-day unit on arithmetic and geometric sequences embedded in a narrative of defending the Earth by testing a top-secret weapon to destroy asteroids. Secondary science pre-service teachers (n=8) completed a three-day unit that included an immersive simulation of the greenhouse effect, but lacked a narrative context. This study reports qualitative analysis of video-recorded interactions, examining how students engaged and participated. In the former, the narrative context pervaded interactions, and invited participation from students who rarely participated. In the latter, the students engaged as scientists, surfacing numerous questions and investigations. Students engaged mathematically/scientifically within the immersive environment.

Standing on the navigation platform in the center of the capsule, a young woman leans forward, plunging her crew into a dizzying dive through space. “On your left!” shouts one of her crew- an asteroid-spotter. The gunner deftly fires the B612 Asteroid Splitter, and the asteroid splits into 3 pieces, each big enough to wipe out life on Earth. The captain leans forward, this time making only minor course corrections so her gunner can finish the job, dividing the remaining pieces repeatedly into three pieces. “Tech, give me a report. How many asteroids do we have out there now and how many are still planet-killers?” she asks. “On our first scan, we had 20. After one strike of the B612, we had 22. After three more strikes, we had 28. Now we have 262, but only 19 are big enough to pose a threat.” “On your right! Watch out!” shouts one of the spotters. “Wait,” says Ignacio, one of the mission recorders, “So would there be a formula? Would? Be like, uh, the number of asteroids minus … minus one when it splits into three?” With the simulation still playing on the dome surrounding them, the teacher encourages his students to discuss, “Can anybody help him out? What do you guys think the formula for this thing should be?”

Introduction

Whereas many technologies place a screen between learners, immersive technology of the type we investigate creates a surround that engulfs learners (Figure 1); the addition of multi-user interactivity allows them to navigate and explore. We explore how immersive, interactive technology might support learning of inquiry practices, such as posing questions, designing investigations, and modeling data. School STEM has long been criticized for not reflecting professional practice (e.g., Rudolph, 2005). New standards focus on STEM practices (Common Core State Standards Initiative, 2010; National Research Council, 2012). STEM professionals engage in *designerly* practices (Cross, 2001), meaning they generate their own questions and design investigations involving variables they select, but in schools, the questions, procedures, and variables are generally provided. Even inquiry activities created by researchers interested in studying how students learn science seldom ask students to generate their own questions or design investigations (Chinn & Malhotra, 2002). Students seldom have opportunities to participate in *designerly* practices (e.g*., posing questions, designing investigations, modeling data*).

As our team works to design low-cost, immersive, interactive projection kits for classroom use, we explore the affordances of this technology; we consider dimensions that provoke authentic context, including how role-play and narrative support students to engage in designerly aspects of STEM practice. We investigate a digital dome-- a type of *panoramic display* in which the learner can look around at “a wide field of view look into the virtual world, seeing many things at once” (Jacobson, 2012, para 10). We focus on two types of *presence*: *sensory* (feeling present in the virtual world (Jacobson, 2012; Slater, 2009)), and *narrative* (feeling present in a story, with the ability to shape it (Jacobson, 2012)). We explore *multi-user interactivity* (multiple learners can interact with the display simultaneously) and role-play. By combining these aspects, we hope to provoke *consequential engagement* – that is, we want students to recognize “the usefulness and impact of disciplinary content” (Gresalfi & Barab, 2011, p. 302)but not necessarily with an understanding
of why one is performing such procedures.
 Conceptual engagement involves more
than plugging numbers into an equation, but additionally
involves understanding why an equation
works the way it does. In contrast, consequential
and critical engagement concern the coordination
of content, contexts, and learner decisionmaking. Consequential engagement involves
recognizing the usefulness and impact of disciplinary
content; being able to connect particular
solutions to particular outcomes.”302{Gresalfi, 2011 #5202}
</research-notes></record></Cite></EndNote>. This paper contrasts two enactments, one of which incorporated narrative, to explore the ways designerly practices-- posing questions, designing investigations, modeling data—were or were not supported.

Figure 1: Similar to a small planetarium, our 15-ft diameter dome can accommodate 12 learners. Six projectors powered by one Mac Pro allow for multi-user interactivity. Here, DomeStroids is controlled with a WiiMote and pressure sensors in a skateboard interface.

Immersive, Interactive display

Immersive displays –such as our dome-- allow for exploration of three dimensional spaces and have been shown to support factual and conceptual learning (e.g., Lantz, 2011). Comparisons of display types have found advantages for immersive displays over standard desktop displays for factual recall and conceptual learning of architecture (Jacobson, 2010) and understanding of the chemical reactions (Limniou, Roberts, & Papadopoulos, 2008). Likewise, learning about Mayan culture and astronomy was significantly higher when viewed in a dome system, compared to theater screens (Heimlich, Sickler, Yocco, & Storksdieck, 2010). *Interactivity* may be an important key for creating sensory and narrative presence, and in turn supporting learning (Dondlinger, 2007). The addition of multi-user interactivity opens up new possibilities for learning (Emmart, 2005; Wyatt, 2005).

Sensory Presence

Sensory presence enhances engagement, which in turn leads to greater learning (Fraser et al., 2012). Immersive displays tend to provide a strong sense of being present in the virtual—as opposed to physical—world (Bailenson et al., 2008). Virtual environments allow learners to feel more present (Kafai, 2006). Even online, interactive environments can evoke a sense of presence (Lessiter, Freeman, Keogh, & Davidoff, 2001). Presence has been measured via survey (Heeter, 1992; Witmer & Singer, 1998), physiological measures (Meehan, Insko, Whitton, & Brooks Jr, 2002), and behavioral measures (Bailenson, Blascovich, Beall, & Loomis, 2003). Based on research on psychological processes, it is not “paramount to create the most realistic or captivating experience regarding immersion and presence” when learning—as opposed to entertainment—is the goal (Schnall, Hedge, & Weaver, 2012, p. 11).

Narrative Presence and Role Play

Evidence from neurobiology, cognitive psychology, and research on memory demonstrates that narrative supports learning by providing coherence and context (Hazel, 2008), allowing learners to construct meaning (Bruner, 1991). Narrative provides a motivating context for problem solving (Dickey, 2006). *Narrative presence* supports learning by providing a situated experience (Dede, 2009). Prior knowledge and culture interact with the degree to which learners feel present in the narrative and this impacts what is learned (Heimlich et al., 2010). Some narratives allow students to take on roles and identities of scientists (e.g., Dunleavy, Dede, & Mitchell, 2009). This is one of the affordances of video games Gee cites, (2003) explaining that games can serve as a mediator between virtual and real identities, engaging students previously uninterested (Dunleavy et al., 2009). Narrative is commonly used in educational games (Dondlinger, 2007) and is effective when the learning goals are closely aligned to the narrative (Fisch, 2005; Malone, 1981; Waraich, 2004). Narrative has been invoked as a means to support students who struggle with the particular content (Waraich & Brna, 2008). Role-playing as scientists has been shown to help learners understand that the goals of science are not producing facts so much as developing and testing explanations (Solomon, Duveen, Scot, & McCarthy, 1992). Role play, especially when embedded in narrative that invests the “role with opportunities for action” (Barab et al., 2010, p. 240), has been shown to support learning (Hickey, Barab, Ingram-Goble, & Zuiker, 2008). Although much research supports the use of narrative, other research questions it necessity, suggesting that simulation alone may be better (Frasca, 2003; Habgood, Ainsworth, & Benford, 2005).

Methods

We co-designed two problem-based immersive units with teachers. This study reports initial enactments with these units, undertaken in courses for pre-service teachers. The first unit, *DomeStroids* focuses on arithmetic and geometric sequences with a narrative context of asteroids threatening to destroy all life on Earth; *DomeStroids* allows users to navigate through space with a skateboard and use a Wii-mote to test a secret weapon to blow up asteroids into a pre-specified number of pieces. Students spent three 50-minute class periods working in groups, with one class period in the dome (n=9). Roles (e.g., pilot, gunner) were assigned. The second unit, *ClimateDome,* focuses on the greenhouse effect and used a short version of a previously tested Web-based Inquiry Science Environment (WISE), (Slotta & Linn, 2009) unit on Global Climate Change (Svihla & Linn, 2012). The unit incorporated NetLogo models (Wilensky & Reisman, 2006) of the greenhouse effect. *ClimateDome* was used to reinforce understanding of the greenhouse effect, allowing the users to control the level of CO_2 with the Wii-mote, and then export data. The teacher did not provide a narrative context, but roles (e.g., CO_2 specialist, model engineer) were assigned connected to a setting (propose experiments to be conducted in the dome). Students produced graphs of changes in the overall heat of the system. Students spent two 75-minute class periods working in groups, with part of one class period in the dome (n=8).

Field notes and artifacts of student work were collected during the lessons, which were video recorded in accordance with field standards (Derry et al., 2010). Pre- and post-tests were used to document changes in understanding. We examine learning through interaction analysis (Jordan & Henderson, 1995) and as evidenced in assessments and artifacts. Elsewhere, we present analysis of pre/post changes in student learning, showing that in both units, students achieved learning gains (Svihla, Dahlgren, Kvam, Bowles, & Kniss, 2013).

Pre-dome session	Dome session	Post-dome session
DomeStroids (40 minutes) Teacher introduced the challenge in a narrative; students worked in groups on the cell division tasks; Students worked individually on the cell division tasks as homework	(50 minutes total) Teacher gave roles to the students; they practiced their roles; Teacher guided them through the activity for first part, (15 minutes); remainder of time spent with the “lights up” and working together on developing a formula, while still sitting under the dome; Students worked individually on the remaining asteroid tasks as homework	(10 minutes) Teacher gave brief lecture on sequences, with class discussion

ClimateDome (70 minutes) Students participated in a previously tested WISE unit on climate change (Svihla & Linn, 2012)	(40 minutes total) Teacher introduced *ClimateDome* and gave roles to the students; students planned experiments with the “lights up” (15 minutes); students carried out experiments they designed (25 minutes)	(40 min) Students finished the WISE unit on climate change and worked with datasets from *ClimateDome*

Table 1: Sequence of activities in *DomeStroids* and *ClimateDome*

Findings

We present findings related to how narrative and role-play supported *consequential engagement* (Gresalfi & Barab, 2011)but not necessarily with an understanding
of why one is performing such procedures.
 Conceptual engagement involves more
than plugging numbers into an equation, but additionally
involves understanding why an equation
works the way it does. In contrast, consequential
and critical engagement concern the coordination
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content; being able to connect particular
solutions to particular outcomes.”302{Gresalfi, 2011 #5202}
</research-notes></record></Cite></EndNote> in *designerly* practices (e.g*., posing questions, designing investigations, modeling data*). We first highlight how this unfolded in *DomeStroids*, which included a narrative, then contrast this with *ClimateDome*, which did not have a narrative context.

Narrative context in *DomeStroids* invited participation

Initially, we see the students engaged with the narrative context, but not necessarily with the mathematical content and practices targeted by the unit. They focused on making the asteroids smaller, repeatedly firing the weapon, but not understanding how the weapon worked. The teacher encouraged them to shift their focus to the task at hand, saying “Okay, we gotta be systematic about this though. We can’t just go shooting -- shooting asteroids like space cowboys, right?” With definite guidance by the teacher, the students began to shift their approach to investigate the number of times an asteroid could be split, still grounding their discussion in the narrative context, but using it to investigate the mathematical content and practices.

1 Teacher: Wull:: cause one became three right so actually we only added (.)

2 Ss: Two

3 Teacher: Two more so how many did we have?

4 Ss: 22

5 Teacher: 22. Okay and then we did it again. We fired again. How many did we have after that?

6 Ignacio: So would there be a formula would be like uh the number of asteroids minus (.) minus one when it splits unto three

7 Teacher: You’re getting kind of the right ide-(.) I’m not sure what you’re saying

8 Ignacio: Minus one times two

9 Teacher: No not times two //

10 Ignacio: //plus two

11 Teacher: (.) You’re almost there you’re almost there.

12 Teacher: Can anybody help him out. What do you guys think the formula for this thing should be?

At first, we see the teacher guiding the students with very specific prompts (turns 1-5). At turn 6, Ignacio's question shifts the focus from answering the teachers' questions (in which we might claim conceptual engagement) to consequential engagement, in which they see utility in the content. This also marks an important moment in the class because Ignacio rarely participated in class. The teacher reflected on Ignacio's work, "He's written down the pattern, and he has uh::h generalized it to have a variable here, which is cool" (see Figure 2). Ignacio's model of the asteroids splitting with each hit shows his ability to represent data in disciplinary ways, even in the context of a fantasy narrative.

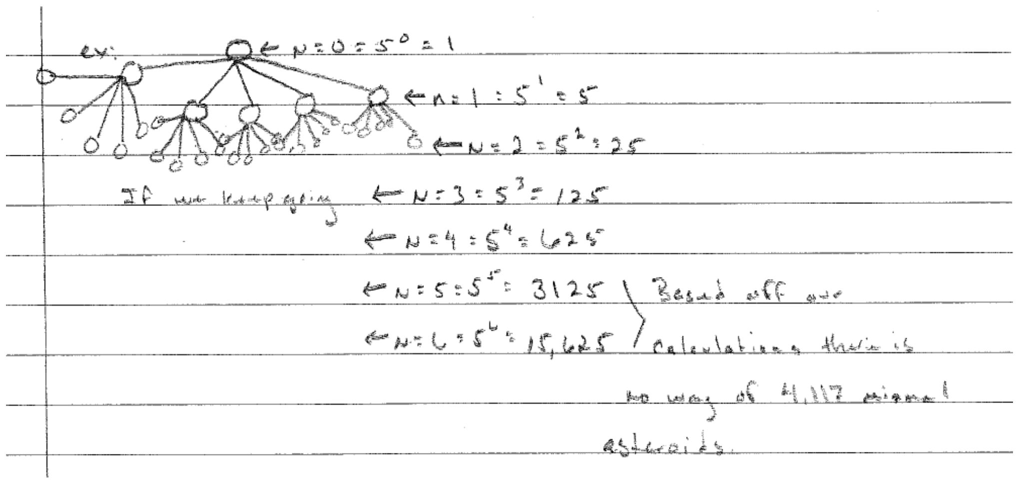

Figure 2: Ignacio's post-dome model of his algebraic expression, "number of asteroids =5(N)"

In the larger corpus of data, the roles are not very visible, though the narrative is, with students embedding their nascent understanding in the fantasy, and using it to engage consequentially.

Role-play and setting in *ClimateDome* supported question-posing

Although *ClimateDome* did not include narrative, the unit did provide a setting; students were asked to propose experiments that could be conducted in the dome. A student took on the role of Lead Scientist, deciding which experiments would allow them to efficiently explore the simulation of climate change. Students posed possible experiments based on their roles, focusing on CO_2 and infrared radiation (IR). He encouraged them to vary only one thing at a time, and after finding the baseline in the simulation, the Lead Scientist asked for proposals:

Student: We narrowed it down to a few questions. Our first questions was, "What happens to infrared radiation in the presence of CO_2 in the atmosphere. And depending on what kind of parts per million we are dealing with now, like current parts per million of CO_2 right now. And then say it's way higher than that, like by a factor of ten maybe. […] Umm, and then the level of infrared radiation would be the variable of interest and we would want to see if that had a direct correlation with the temperature or the heat. And the inverse of that, is what happens to the infrared radiation in the absence of CO_2 or very low parts per million.

In the larger data corpus, the roles –as scientists-- were consistently visible as students engaged, posing questions, negotiating the potential value in specific experiments, and interpreting results. After they returned to the classroom with data from the simulation, they modeled it, surfacing further questions such as why there was more solar radiation than heat energy and infrared radiation, why the overall heat of the system increased when there was a higher level of infrared radiation, and why variables changed together. Overall, the experience was generative and the students were consequentially engaged, but the patterns of participation – meaning the level of participation by particular students and the exchanges between particular students – largely reflected normal classroom participation (based on video and field notes of two other class periods). Students who contributed infrequently in class, contributed infrequently in *ClimateDome.*

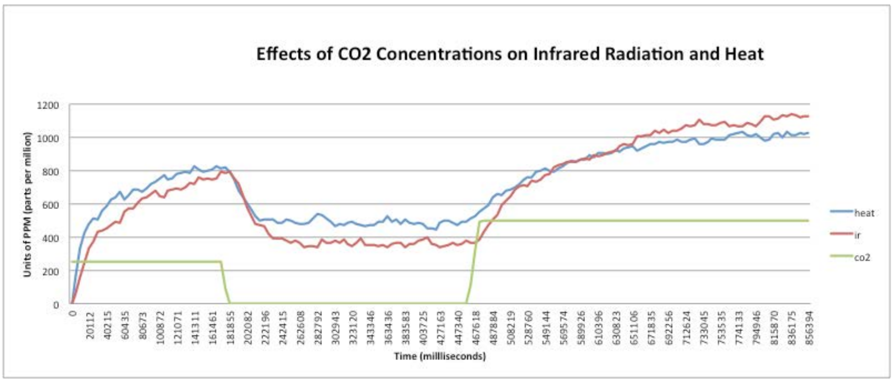

Figure 3: Example graph produced by a student using data exported from *ClimateDome*, showing the effects of CO_2

Conclusions and Implications

Although our findings are yet tentative and studies ongoing, we can draw initial conclusions about how immersive, interactive media can support learning when paired with role-play and narrative. In both units, student work and video data show evidence of learning and participation in *designerly* practices (e.g*.,* posing questions, designing investigations, modeling data). This engagement was consequential, with students seeing how, when, and why to pose questions, pursue experiments, and model data. We see this as important particularly for future teachers because the majority of their prior content courses engaged them in *procedural* or *conceptual* ways.

By contrasting two different units with different foci, and with different learners, we are afforded the opportunity to consider why both units supported students to engage in *designerly* practices. First, we consider that the elementary pre-service teachers—typically fearful of math-- were successful in part because the narrative context invited them to participate in *DomeStroids*. In *ClimateDome,* the secondary science pre-service teachers were already comfortable with taking on the roles of scientists. Although this may seem to mean that narrative is not needed in such cases, we consider that there is still potential value in using it; the patterns of participation remained intact from classroom to dome, with a few students consistently participating less. This was not the case with *DomeStroids*, where we saw a struggling student emerge as a leader. While we cannot definitely attribute this reconfiguration of participation to the use of narrative, we do intend to pursue contrasts with future iterations to clarify this. The narrative may have invited participation from a broader range of students, including those who rarely participated.

Although these pilot studies show promise for teaching and learning with immersive, interactive technology, we cannot disambiguate the impact of the technology itself. Further studies are needed to understand how and why the technology might support learning.

References

Bailenson, J. N., Blascovich, J., Beall, A. C., & Loomis, J. M. (2003). Interpersonal distance in immersive virtual environments. *Personality and Social Psychology Bulletin, 29*(7), 819-833.

Bailenson, J. N., Yee, N., Blascovich, J., Beall, A. C., Lundblad, N., & Jin, M. (2008). The use of immersive virtual reality in the learning sciences: Digital transformations of teachers, students, and social context. *The Journal of the Learning Sciences, 17*(1), 102-141.

Barab, S. A., Dodge, T., Ingram-Goble, A., Pettyjohn, P., Peppler, K., Volk, C., & Solomou, M. (2010). Pedagogical dramas and transformational play: Narratively rich games for learning. *Mind, Culture, and Activity, 17*(3), 235-264.

Bruner, J. (1991). The narrative construction of reality. *Critical inquiry, 18*(1), 1-21.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education, 86*(2), 175-218.

Common Core State Standards Initiative. (2010). Common core state standards for mathematics. *Retrieved June, 2*, 2010.

Cross, N. (2001). Designerly Ways of Knowing: Design Discipline Versus Design Science. *Design Issues, 17*(3), 49-55.

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science, 323*(5910), 66.

Derry, S., Pea, R., Barron, B., Engle, R., Erickson, F., Goldman, R., . . . Sherin, B. (2010). Conducting Video Research in the Learning Sciences: Guidance on Selection, Analysis, Technology, and Ethics. *Journal of the Learning Sciences, 19*(1), 3-53.

Dickey, M. D. (2006). Game design narrative for learning: Appropriating adventure game design narrative devices and techniques for the design of interactive learning environments. *Educational Technology Research and Development, 54*(3), 245-263.

Dondlinger, M. J. (2007). Educational video game design: A review of the literature. *Journal of Applied Educational Technology, 4*(1), 21-31.

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology, 18*(1), 7-22.

Emmart, C. (2005). The Powers of Ten with a Steering Wheel on the Global Visualization Superhighway. *Planetarian: Journal of the International Planetarium Society, 34*(4), 19-26.

Fisch, S. M. (2005). *Making educational computer games educational.* Paper presented at the Proceedings of the 2005 conference on Interaction design and children.

Frasca, G. (2003). Simulation versus narrative. *The video game theory reader*, 221-235.

Fraser, J., Heimlich, J. E., Jacobsen, J., Yocco, V., Sickler, J., Kisiel, J., . . . Stahl, J. (2012). Giant screen film and science learning in museums. *Museum Management and Curatorship, 27*(2), 179-195.

Gee, J. P. (2003). What video games have to teach us about learning and literacy. *Computers in Entertainment (CIE), 1*(1), 20-20.

Gresalfi, M., & Barab, S. (2011). Learning for a Reason: Supporting Forms of Engagement by Designing Tasks and Orchestrating Environments. *Theory into Practice, 50*(4), 300-310.

Habgood, M., Ainsworth, S., & Benford, S. (2005). Endogenous fantasy and learning in digital games. *Simulation & Gaming, 36*(4), 483-498.

Hazel, P. (2008). Toward a narrative pedagogy for interactive learning environments. *Interactive Learning Environments, 16*(3), 199-213.

Heeter, C. (1992). Being there: The subjective experience of presence. *Presence: Teleoperators and virtual environments, 1*(2), 262-271.

Heimlich, J. E., Sickler, J., Yocco, V., & Storksdieck, M. (2010). Influence of immersion on visitor learning: Maya Skies research report. *Edgewater, MD: NSF, 610253*.

Hickey, D. T., Barab, S. A., Ingram-Goble, A., & Zuiker, S. J. (2008). *First things first: design principles for worthwhile educational videogames.* Paper presented at the Proceedings of the 8th International conference for the learning sciences-Volume 1.

Jacobson, J. (2010). *Digital Dome Versus Desktop Computer in a Learning Game for Religious Architecture.* Paper presented at the AERA.

Jacobson, J. (2012). Interaction Beyond the Desktop. *arvelsig*. Retrieved from arvelsig.wordpress.com/2012/07/19/interaction-beyond-the-desktop/

Jordan, B., & Henderson, A. (1995). Interaction Analysis: Foundations and Practice. *Journal of the Learning Sciences, 4*(1), 39 - 103.

Kafai, Y. B. (2006). Playing and making games for learning. *Games and Culture, 1*(1), 36.

Lantz, E. (2011). Planetarium of the Future. *Curator: The Museum Journal, 54*(3), 293-312.

Lessiter, J., Freeman, J., Keogh, E., & Davidoff, J. (2001). A cross-media presence questionnaire: The ITC-Sense of Presence Inventory. *Presence: Teleoperators & Virtual Environments, 10*(3), 282-297.

Limniou, M., Roberts, D., & Papadopoulos, N. (2008). Full immersive virtual environment CAVE TM in chemistry education. *Computers & Education, 51*(2), 584-593.

Malone, T. W. (1981). Toward a theory of intrinsically motivating instruction. *Cognitive Science, 5*(4), 333-369.

Meehan, M., Insko, B., Whitton, M., & Brooks Jr, F. P. (2002). *Physiological measures of presence in stressful virtual environments*.

National Research Council. (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. In Committee on Conceptual Framework for the New K-12 Science Education Standards, Board on Science Education & Division of Behavioral and Social Sciences and Education (Eds.). Washington DC: The National Academies Press.

Rudolph, J. L. (2005). Epistemology for the masses: The origins of "The Scientific Method" in American schools. *History of Education Quarterly, 45*(3), 341-376.

Schnall, S., Hedge, C., & Weaver, R. (2012). The Immersive Virtual Environment of the digital fulldome: Considerations of relevant psychological processes. *International Journal of Human-Computer Studies*.

Slater, M. (2009). Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1535), 3549-3557.

Slotta, J., & Linn, M. C. (2009). *WISE Science: Web-Based Inquiry in the Classroom*. New York: Teachers College Press.

Solomon, J., Duveen, J., Scot, L., & McCarthy, S. (1992). Teaching about the nature of science through history: Action research in the classroom. *Journal of Research in Science Teaching, 29*(4), 409-421.

Svihla, V., Dahlgren, M., Kvam, N., Bowles, J., & Kniss, J. (2013, 4/27-5/1). *We Can't Just Go Shooting Asteroids Like Space Cowboys: Teaching and Learning with Immersive, Interactive Projection*. AERA. San Francisco, CA.

Svihla, V., & Linn, M. C. (2012). A Design-based Approach to Fostering Understanding of Global Climate Change. *International Journal of Science Education, 34*(5), 651-676.

Waraich, A. (2004). *Using narrative as a motivating device to teach binary arithmetic and logic gates.* Paper presented at the ACM SIGCSE Bulletin.

Waraich, A., & Brna, P. (2008). A narrative centred Informant Design approach for interactive learning environments. *International Journal of Continuing Engineering Education and Life Long Learning, 18*(2), 181-196.

Wilensky, U., & Reisman, K. (2006). Thinking like a wolf, a sheep, or a firefly: Learning biology through constructing and testing computational theories—an embodied modeling approach. *Cognition and Instruction, 24*(2), 171-209.

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence, 7*(3), 225-240.

Wyatt, R. (2005). Planetarium Paradigm Shift *Planetarian: Journal of the International Planetarium Society, 34*(4), 15-18.

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