Awe and Blunder in Science Games

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Abstract: From 2008-2010, the author produced dozens of science education games and interactives at National Geographic's The JASON Project. Created in collaboration with scientists from numerous agencies and universities, these games are currently being played in classrooms across the globe. Many of these games have gone on to win awards and several are currently available for free online. These successes, however, were purchased with fruitful mistakes. This paper presents the most productive failures during those two years and highlights guiding principles that informed more successful subsequent projects. I focus on science games in particular with the hopes of initiating a dialog about issues specific to science games and others relevant to educational game design writ large.

A Collection of Science Games

This is a discussion of lessons learned in developing a portfolio of science education games targeted at middle school age youth designed primarily to be played in formal education settings. These games were developed as part of a standards-aligned science curriculum with The JASON Project, formerly a subsidiary of National Geographic. All of the games discussed in this paper have eventually gone to "market" (free, and online at the time of release) and have been used by teachers and students. All of the games were created in collaboration with a single developer, Filament Games. Some games have gone on to receive industry recognition. While many games continue to be played and used in classrooms, others have not stood the test of time. This paper connects the experiences of the author to theory and research with the goal of documenting and initiating a dialog on best practices in science education game design. I offer the following ideas as evolving theories developed in practice to that dialog.

Narrative-Based Games: Worth the Trouble?

Our first project as a team was to design "Mission 4: Hawaiian Islands" for *Operation: Resilient Planet (*The JASON Project, 2008*)*, an underwater ecology game. "Mission 4" was based entirely on a research expedition by marine ecologist Enric Sala. Dr. Sala's research explores relationships in near-pristine ecosystems off the coast or remote Hawaiian atolls. Sala's research flipped the widely accepted understanding of apex predator and prey relationships on its head (Sala et al., 2005) and provided increased urgency for the maintenance of marine biodiversity. "Mission 4" was unique among existing science video games as it was designed to be an adventure game that walked players through the actions, choices, and arguments that Sala went through in his groundbreaking research. In other words, the game allows students to play out a research paper then in press for publication in *Science*. In this respect the game was successful at telling a story and allowing students to play through a scenario modeling a type of authentic inquiry and scholarship (Chmiel, 2009). Research in other academic areas, such as writing (Dickey, 2006) suggests that 3D environments with game-play driven by narrative provided "a cognitive framework in which players can identify and construct casual patterns which integrate what is known with what is conjectural yet plausible within the context of the story" (p.2).

This is to say that at the individual, student level, this game design had a lot of promise. However, when we move the unit and context of analysis from student to classroom, several drawbacks emerged. A developed narrative with naturally integrated content meant that game play could take anywhere from four-six hours for middle-aged students and likely even longer for younger students. This was difficult for teachers to integrate into the classroom context, where they often have as little as 20 minutes in the course of a week to focus on science content. Many teachers expressed interest in the game, but would point out that their pacing guides address the same standards that the game addresses in a fraction of the time.

Narrative games always present game designers with a challenge to balance story-telling and player agency (Reeve, 2009). Beyond this, narrative driven games require game designers, programmers, and writers to hard-code many of the meaningful and interesting choices (Rollings & Morris, 2000, p. 38). As Schaller suggests, "this approach serves both story and gameplay poorly, as it forces players into increasingly meaningless choices simply to keep the number of story branches manageable" (2011). The problem of managing story branches is especially poignant when creating educational games, which are often done on very small budgets compared to commercial games.

As a narrative, Mission 4 of *Operation: Resilient Planet* did a few things very well. It provided an immersive experience and served as a virtual "field trip" to an exotic biome. It allowed students to walk through the evidence and argumentation of one specific scientist's research project and much of the success of doing this particular game as a narrative likely rests in the fascinating and kid-friendly research conducted by Sala. We were able to document, via game experience, this cutting-edge ecology research at the expense of time (the game took more time than most teachers could allot) and at the expense of authentic choice. We ended up dividing the full game experience into standards-aligned fully playable "mini-game" versions and found great success with these. Mini-games aligned better with the tempo at which teachers needed to hit their learning objectives and also solved the time problem. We also found that on this smaller scale, players' choices seemed more meaningful. In the end, the narrative approach to the game seemed like "more game" than what teachers wanted and what we found sustainable as a non-profit. As we moved on to other curricula, these findings informed our planning.

Working with Specialists

Scientists can lend wonderful expertise to game development. In our game development, we worked with a number of leading scholars and specialists in energy, ecology, and geology. These specialists allowed us to bring cutting edge research findings into our games and brought perspective and rigor to our games that would be otherwise impossible to capture. But it is important for specialists, content writers, artists, game designers, and project managers to work towards a common understanding of the end goal.

Note that most instructional design projects refer to this role as the subject matter expert and I don't do that here quite intentionally. Specialists give unique insight to high-level scientific concepts, but these are often beyond the scope of K-12 learning standards. For this reason, I consider the subject matter expert to be a hybridized role (rarely occupied by one single person) of a science topic specialist and a person with a more generalized background in science education or science curriculum. For this reason I want to be careful to distinguish the person with the advanced science knowledge and the person who can integrate that subject knowledge into the context of school curriculum.

We found that one of the greatest challenges in working with specialists was effectively communicating what they saw as the necessary elements of their field to bring into the game. After all, specialists acquire a very specific way of seeing the world, frequently with complexities and nuances that our untrained eyes miss. Games, on the other hand are, by their nature, models of complex systems which highlight a few complexities in game mechanics and ignore many of the other issues in order to focus attention on particularly significant content elements and relationships. The following were some useful guidelines we developed in working with science specialists in developing games:

1. *Partner with scientists who are actively involved in science communication or outreach.* Specialists with a demonstrated record in working toward public understanding are often sympathetic to the nuances of communicating with a K-12 audience and have cultivated skills in relating to lay audiences.

2. *Be clear about the learning objectives your game is designed to target.* Have these objectives prominently displayed and to keep the conversation on target.

3. *Ask the specialist: What are three things you wished everyone understood about "X"?* Invite the specialist to establish content priorities.

4. *Decide ahead of time which assets, and to what extent, the specialist is part of the feedback cycle.* Build these into the project timeline, allowing specialists an ample timeline to weight in.

5. When soliciting feedback from a specialist, be explicit about what aspects you are looking for which you require feedback (i.e., is the fish anatomy correct? Is the monk seal moving in a realistic manner?) and provide the specialists with copies of learning standards you are seeking to address, to aid them in contextualizing their feedback.

Scientific Explanation, Mechanisms, and Mechanics

A goal of our games was to facilitate student understanding of complex scientific phenomenon and utilize non-game curricular materials to enhance student practice of scientific explanations. Currently, much of what passes as "scientific explanation" in classrooms is more truly scientific description as textbooks and curricula often use stated laws to describe a phenomenon. In other words, to say that a barometer goes down because air pressure has increased is merely a description, not an explanation. Rather, to provide a description of the molecular mechanisms that link the two phenomenon is a true explanation. Rigorous scientific explanations require some examination of mechanism, where by "mechanism" I mean "an *account* of the makeup, behaviour and interrelationship of those processes which are responsible for the regularity [of a scientific phenomenon]" (Pawson & Tilley, 1997).

Games provide a unique opportunity to do this because they can provide on-demand information, or layers of information that are de-coupled in the real world. For example, in teaching kinetic and potential energy, it is common to get students to build a series of ramps and observe the motion of something along these ramps. At The JASON Project, our game *Coaster Creator* (The JASON Project 2009) added an additional layer of algebraic equations on top of the visible phenomenon. Students were able to see the relationships of the algebraic variables in real time with the physical phenomenon. Games such as *Coaster Creator* make visible the causal mechanisms of a scientific phenomenon in a way that is impossible without this toy like digital environment. This emphasis on causal mechanisms is valuable because it allows students practice and take ownership of deeper levels of scientific explanation in the relationship between an equation and their tacit understanding of forces and motion.

To be sure, games in physical science or statistics-ruled aspects of life sciences or science policy lend elegant mechanistic explanations. Here we found opportunities to weld clever game design to mechanic, and these games yielded not only massive amounts of play numbers as part of classroom activities, but noted that many students logged in to play on their own during the evening and even on weekends. Discussions of increasing their scores took place on student discussion boards on the JASON website, as well as external websites such as Yahoo answers (Chmiel, 2012).

Don't Make Navigation A "Thing"

During development of a downloadable3D game in which players primarily piloted a watercraft, designers went back-and-forth over ideas about how to manage controls. A typical convection for this navigation on a PC is to use the W(forward) A(left) S(backward) and D(right) keys. In player testing, we found that students had no trouble with this navigation. Teachers, on the other hand, were frustrated by the WASD navigation. At first, we had a hard time convincing teachers that WASD was not simply a random assignment of characters with no rhyme or reason. In addition to WASD, we required depth navigation to maneuver the craft throughout water. This required additional use of the arrow keys, to be used in conjunction with WASD and various hotkeys to perform key actions. All of this was presented to first time players in an optional in game tutorial that took less than five minutes. With professional development and encouragement, we were able to convert most teachers into WASD believers. However, a small percentage of teachers decided that navigating the 3D environment would simply pose to be too challenging or too time consuming to learn for students and even a brief tutorial took too much time for teachers with little to spare.

This presented us with a dilemma. On the one hand, the 3D underwater graphics were beautiful and allowed for authentic models of marine life. We were able to bring students a real sense "being there" in the Hawaiian Islands. On the other hand, the environment demanded navigation that was unattractive for some teachers. We decided to abandon 3D environments and demanding navigation in subsequent game development and consequently had far better uptake and reception among teachers and students. Those games were developed to be accessible via Flash and allowed us to better standardize welcome screens, basic user-interface style conventions, and in-game tutorial help.

Navigation and usability in games is well documented at the early-childhood level, but there is a dearth of research when it comes to navigation and usability for the older child, particularly in considering limitations of a full classroom of children playing together (Muehrer, Jenson, Friedberg, & Husain, 2012). This is an issue I would like to see the Games, Learning, and Society community pursue in future research as our field continues to mature.

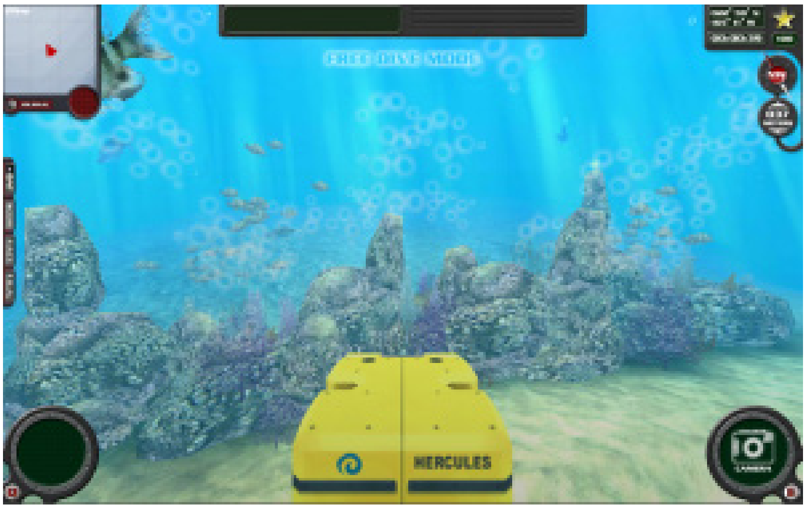

Figure 1: Teachers loved the underwater environment, but many struggled with the navigation.

Embracing the learning standards

Some topics in science are very sexy and seemed ripe for great game play. For instance, blowing up asteroids, settling Titan, Saturn's largest moon, or trying to out-survive other dinosaurs during the Jurassic are all fun ideas this author would love to play, but would not produce in a formal education project. Why? I'll forward the following proposition: If you are looking to develop an educational science game, you have two options 1) develop a game about whatever science topic you want and create a marketing plan around home/ recreational play or 2) consult national and state standards to get a sense of what topics are taught at particular grade levels to specific learning objectives. No matter how fun and rigorous your game about T-Cells is, few middle school students will play it during class-time. That is because immunology is sparse in most school curricula.

Maximizing the appeal of an educational game to teachers and schools helps secure their place in curricula and by securing the place of these games in the school day maximizes students' opportunities to access these games. Games with more specialized themes might be played as part of an after-school program or as an enrichment activity, but fewer students have access to these outlets. Furthermore, Next Generation Science Standards advocate for the same types of practices supported by games such as scientific argumentation (Steinkuehler & Chmiel, 2006). Designers looking to design science games at the K-6 level should also remember that science is often neglected at that level in favor of math and reading standards. These designers would do well to be mindful of The Common Core standards and seek literacy and math applications as part of their learning objectives. Many of these standards specifically call for the application of literacy and math to real life problems and situations. A vital strength of digital-game based learning is its ability to situate children in real-life applications (Gee, 2003) thereby underscoring the unique role games can play in bringing meaning and value to learning standards.

While public education is by no means an equalizer when it comes to digital access, it is the closest thing we have. For this reason, I am a proponent of working closely with teachers and understanding their needs, particularly when it comes to working within the learning standards.

Transgressive Play, Point of View, and Learning Science

Finally, I want to address the role of transgressive play in science games. Good educational game design supports children's desires to break the rules or transgress (Wilson, 2009). Games can do this by intentionally building transgression into the game by, say, inviting them to crash roller coasters or "design" simulated invasive species. Or game developers can design a game that anticipates that children will want to push the game boundaries by, for example, rewarding them with a unique or silly find at the edge of the game world. Considering some of the other pedagogical priorities of science education discussed in this paper such as scientific argumentation, scientific explanation, and the engagement in the practice of science can make these opportunities for transgression rather tricky.

In the case of the crashed roller coaster, the lesson plans surrounding the game promoted engineering practices whereby students married design and mathematical thinking to prevent future crashes, but the transgression design of the invasive species presented us with a dilemma. If a child designs an invasive species, that child may learn a great deal about ecological niches and survival of the fittest for his or her designed species. In *EcoDefenders* (The JASON Project, 2010), we wanted children to have a better understanding of a variety of ecological niches and we also wanted the children to understand how an ecologist comes to ascertain the impact an invasive species has on an environment. As such, the point of view of the invader becomes restrictive and obscures critical learning standards. The player learns *about* science, but the player doesn't *do* science.

For this reason, Ecodefenders was designed so that players were required to shift their point of view from the "first person" of natural selection (embodied as the invasive species) to that of a scientist gathering data about the animal. When the transgression of a game centers on the subject of a learning objective, the game loses its potential as an epistemic frame (Shaffer 2006), and it is this epistemic frame that is at the heart of authentic inquiry (Chinn & Malhotra 2002).

Conclusion

By designing, developing, play-testing and launching as many games in a 3-year span, The JASON Project and their partners Filament Games learned a great deal about producing high-quality, popular, useful and used science games. By enumerating our findings in this paper, it is my hope that the Games, Learning, and Society community can discuss academic-domain specific game design challenges and grow our understanding of the unique design challenges faced when the classroom, not just the individual player, becomes the unit of analysis. Various game mechanics highlight and obscure scientific ways of knowing in different ways. We've only begun to explore the ways in which mechanics and epistemology can work together. In a new era of science standards, there has never been a better time to make the case that digital games can magnify these standards beyond what traditional curricular resources bring to the table.

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