Game Design towards Scientific Literacy

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As global citizens grapple with complex issues such as human impacts on the environment, the need for a scientifically literate public becomes increasingly urgent. This descriptive case study examines the design decisions behind *Operation: Resilient Planet*, a "game for good," and how those decisions reinforce or limit play in the context of fostering scientific literacy. By uniting research from the fields of science education, game design, and situated cognition, I underscore several important elements for mapping specific game design restrictions and mechanics onto authentic scientific inquiry. This paper provides an argument for how game designers can utilize contemporary research in science education and educational psychology with game design literature to make informed design decisions and develop a content-rich game experience requiring players to master certain "habits of mind" that map directly onto standards for scientific literacy.

KEYWORDS: Science Education, Game Design, Socio-Cultural Learning, Game Mechanics

INTRODUCTION

Concern about the character of American science education has been a perennial issue (Schwab, 1962; NCEE, 1989; Martin, Mullis, Gonzales, & Chrostowski, 2004), but current calls for scientific literacy emerge from the recognition that, "science is no longer the specialized activity of a professional elite" (Wilson, 1998, p. 2048). With U.S. Americans increasingly showing a lack of understanding in areas of scientific consensus like climate change (Jakobsson, Mäkitalo, & Säljö, 2009; Kohut, 2009) and evolution (Keeter, 2009), the need for scientific literacy among citizenry becomes increasingly apparent.

Scientific issues influence a variety of core public policy concerns, and a basic understanding of these issues is crucial for civic engagement in a democratic society. Science education must aim to produce students who are prepared to not only "increase economic productivity through the …knowledge…and skills of the scientifically literate person" but also "engage intelligently in public discourse and debate about matters of scientific and technological concern" (Yager, 2006, p. ix).

Many stakeholders in science education fear an apparent disconnect between current teaching methods in science and the habits of mind required to engage with contemporary science (NRC, 1996; NRC, 2000; AAAS, 2009). The etiology of this disconnect was elegantly diagnosed by population geneticist and science education thought leader Joseph Schwab, who wrote many decades ago that most students encounter science as a "rhetoric of conclusions" (Schwab,1978, p.134) in a textbook. Schwab noted that students see the results of years of study, questioning, professional dialog, revision, and argumentation as neat and sterile facts. In other words, the science we hear or read in the news about vaccines, climate, a newly discovered hominid, metabolism of "carbs," etc., is structured very differently from the science we learned in high school where all of our experiments had a predetermined right and wrong answers. Anomalies were "corrected," not pursued or explained.

Science that is current and alive is different from the neat "rhetoric of conclusions" often portrayed in curricula created for school science (Hodgson, 1988; Chinn & Malhotra, 2002). The actual work of scientists doesn't allow for looking up a correct answer in the back of a book. This dissonance between what we might call (for lack of a better term) "textbook science" and "authentic science" is particularly problematic when we consider the nature of scientific issues that arise in the public sphere. Students are rewarded for providing a singular, correct answer at the expense of developing reasoning and evidence-based arguments (Russ, Coffey, Hammer &Hutchinson, 2008). This leaves students unprepared to understand the nature of evolving problems in the public sphere.

Public policy does not take place around "textbook science." Scientific literacy requires an understanding of what science looks like on its way to the textbook. The most pressing scientific issues of our time occur at the frontiers of science: at the height of conceptual uncertainties with anomalous data. The problem with "textbook science" isn't simply that students *aren't learning* science, it's that they are developing overt *misconceptions* about the nature of science. In establishing benchmarks for scientific literacy, the American Association for the Advancement of Science ultimately envisioned an education that would provide citizens with the habits of mind required to make sense of how the natural and designed worlds function, think critically and independently, and deal with problems that involve evidence, patterns, arguments and uncertainties (2009).

PURPOSE AND METHODOLOGY

In this paper, I use a descriptive case study to begin a dialog between disparate disciplines that have only recently begun conversation (Federation of American Scientists, 2006; NRC Division of Behavioral and Social Sciences and Education, 2009). I synthesize the guiding principles of scientific literacy, their implications for instruction, the challenges faced by classrooms attempting to implement such a curriculum, and link these issues to some of the findings in situated cognition (Brown, Collins, & Duguid, 1989). Next, I will examine the unique features particular to video games as instructional tools and integrate some of the overarching ideas from video game design into the domain of scientific literacy. Using a descriptive case study of the game Operation: Resilient Planet (ORP), I argue the unique features of video games, if purposefully designed, are well suited to address the contextualized, process and content rich curriculum associated with "scientific literacy" (AAAS, 2009). ORP is being described as a "game for good" on two levels. First, on a surface level, ORP challenges players to examine evidence demonstrating the serious impact humans make on even the most remote ecosystems. On a deeper level, ORP is a "game for good" in that it incorporates features of scientific literacy directly into its design mechanics, opening the doors for discussion on how game mechanics can advance or limit nuanced learning objectives.

Scientific literacy is something that takes years of deliberate instruction to develop. The best-designed curricular materials, whether they are video games or textbooks, are no substitute for well-trained, knowledgeable teachers. This paper makes no generalization that one well-designed game or a million well-designed games can change the ways science education proceeds in the classroom. Rather, I hope to raise some of the challenges faced in designing any learning environment for authentic inquiry and demonstrate that with appropriate design considerations, games can be uniquely suited to overcome some of these challenges.

CHALLENGES OF TEACHING SCIENTIFIC LITERACY

The most accepted pathway toward scientific literacy in the science education community is to teach a greater understanding of the nature of science (NOS) using inquiry as an instructional method (AAAS, 2009; Lehrer & Schauble 2004; Rudolph, 2005 p.804; Stewart & Rudolph 2001; Yager, 2006). NOS emphasizes science as a complex social activity where scientists work to identify and avoid bias, demand evidence, explain and predict phenomenon, and provide durable information (AAAS, 2009). "Inquiry" is the instructional method that aims to teach content standards in tandem with NOS, in order to engage students in activities cognitively modeled on the work done by scientists. Ideally, this approach towards scientific literacy rejects the notion of one single, universally applicable scientific method taught separately from content. Inquiry exposes students to the understanding that science is a context and community-dependent dialog of questions and evidence.

A number of challenges have been identified in implementing NOS through inquiry in the classroom. Traditional curricular materials offer impoverished understandings of NOS (Abd-El-Khalick & Waters, 2008; Chinn & Malhotra, 2002). Schools lack the time, money, resources, and equipment to develop authentic inquiry experiences (Chinn & Malhotra, 2002) and activities billed as "inquiry" are often straightforward, hands-on, design and engineering problems (Rudolph, 2005). While such task-oriented activities offer important pedagogical benefits, (Roth, 2001; Schneider, Krajcik, Marx, & Soloway, 2002) they do not represent a full or accurate picture of most scientists' work. Rather than designing objects, scientists are more often engaged in the construction of ideas (Rudolph, 2005). Highly constructivist (or "pure discovery") approaches fail at teaching students the discourse and social nature of science (O'loughlin, 1992). Pure discovery or highly exploratory learning environments have been found to be ineffective (Mayer, 2004) with novice learners. Students need to be engaged in the dialog of idea creation, and they need scaffolding into this dialog. Science education needs to provide opportunities for structured arguments, public reasoning to develop claims, and evaluation of those claims using the language of science (Zembal-Saul, 2009).

These recommendations resonate with the theory of situated cognition. Situated cognition posits that knowing cannot be separated from context, culture, and activity (Brown, Collins, & Duguid, 1989; Greeno, 1989). Studies in situated cognition empirically demonstrate that the decontextualized "rhetoric of conclusion" often found in textbook science simply does not transfer into every-day scientific thinking. One of the primary recommendations that emerge from studies in situated cognition is that learners hold "cognitive apprenticeships," (Brown, Collins, & Duguid, 1989) a sort of purposeful coaching by a master who models a cognitive discipline to a novice in a contextually authentic environment. The importance of situated cognition in commercial games has been well documented by Gee (2003), but the implications for designing games for good remains under-theorized.

THE PROMISE OF GAMES FOR GOOD IN SCIENCE EDUCATION

The promise of video games in science education was acknowledged long before the technology was easily accessible to realize such hopes (Ellington, Addinall, & Percival, 1981; Sagan, 1978). Serious efforts investigating video games and their role as tools for science education have only recently been discussed. For instance, persistent multi-player spaces have been found to develop understandings of epidemiology (Kafai, 2008), informal scientific habits of mind (Steinkuhler & Chmiel, 2006) and pro-social values (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005). The multi-user virtual environment River City promotes inquiry and self-efficacy in data gathering (Ketelhut, 2007). There is also an emerging body of work demonstrating the inquiry-like habits developed by students who design and build their own science-based video games (Sheridan, Clark, & Peters, 2009). These groundbreaking projects demonstrate the pedagogical possibilities of games, but they do not delve into specific design principles that can bridge desired cognitive outcomes and game design. The need for such a conversation is clear. During their Edugames Summit, the Federation of American Scientists summarized, "Research is needed to develop a sound understanding of which features of games are important for learning and why, and how to best design educational games to deliver positive learning outcomes" (2006, p.5).

Unlike traditional curricular materials such as textbooks and laboratory exercises, all video games are constrained by video game "mechanics". Video game mechanics are sets of rules that bind play, provide the foundation of the game, and make the game play experience at once enjoyable and challenging. Understanding video games as science curricula requires a specialized understanding that straddles a mastery of problems in science education and video game design.

Defining Game Mechanics

Game mechanics are the elements that are unique to games as a media. The mechanics of a game are what give the game interactivity; the designed features which allow the player to play the game. Game mechanics are frequently understood as the rules of the game. (See Prensky, 2001; Salen & Zimmerman, 2004). Salen and Zimmerman describe mechanics as the "systems of emergence, uncertainty, information, feedback, decision making, and conflict" which create play in games (p.124). Salen and Zimmerman focus on the way in which game rules limit player action in a fixed and repeatable fashion. It is also important to consider mechanics as a component of game genre. Focusing primarily on rules isolates that component from the interconnected set of issues embedded in decisions about what mechanics are viable in a given context. In commercial game design, genres provide broad frameworks for game development and serve an important role in setting player expectations for game play. Coming from a commercial game design perspective, Novak defines genres as "categories based on a combination of subject matter, setting, screen presentation/format, player perspective, and game-playing strategies" (2005, p.85). While genre is a broader category in game design than mechanics, discussions of genre illuminate critical elements for understanding mechanics. As Foster and Mishra have noted, different game genres support different learning objectives, for example role-playing games provide better scaffolding for identity development than puzzle games (2009). Most importantly, game players' experiences with specific game mechanics in specific game genres give players a clear set of expectations about the relationship between game mechanics and content. Those expectations are important considerations for deciding which mechanics are the best fit for different goals.

Gredler, an educational psychologist, offers another useful lens for examining mechanics by framing them as surface structures and deep structures (Gredler, 1994). The surface components are understood as the basic activities in which the player engages. For example, eating up dots, avoiding ghosts, acquiring points, moving to new levels, and the space of the maze are surface structures of Pac Man. For Gredler, the deep structure of the game is the overarching cognitive and social interaction the game requires. Gredler proposed that educational games should reinforce behavior that leads to mastery of the concepts at the core of learning objectives (Gredler, 1994).

Mechanics are both the descriptions of the individual features surrounding player action as well as the deeper cognitive work, which supports the overall argument of a given game. Through this understanding of game mechanics and genre, we can see that authentic scientific inquiry can be understood as having its own sets of mechanics. The challenge is to map the inquiry mechanics onto game mechanics in a meaningful way.

DESCRIPTIVE CASE STUDY: DESIGNING FOR INQUIRY

A detailed investigation of the design challenges and resulting decisions of The JASON Project's ORP game allows us to fold together many of these concepts from science education, situated cognition, and game design. ORP is beginning to receive attention as an exemplar in science education (Clark, 2009; Squire, 2009). ORP was developed as part of the ecology curriculum for The JASON Project, a 20-year old organization that focuses on bringing the work of scientists and explorers to middle school students. Funded by the Kauffman Foundation, ORP is a free, downloadable, 3-dimensional game available from The JASON Project website (www.jason.org). For the past three years, The JASON Project, a nonprofit subsidiary of the National Geographic Society, has been developing digital labs and science games in accordance with best practices for classroom-ready games based learning (Wilson, 2009). The JASON Project's curriculum presents standards-based middle school science content from the perspective of current scientific research being performed by scientists from any number of JASON partner organizations. In ORP, students accompany marine ecologist Enric Sala on his research in remote Pacific reefs and atolls as they reconstruct his investigations into the dynamics of apex predators and local food webs (Bascompte Melián & Sala, 2005). The specific game design challenge was to deliver an experience in which middle schoolers would be engaged in a virtual cognitive apprenticeship with a scientist working on the cutting edge of marine ecology. We wanted to design a game that would be approachable to students with a variety of previous video-game play experience and attractive to teachers with little gaming experience and concerned with teaching a standards-based curriculum.

From a genre perspective, ORP is most accurately characterized as an adventure game. Adventure games are story driven and require players to solve puzzles and overcome cognitive challenges, as opposed to physical ones (i.e., fighting, shooting) (Rollings & Adams, 2006). ORP uses a narrative structure situated in a 3-dimensional environment (Figure 1). The narrative is connected by mini-games (the puzzle-components of an adventure game) that simulate gathering evidence and are attached to a platform for scientific argumentation. The advantage of this genre is that the narrative component "tells the story" of a scientist's actual research agenda. It serves as the surface structure for the game play and provides the content components of inquiry: navigating the deep ocean; locating endangered monk seals; and counting tiger sharks. The mini-games, or puzzle components of the adventure game, provide opportunities for building in the deep structures of the game as the process components of authentic inquiry: evaluating data; supporting a hypothesis; and reconciling anomalous or unexpected findings. Both scientific process and content were central to the game design. Furthermore, both the content and process are presented in the context of a greater research agenda whereby process and content are not learned for their own sake, but as tools employed by scientists to investigate and probe greater questions and wider concerns as part of ongoing scientific discourse.

***Figure 1.* A View of Marine Life as Seen from the Game's 3D Underwater Environment**

There are, of course, limitations to this approach. Closely following Sala's research trajectory means that the possibilities for independent exploration are somewhat constrained. As players retrace Sala's research, they can veer off and explore the 3D underwater game world. They are rewarded for doing so with extra points hidden away in the far corners of the map. Players also acquire points for photographing and identifying each of the species of aquatic life in the environment (Figure 2). Players have the freedom to choose whether they want to first explore what is happening with the seal population or the shark population. However, players do not have the ability to develop a research agenda outside of the process involved in understanding the research question Sala has presented to them. The design team decided to use this constraint to guide the players through the overall narrative of Sala's research trajectory. While more open-ended game structure might provide players with more freedom, this is not necessarily an asset (Gee, 2003, p.113). It would be difficult to ensure that players gain an understanding of the scientific process through the legitimate peripheral participation model (Lave & Wenger, 1991) where the students conduct and explore the existing research questions using scientifically sound methodologies. Furthermore, a solid structure to the game facilitates the creation and use of accompanying paper-and-pencil assessments, which facilitate the integration of the game into the classroom curriculum (Wilson, 2009, p.15).

***Figure 2.* Photographing Reef Fish from the Remote Operated Vehicle (ROV)**

A SCIENTIFIC DIALOG

As the player enters the game world she meets Enric Sala, the marine ecologist whose research trajectory she will recreate. Sala uses his research to scaffold the player through an authentic inquiry experience inspired by his own work. Sala briefs the player on the situation: The population of the endangered Hawaiian monk seals is dangerously low, but the population of a different predator, the tiger shark, is quite high in the Papahānaumokuākea Marine National Monument. A reputable (alas, fictional) scientist named Dr. Cull believes that the sharks are over-feeding on seals and has recommended opening the waters for shark hunting in an attempt to bring a balance to the region. Dr. Cull is used to represent a popular interpretation of the problem. Sala, however, cautions the player against this extreme solution and advocates the player join him in approaching the proposal with skepticism. This skepticism sets the stage for the investigation that directs the game play.

Observations and Theory-laden Methods

Sala establishes his reluctance to accept Cull's recommendation without evaluating the evidence. This sets the over-arching goal of the game (is Cull's recommendation a good one?) and starts the player on her quest of mini-games to evaluate Cull's recommendation. The player begins by selecting a research trajectory to either better understand the area's sharks or seals. If she chooses to explore the shark research trajectory, she starts with a mini-game identifying tiger sharks in the area by collecting photos from her underwater remote operated vehicle (ROV). In the next mini-game, she sneaks around the reef to tag and recapture some of the tiger sharks to gather an accurate population count. Since the mini-games re-enact segments of a research agenda, they introduce students to the methods scientists use to obtain data. As identified by Chinn and Malhotra (2002), an important epistemological feature of science is the "theory-ladenness of methods" (p. 187). That is to say that methods employed by scientists are driven by theory, a feature absent in the simple inquiry or simple illustrations frequently found in textbook science curriculum.

For instance, as Sala informs players, the tag-capture-and recapture method of population estimation is used primarily for large animals with a large range but the method has its drawbacks for different types of organisms. Later in the game, players perform several population studies on different animals, and use different population count methods accordingly. This demonstrates a theory-practice-theory loop that is essential to science but often overlooked in “textbook science”. Scientific instruments and methods are built on theories. For instance, a mercury thermometer is built on the idea that heat accompanies accelerating atomic motion that causes mercury to expand. Radiometric dating is based on the assumption that organisms take in carbon atoms while they are alive, and a certain percentage of those carbon atoms will radioactively decay. The variety of theory-laden population count methods demonstrates this theory-practice-theory loop. Likewise, the shark stomach-contents analysis method comes from a theoretical perspective that discourages scientists from making an imprint on the ecosystem she is studying. Thus, rather than use a more traditional approach of performing a shark autopsy, some scientists choose the more ecologically conservative and humane approach of inducing the shark to vomit.

Another important piece of the mini-games is their integration with an “argument constructor For instance, in the shark stomach analysis mini-game, the player is confronted with the shark hoisted above the water on the side of her ship, where she needs to place a hose into the shark's mouth to induce vomiting. The resulting vomit is displayed across the player's screen (Figure 3). The player is prompted to identify the contents of the shark's stomach (Figure 4). Each correct identification from a menu of organisms results in the player receiving a star. If the player incorrectly identifies an item in the shark’s vomit, they have the ability to try again, without receiving a star. Each of these mini-games can be replayed again if the player misses a star to increase her overall game score.

***Figure 3*. Players Identify the Contents of a Tiger Shark’s Stomach**

***Figure 4*. The Player Then Identifies the Contents of the Shark’s Stomach from a List of Creatures in the Area**

The example of the shark’s stomach content analysis game is illustrative of the general decisions that guided the data-gathering mini-games. In each case we worked to translate the actual practice scientists engage in, into surface structures that involve calculating populations, identifying, and otherwise observing marine life using the same theory-laden methods employed by marine ecologists. On one level, these mini-games provide opportunities for authentic inquiry that are otherwise impossible to recreate in classroom lab experiences. At the same time, the mini-games are anchored in the standards-based needs of school science. It is not uncommon for students to examine the diet of an apex predator, for instance, by dissecting an owl pellet, or simulate an animal population count using candy scattered in a school prairie. However, in the game environment, each of those individual lab activities serves a purpose in a research agenda. This again models science in a more authentic fashion. Contemporary scientists don't examine animal's stomach contents "just because", they do so as part of a bigger research question. Stomach contents are examined to gather evidence to point them towards asking the right set of questions geared toward addressing a larger question, as part of a dialog with a larger community.

Translating Observations into Data

After performing the tasks in the mini-games, the player receives a "data item": an item that translates her observations into data. Upon receiving several data items, the player engages in a dialog with Sala to explore the research implications of their observations in the mini-game in a part of the game we have dubbed the "argument constructor". These dialogs with Sala serve to demonstrate the role of data in scientific argumentation while modeling the skeptical habits of mind that are key to scientific literacy. The argument constructor was inspired by the Capcom game Phoenix Wright: Ace Attorney for the Nintendo DS. In both games, players make claims, support those claims with discrete pieces of evidence they have acquired, and support their reasoning through answering follow up questions. The metaphor of an argument constructor provides a tangible interface focusing on the building of ideas and thus preventing us from falling into the common trap of making science appear overtly focused on engineering-type work (Rudolph, 2005). To customize this mechanic for robust scientific argumentation, ORP designers assigned an algorithm for each of the arguments and data pieces so that the game provides feedback evaluating the player's arguments as "perfect", "strong", "weak", and "confused". Sala asks the player to evaluate the data (Figure 5) and use the evidence to further inform the research agenda (Figure 6). The argument constructor provides targeted feedback and provides an interface for making scientific reasoning visible and public (Bell & Linn, 2000) (Figures 7 and 8).

***Figure 5*. This image of the Argument Constructor Shows the Player about to Suggest that according to the Data, Tiger Sharks Eat More Reef Fish than Monk Seals**

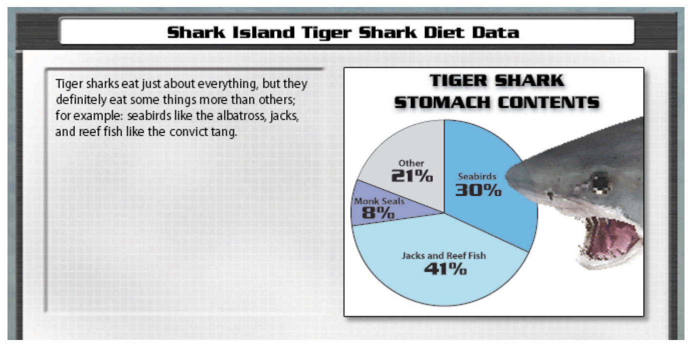

***Figure 6*. A Pie Chart the Player Constructed from Her Analysis of the Sharks' Stomach Contents**

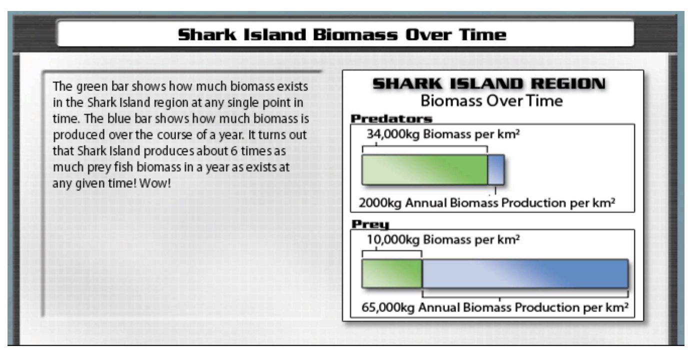

***Figure 7*. The Shark Island Biomass Data is Synthesized from Multiple Data Sources**

***Figure 8*. The Player is Using Shark Island Biomass Data to Argue that Shark Island Has Considerably More Bottom Level Biomass than Tabuaeran Atoll. This Indicates a Healthy, Pristine, Ecosystem**

After gathering a wide range of data about tiger sharks and monk seals, the player enters the final round of argumentation with Sala. Marshaling the full range of the data players have gathered, Sala scaffolds the player into the discovery he made a few years ago. Sala points out some of the anomalous data they have gathered, and guides the player into an analysis of this data. While the shark populations are very high, the data suggests that this is actually an indicator of a particularly healthy ecosystem. Sala's research shows that apex predator biomass (total population x average adult mass of organisms) is greater in ecosystems with fewer humans (Figures 9 and 10). These ecosystems contain a greater overall biodiversity. Sharks keep the ecosystem healthy because they eat so many reef fish, that the overall reef fish population is very young and very small. Smaller fish eat less coral. Thus, the coral is not over-eaten. Additionally, players learn that monk seals and tiger sharks have healthfully co-existed for 40 million years. Human impact may have been the factor that threw the monk seal population off-balance in other areas. Contrary to Dr. Cull's recommendations, killing the sharks would only hurt the fragile balance which nature has developed in this marine sanctuary.

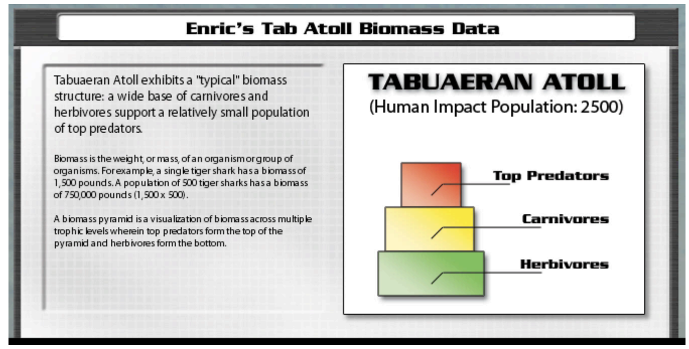

***Figure 9*. Sala Provides this Data on Nearby Tabuaeran Atoll.**

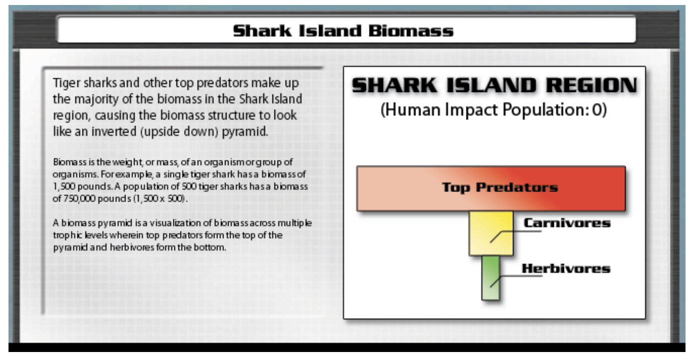

***Figure 10*. The Player Creates the Shark Island Region Biomass Pyramid by Combining Her Observations of Sharks, Reef Fish, and Monk Seals. She then Uses this Combined Data in Later Arguments.**

DISCUSSION

Genres and game mechanics will have implications for how they can or cannot foster scientific literacy and these implications must be explored in order to fulfill the call for research set out by the Federation of American Scientists. One notable caution moving forward is to understand that according to the best practices outlined by organizations such as the National Research Council and the American Association for the Advancement of Science (and the state standards influenced by these organizations) as well as what we know from the situated cognition body of literature, the cure for didactic science instruction is not overly constructivist, open-ended game environments. Alone, such games cannot address some of the most challenging cognitive requirements attached to scientific literacy. To neglect the role of contextualized scientific work recapitulates the misconceptions of past science curricular materials. Games have a chance to do something new, and students need the language and context of real scientific work in order to learn the dialog of science literacy. After examining some of the design-decisions that went into ORP, some of the primary lessons learned include:

1) Because of the narrative-puzzle mix, adventure genres are particularly useful for integrating and balancing content and process learning objectives. This balance of process and content can be difficult to achieve in designing learning activities for authentic inquiry. The apparent interplay of surface and deep game structures in adventure games help mitigates some of this difficulty.
2) Adventure genres, by nature, will restrict the degree of open-endedness of a game. This is an asset or limitation depending upon the individual learning objectives, envisioned usage, and cognitive theory guiding game development.
3) The interactive, visual nature of video games allows them to capture some of the work of scientists that might otherwise be challenging to make tangible. In particular, the notion that scientists construct ideas and arguments.
4) Because place, context, and story are so important to adventure games, not all science can realistically be translated in this format. Ecology, especially when it takes place in remote, tropical oceans, creates an engaging backdrop for a 3-dimensional adventure game.

CONCLUSION

The core design elements of ORP presented in this paper are consistent with the principles of scientific literacy as well as the prescriptions for learning from situated cognition. Scientific literacy asks that students prioritize argumentation and evaluation over experimentation and exploration (NRC, 2000) using the language of science (Lemke, 1990). A model of situated cognition provides us with a clear understanding that through cognitive apprenticeships and legitimate peripheral participation, students can be scaffolded into such a discourse. Some of the key implications for designing educational science games are that: 1) there is a limit to how "open-ended" the game can be if it is to facilitate a cognitive apprenticeship, 2) players need to engage in cognitive apprenticeships in order to understand how scientist might approach encountered problems, 3) a mechanism must be in place to facilitate argumentation and evaluation, and 4) core content and the language of science need to be central to the game's story arc. Students need purposeful, deliberate opportunities to engage with scientific subject matter from the point of view of scientists.

ORP is a "game for good" in that its surface structures address issues of ecological responsibility, while its deeper structures help target issues of scientific literacy that may be challenging to achieve in the typical classroom. As we consider game mechanics that foster science learning principles, the literature from science education and situated cognition should serve as guideposts. While there are many game mechanics to consider, some offer more hospitable templates towards scientific literacy than others. We cannot imagine the science policy arguments waiting for our children and future generations, so we owe them the insights from the greatest scientific imaginations of our own generation. Video games can offer engaging yet authentic contexts in which students can apprentice scientists as they work through today's most pressing problems and engage students in a discourse towards scientific literacy that can prepare them for a lifetime.

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