Abstract
During the summer of 2012, The Field Museum of Natural History (FMNH) began a collaborative project with the University of Wisconsin - Stout in order to analyze the effectiveness of the museum’s WhyReef program. WhyReef, an online, socially interactive coral reef simulation designed for youth ages 8-16, launched in March 2009 and has since reached over 160,000 unique players. The overall goal of this research project was to analyze the educational effectiveness of WhyReef. This was accomplished by a robust evaluation and analysis of WhyReef's learning goals and gameplay mechanics. The research was made possible by a data set of player content and statistics provided by FMNH, as well as a personal trip to the museum to interview the WhyReef educational team. Research was divided into three topics and determined that 1. WhyReef is very successful in increasing coral reef attention and appreciation; 2. The best time to launch attention-grabbing, critical events is on weekdays during the summer; 3. Meaningful Motion is a key gameplay mechanic for increasing WhyReef participation and comprehension. The analysis of the WhyReef data set provided valuable feedback to the WhyReef development team, as well as opened the door for continued collaboration between FMNH and UW-Stout. Research findings were presented to the WhyReef educational team at The Field Museum and at the Games Learning Society 9.0 conference in Madison, Wisconsin. Keywords: WhyReef, educational games, meaningful motion, GLS conference

Purpose
WhyReef is a virtual, interactive coral reef simulation housed within Whyville.net that launched on March 30, 2009. It is
accessible for free by anyone using a computer with internet access. The WhyReef project enables students to learn about the many diverse species living within coral reefs as well as the scientific processes that are required to understand and conserve these reef ecosystems. The educational gameplay and design elements of WhyReef, coupled with its online, social architecture, make it a prime example of successfully combining educational and entertainment aspects in a video game.

The WhyReef project is made possible by a collaboration between The Field Museum of Natural History (FMNH) in Chicago, Illinois, and the learning-based virtual world developer Numedeon, Inc. in Pasadena, California. Numedeon created Whyville.net in 1999. Since then more than 5 million registered users have accessed Whyville (Numedeon, Inc., 2012), with over 160,000 unique users visiting WhyReef. The FMNH continues to regulate WhyReef and institute changes and events in pursuit of their program and learning goals. These goals include awareness of conservation biology, ecosystem ecology, stewardship and management, and science literacy (Babcock & Aronowsky, 2010, p. 3).

Before development of WhyReef began, high priority was given to a list of thirty learning goals stemming from these four broad educational goals. These goals are brought to life within WhyReef through the use of coral reef videos, graphs, forums, encyclopedia entries, three educational games, and more. The Mini Food Web Game tasks players with completing fifteen food web chains focusing on various coral reef animal and plant life. The Reef Simulator allows players to observe disturbances in coral reef biology over time by analyzing graphs, from which hypotheses may be formed as to the cause of the changes. WhyReef’s most popular game, the reef counter, sees players moving their avatars around a virtual coral reef in order to count the diverse species of plant and animal life present on the reef. Throughout all three of these games both Numedeon and the FMNH strove to find an optimal balance between online gameplay and scientific authenticity.

Following several successful years, the FMNH wished to examine what aspects of WhyReef made the program so successful (Babcock & Aronowsky, 2010, p. 3). This led to the formation of a collaborative effort between The Field Museum of Natural History and UW-Stout. The FMNH supplied a data set
containing selected WhyReef user statistics, writings, and digital media created by some of the over 140,000 unique users that visited WhyReef between March 30, 2009 and May 5, 2011. In September of 2009 the FMNH also conducted the Kids Advisory Council (KAC). Consisting of a group of on-site and off-site youth ages 10-14, the council aimed to better understand how content knowledge is acquired by youth through a virtual world and how this is supplemented by real interaction with specimens at The Field Museum. The data set supplied by the FMNH includes a wealth of first-hand data gathered during the KAC, as well as kid-produced videos showcasing what they have learned.

In addition, this author interviewed key members of the WhyReef educational design team and took a tour of the museum’s fish collections to better understand the goals and implementation of the WhyReef project. Witnessing the fish collections that influenced the appearance and behavior of the organisms appearing in WhyReef was very helpful in understanding the scientific authenticity of the game. Asking design and gameplay-related questions of the WhyReef team helped the author understand educational and gameplay aspects included within WhyReef.

Having thoroughly explored WhyReef and examined the data set supplied by the FMNH, this author focused efforts on answering three research questions that he felt would provide the best feedback for the WhyReef educational team at The Field Museum. These research questions came to be: 1. What gameplay elements and information increase WhyReef user participation and comprehension? 2. How do the WhyReef program goals align with Whyville’s virtual world interface? 3. Does social activism increase during critical events, such as WhyReef’s “Save The Reef” events?

Research Question #1 – Game Design

What gameplay elements and information increase WhyReef user participation and comprehension? This research question allowed the author to blend his personal and classroom experience in game design with the social, online world created by WhyReef. The author strove to center game design recommendations upon a single aspect that would boost WhyReef user participation and comprehension the most: meaningful motion.
Objects that move present a sense of significance to the player. These objects may be interactive objects (ex. icon to click to start a game) or objects that will give the player valuable information (ex. moving textbox with directions). However, motion must not be wasted. Limited resources in an online, browser based game such as WhyReef are not allocated to objects that have no significance to the player. This type of game is not one that wants to make the young target audience guess what is important. WhyReef is a scientific, educational game that aims to inspire the player to learn about and conserve coral reefs. This can be done in a timely, efficient manner that will capture and keep the player’s attention through the use of meaningful motion.

Meaningful motion is defined as motion that grabs the player’s attention and supplies clues as to what should be focused upon. Used effectively, this will enhance the scientific accuracy discussed by Aronowsky et al (2010), increasing player comprehension and scientific inquiry. There are two kinds of meaningful motion: physical and implied. Physical motion can be seen in the WhyReef hub world. This central area describes the different areas and games within WhyReef, allowing players to navigate their avatars between them. An animated graph icon signals to players that clicking on this will likely result in analyzing changes in a graph. This motion is meaningful to players. It is also positioned right next to the focal point created by the implied motion of Mark’s waving hand. Mark, a marine biologist at The Field Museum of Natural History, welcomes newcomers to WhyReef. He is one of the first things players notice when entering WhyReef. Mark’s hand does not move, yet the player’s attention is drawn by the implied motion created by Mark’s hand.

The most effective use of meaningful motion within WhyReef can be seen in action within the virtual coral reef that serves as home for the popular reef counter game. The flagship game of WhyReef tasks players with counting fish, mammals, plants, and other coral reef life within a lifelike 2D replica of a tropical coral reef (Figure 1). Animal and plant life move and behave in a manner that reflects their real-life behavior, such as clown anemone fish darting in and out of their sea anemone homes. This immediately grabs players’ attention and keeps it, as players attempt to fill their reef journal by using what they have learned about the commonly appearing species to find and count the rarer species.
A clever combination of physical and implied motion is the key to steering players’ attention toward the most important topics within WhyReef. However, this must be done conservatively, as the effect of meaningful motion is reduced if an excessive amount of motion is onscreen at any one time. This limit will differ with the application, but the concept can be easily visualized by thinking of focusing on one fish in a fast moving school of fish. It would be rather easy to focus upon a lone fast moving fish, but once the number reaches the hundreds the task becomes nearly impossible. As a result of WhyReef’s reef counter game employed meaningful motion, leading to thousands of players have counting millions of plants and animals since WhyReef launched in 2009. By expanding this concept to the other games within WhyReef, or even the whole of Whyville, one would see a similar increase in player participation and comprehension.

**Research Question #2 – Program Goals**

How do the WhyReef program goals align with Whyville’s virtual world interface? This research question stems from the need for an understanding of how well the WhyReef program goals aligned with the way they were implemented, namely through an online, social game environment. Qualitative analysis was used to code the WhyReef user data to the set of
thirty WhyReef learning goals, as listed in the WhyReef Final Report (2010). The coding process is one common to many analysis efforts that draw from qualitative data (Zheng, Spires, & Meluso, 2011, p. 194), and is described as using one’s own educated judgment to determine if criteria are met (Figure 2). In this case, the criteria were whether or not a player-written article demonstrated understanding of each individual WhyReef learning goal. These articles were submitted for publication in the Whyville Times, an online newsletter that is sent to Whyville players on a weekly basis. These WhyReef articles ranged from simple two-sentence statements of support for WhyReef to multipage submissions that went into great detail on how best to conserve WhyReef and real life coral reefs.

By closely coding these 85 player-written articles and examining the Kids Advisory Council results, an understanding of how well WhyReef accomplished its educational goals was attained (Figure 3). These results indicate that WhyReef is successful in increasing coral reef attention and appreciation among its players. This was evident by the high involvement and successful survey results of the Kids Advisory Council members, part of which showed that 94% of members thought coral reefs were either beautiful or interesting. Furthermore, player-written articles showed a high tendency to demonstrate WhyReef learning goals, such as “feel positive about reefs” (95% of articles) and “feel reefs are important” (99% of articles). However, the results show that Whyville could improve upon its delivery of
scientific knowledge. This was demonstrated by inconsistent Kids Advisory Council survey results, such as knowing which trophic level has the highest population (33% of members). Player-written articles also demonstrated low understanding of such WhyReef learning goals as “understand how to read a graph” (4% of articles) and “know what a hypothesis is” (0% of articles).

![WhyReef Program Goals vs. Article Occurrence - All 85 Articles](image)

**Figure 3:** WhyReef program goal occurrence in 85 player-written articles

**Research Question #3 – Social Activism**

Does social activism increase during critical events, such as WhyReef’s “Save The Reef” events? Quantitative analysis was used to determine if social activism, demonstrated by the level of player interest and involvement, increased as a result of critical events. The critical events examined were WhyReef’s “Save The Reef” events. During these events, perturbations were introduced to the virtual coral reefs housed within WhyReef. Players responded to such dangers as overfishing and coral bleaching by wearing special virtual clothing, donating virtual currency, creating management plans, and spreading the word among their peers. Over time their efforts would lead to a healthier coral reef, in which the frequency of plant and animal species would return to a normal, balanced level.

The WhyReef data set supplied detailed records on the number of unique player visits to WhyReef during days on which a critical event was occurring, as well as on normal days when no critical
event was taking place. These numbers were grouped to show the apparent increase in player participation during the summer months. SPSS statistical analysis software (SPSS, 2012) was used to run independent samples t-tests in order to assess any significance (< .05) between the daily average players on normal days versus critical days (Figure 4). A significant difference indicates that there is a decrease in the number of players on that critical day of the week. These tests were conducted for all days of the week, with a significant difference evident on Friday (.021), Saturday (.018), Sunday (.022), and on Tuesday (.047) as shown in (Figure 5).

![Significance Level of “Normal” Day of Week vs. respective “Critical” Day of Week](image)

**Figure 4:** Significance level of “normal” vs. “critical” days of the week.

![Initial Days (with high visits) Excluded for More Focused Analysis](image)

**Figure 5:** Number of unique players on “normal” days vs. “critical days” (bold)
Summer months produced the highest unique WhyReef player visits, particularly on weekdays. This demonstrates strong evidence supporting the timing of critical events on weekdays during the summer, helping to answer questions for further research posed by the WhyReef Final Report (Babcock & Aronowsky, 2010). There is no concrete answer for why summer weekdays generated more player participation than summer weekends. One possible explanation is that this is the time when parents are away at work and children are left at home with WhyReef only a quick click away.

Limitations
The primary limitation of this research was the scope of the WhyReef data set supplied by the FMNH. The roughly two year timeframe (March 2009 – May 2011) and specific topics that the data set covered only afforded analysis based upon the included data. While this data was enough to draw conclusions from, more data would allow for further investigation into the educational effectiveness of WhyReef.

Another limitation was the fact that it is impossible to know the exact set of external variables that are impacting players. Do children play WhyReef because they are already interested in coral reef science? Is the information players communicate on forums and surveys learned from playing within WhyReef, or is it knowledge the players already had? Access to WhyReef itself is an issue, as it requires a PC (or similarly powerful device) and an internet connection to play. This limits the amount and type of players that have the potential to learn from WhyReef, as children in poverty-stricken areas may not have easy access to the internet.

Limitations were also imposed by the objective of this research, namely to analyze the educational effectiveness of WhyReef and recommend improvements from a game design perspective. This allowed for effectively narrowing the scope of this research, but limited the findings that could result from looking at these specific aspects of the WhyReef data set.

Conclusions
WhyReef, the online, socially interactive coral reef simulation designed for youth ages 8-16, led to the formation of a collaborative research project between UW-Stout and The
Field Museum of Chicago. Coding techniques used in a similar gameplay study (Zheng et al, 2011) were applied to the WhyReef data set to code 85 player-written articles, determining that WhyReef is successful in increasing coral reef attention and appreciation among its players. This was shown by player-written articles demonstrating learning goals, such as “feel reefs are important” (99% of articles), and Kids Advisory Council survey results, such as 94% of members thinking coral reefs were either beautiful or interesting. However, WhyReef could improve upon its delivery of scientific knowledge. This was shown by a lack of player-written articles demonstrating certain learning goals, such as “knowing what a hypothesis is” (0% of articles), and inconsistent Kids Advisory Council survey results, such as knowing which trophic level has the highest population (33% of members).

SPSS statistical analysis indicated that the optimal time to conduct critical “Save The Reef” events is on weekdays during the summer months. Tests were conducted for all days of the week, showing a statistically significant difference calculated on Friday (.021), Saturday (.018), Sunday (.022), and on Tuesday (.047). These statistics draw from the raw data contained within the WhyReef data set in order to answer further research questions posed by the WhyReef Final Report (Babcock & Aronowsky, 2010).

In addition, WhyReef’s gameplay mechanics may be improved through the use of meaningful motion. This game design mechanic grabs the player’s attention and supplies clues as to what should be focused upon. Adding more meaningful motion will enhance the scientific accuracy discussed by Aronowsky et al. (2010), increasing player comprehension and scientific inquiry.

**Recommendations**

While this research targeted the educational effectiveness of WhyReef, there are many further studies that may be conducted to expand upon these findings or investigate different aspects of WhyReef. The WhyReef data set may be analyzed within a different context, such as determining more details about the external variables that shaped the data seen within the set. The player-created content may be investigated from a different point of view in order to see if the success of WhyReef is in fact
due to its game design and scientific authenticity, or if other significant factors are at play. The social aspect of WhyReef itself may be investigated to determine what extent playing with friends has on the educational experience that WhyReef provides.

Expanding beyond the data set, a worthwhile endeavor would be to add more meaningful motion to WhyReef, collect data over several months, and then analyze whether or not this motion increased player participation and comprehension. Furthermore, increasing the amount of interaction between players and the FMNH on the forums and directly within the game would generate new data. This data could then be used to determine, for example, whether the lessons learned during the Save The Reef critical events have been retained by players, or if the engagement was brought about more by the excitement of new content.

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**References**


WhyReefEducatorGuide.pdf

