# Mission HydroSci: A Progress Report on a Transformational Role Playing Game for Science Learning

Extended Abstract

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## ABSTRACT

Mission HydroSci is a game-based 3D virtual environment for enacting transformational role-playing for middle school science students. Student-players will be engaged in a narrative about needing to investigate water resources and use scientific argumentation to complete missions critical to the survival and accomplishments of the members of their scientific enterprise. Our poster presents our progress in years 1 and 2 of a funded project to integrate pedagogical and gameplay objectives, and build mechanisms for purposeful player engagement and activity.

## CCS CONCEPTS

Human-centered computing~User interface programming

## KEYWORDS

games for a purpose, science learning, scientific argumentation, transformational play, 3D virtual learning environments

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## 1 INTRODUCTION

Engagement with core ideas of science and undertaking important practices of science are key parts of the vision for science teaching and learning in the *Next Generation Science Standards (NGSS)* [9]. Meeting these new science education goals requires rich learning contexts for exploring substantive science ideas through engagement in scientific practices. In Mission HydroSci (MHS) [5] students learn key concepts and knowledge of water systems and build competencies in scientific argumentation by applying their new knowledge to decision-making and problem solving. MHS is being developed for middle school science as a replacement unit of about 6 to 8 hours of instructional time. MHS is being developed in Unity and includes narrative-based game play, learning progressions for water systems science and scientific argumentation, a teacher support system, and learning analytics.

A review [8] of the role of games and simulation in science education suggests that *"Simulation and games have potential to advance multiple science learning goals, including motivation to learn science, conceptual understanding, science process skills, understanding of the nature of science, scientific discourse and argumentation, and identification with science and science learning."* (p. 54). In short, the potential of game-based learning aligns well with the NGSS. Although the research base is limited, some progress has been made in the design and development of games in science education. Learning systems, such as Quest Atlantis [1], River City [3], Mission Biotech [11] and EcoMuve

[6] show potential for virtual learning environments with game-like features to engage students and support learning.

Transformational play [1] includes the student taking a role (playing a protagonist) who must use subject matter knowledge to make decisions and take action during play. These actions and decisions transform the problem-based situation. In turn, the student's understanding of the subject matter and identity is transformed through the process of game play. Our vision for a game-based learning environment for water systems and scientific argumentation is unique from most other 3D virtual learning efforts. Among a variety of distinctions, two are noted here. First, we plan to employ Learning Analytics to create an adaptive system for student learning and assessment and provide monitoring and awareness for teachers. We will develop analytics that focus on tracking individuals' specific choices, then analyzing those discrete choices against a backdrop of learning outcomes and argumentation competencies; thus assessment is built into playing the game**.** Second, teachers need support to be effective in teaching in online environments. In addition to traditional teacher support materials helping orient and providing practice for the new elements of the teaching role, we plan a dashboard to visualize student activity and progress. The dashboard for visualizing student activity will be designed from a performance support framework to optimize acting upon insights such as recognizing when a student is falling behind and adding an additional support to the next lesson to help structure the activity for the student.

In the proposals we wrote for funding support, we provided a systematic plan based on our prior work, knowledge of prior work by others, and our interpretation of best practices for curriculum design, learning systems design and 3D game development. Once a unit of game play was developed we described an iterative plan for how it would be tested including (1) usability testing to assess interface decisions and engagement with the narrative and media, (2) usage testing to assess the implications of delivering MHS in a real classroom (but with lots of support and help from our team), (3) feasibility testing to assess the implications of delivering MHS in classrooms and distance learning contexts where we would not be present and the systems for supporting students and teachers had to stand on their own, and (4) field testing to assess outcomes of MHS in randomized controlled trials (RCT). We did follow our systematic plan, but with much more iteration through the design and development process than originally envisioned. Also there was much iteration through the design and development tools so that the way we work today is substantially different than the way we worked at the start of the project. Our poster will be able to tell the story of our development of MHS through completion of some usage testing and our plans for field testing in the Spring and Fall of 2018.

## 2 CURRICULUM AND GAME PLAY

As introduced above, we developed curriculum design documents that led to system requirements documents that led to storyboards and eventually to first iterations of game play mechanisms that were assembled into units for usability testing. Each of the steps, in turn, had subcomponents; such as identifying driving questions, identifying student ideas and potential alternative conceptions about the topics, and scenarios for how the lesson ideas could be part of game play. Each of the steps and subcomponents also included lots of conversation and paper and whiteboard prototyping for how the ideas might look in the game play, as well as for considerations for system capabilities, time, resources, and what would be fun.

The MHS narrative has our novice scientist exploring, shaping and managing the water systems and topography of a distant planet as a potential resource for saving the human race, Fortunately for our student, she will have access to a number of tools. Some of the tools she may find in a present-day laboratory like water sensors and water quality testing materials. Other tools are fantasies, like an agent to assist her in making decisions and carrying out experiments. The fantasy environment and tools are developed from models of how water systems on earth function, and provide the learner with a sense of agency that supports exploration. In the game, the learner is asked to be a scientist conducting experiments while testing and building the case for solutions. As the game unfolds, the player will receive missions that challenge her to explore surface, ground and atmospheric water systems. Knowledge of these water systems is required to engage in argumentation necessary to continue her mission. The tasks in these argumentation opportunities are provided in a progression [8] to assist in learning scientific argumentation.

**Figure 1: Player is introduced to ARF who will serve as an agent for game play and curriculum objectives.**

Unit 1 introduces students to game play, to the narrative, and to the argumentation engine that will be used to conduct arguments during game play. Because we anticipate that MHS will be used by teachers for their whole class of students, we cannot assume that all students will be familiar with basic techniques of navigation and interaction in the 3D environment. Similarly, whereas in game play for recreational purposes how long it takes to master some basic techniques of the game may matter only for student engagement. These interface techniques become even more time critical for classrooms where the teacher only has 45 minutes for a lesson and where the teacher is hoping that all students can make relatively equivalent progress during class periods. Of course, in a game, too much tutorial or too much adhering to a time schedule can compromise the students ability to learn through failure and diminish any fun the player may be having. We see the design task during unit 1 as one of helping the player get off to a good start, but also one of setting the stage for engaging at your own pace, so as to learn how to succeed in the game and not just to move through the game. The tutorial nature of some of the starting tasks are counter balanced by interesting and fun visuals, learning about interesting NPC characters, and an exciting start to the game, as the space ship explodes and the player must escape.

Units 2 through 4 begin the tasks of exploring surface and ground water. In unit 2 students are tasked with finding members of their team (which have been scattered around the planet after the space ship explosion) as a means for learning to interpret topographic maps. They also must judge the relative sizes of water-sheds as part of identifying the best location for setting up a base camp. In unit 2 they also learn to support claims with evidence. In unit 3 players retrieve scattered supplies and send them back to base camp as they learn to identify the direction of water flow based on a map of the watershed. They also learn how to predict the spread of dissolved materials throughout a watershed, as they trace pollutants and identify best places for planting vegetation. Their argumentation objective is to identify a warrant (reasoning) and construct a warrant that links a claim with evidence.

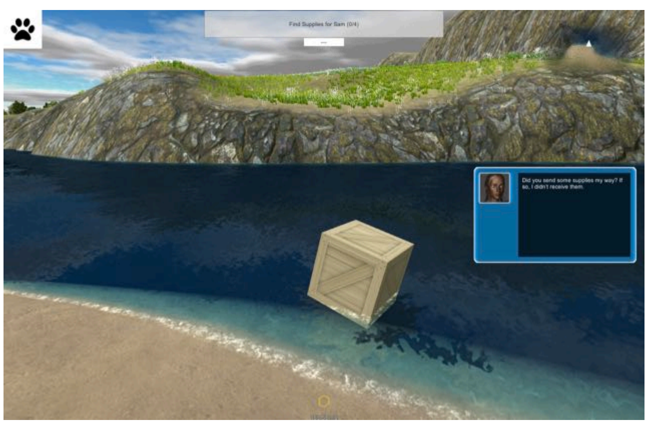


**Figure 2: After finding a crate and locating the river in unit 3 the player tosses the crate into the river and watches it float toward camp.**

Unit 4 has students learning about ground water by predicting the location of the water table, predicting rates of infiltration based on permeability of the substrate, and manipulating soil types to divert water to a target area. Their argumentation objective is to generate a complete argument including a claim, reasoning and evidence. Units 5 and 6 have not been developed yet, nor fully designed. The plan for unit 5 is to teach players about the movement of water through a cycle focusing on changes of state within atmospheric water and water on the terrain's surface, as well as developing the ability to provide a counter to a given argument. Unit 6 provides a wrap up for the narrative and a chance to put the knowledge and competencies developed in the earlier units into practice.

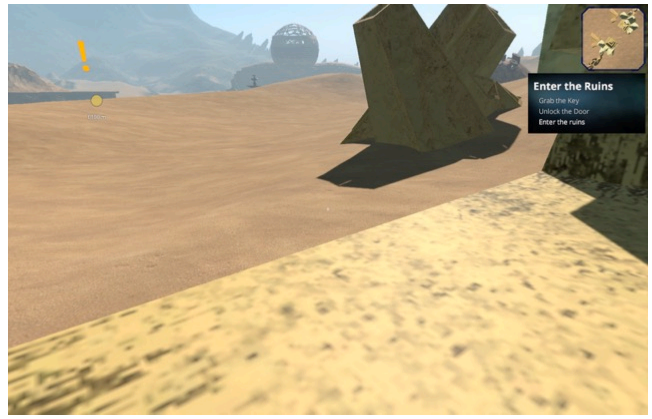


**Figure 3: Entering the ruins to restore the water system**

## 3 WHAT DOES THE PLAYER DO?

We know that kids can learn by playing games, but what we are less sure of is, can we teach students academic curriculum that we want them to learn through games. Especially challenging is teaching curriculum for application and upper level forms of knowing, and for teaching in ways that generalize the new knowledge to practice outside the game. Key to achieving curriculum objectives is in what the player is able to do and the context in which they are able to do it. Doing this well requires the collaboration of multiple game development contributors (curriculum, game design & developers) and a commitment to iteration to get it right.

In the limited space available for the poster we will discuss the argumentation engine as an example of developing a mechanism to enable learning. Several innovative efforts have been made to support learning argumentation processes in games. Bertling and her colleagues [10] demonstrated that their Mars Gen One: Argubot Academy improved student engagement and structural argumentation skills during gameplay. Other games such as Argument Wars and Citizen Science [2, 7] also showed potential to improve students' deliberation and civic engagement. These games typically conceptualize argumentation as part of dialogue between the player and NPCs to solve problems or issues in the game environments; and provide structured scaffolding and feedback to support argumentation skills development. While these games are innovative and show some success in promoting aspects of argumentation, they are limited, in that students are given pre-selected evidence sets and structures which reduces complexity, and diminishes the authentic scientific thinking and practice necessary to foster argumentation strategies. These types of learning structures invite naïve strategies such as a process of elimination, which is generally not generalizable outside the game context. Our attempt in MHS was to more authentically capture the dynamics and engagement involved when people practice scientific argumentation in non-game settings.

While we wanted to reduce the potential of naïve strategies for argumentation, another goal of our design work [4] was to make sure that the look and feel of the system did not remind students of the tree-structure typically used in prior school activities. Instead, we created a user interface with similarities to a solar system with the claim represented as the sun, reasoning statements as planets, and evidence statements as moon-like entities for the full system. This new structure reimagines the visual representations of connections between claim, evidence and reasoning while still adhering to its underlying model. Players are given the largest possible tree structure without pre-set drop-zones; allowing students to fill out their solar system as much or as little as they wanted. The system therefore allowed us to facilitate pseudo openness and used a simplistic implementation of regular expressions to create logic rules for how different components can combine. We then created a priority list of all the possible player feedback; so that if a player's argument matches two of our logic rules; we can display the most desired feedback.

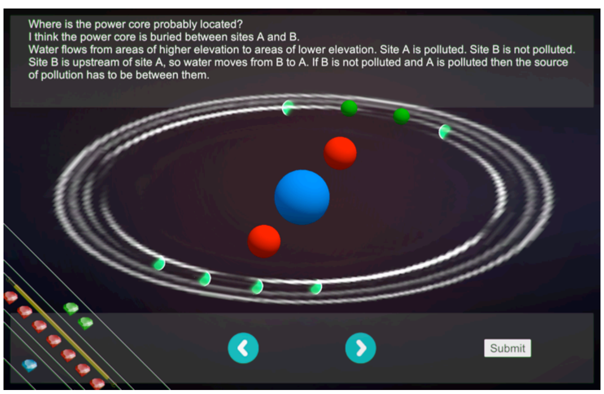


**Figure 4: MHS uses a solar system analog to progressively construct an argument of claims, reasoning and evidence as the student builds competencies with scientific argumentation.**

The argumentation engine allows us to input a number of argument scenarios from simple, such as simply stating a claim, to more complex, such as is shown in figure 4 with multiple evidence items and multiple reasoning statements.

## 4 CONCLUSIONS

In summary, we are in the process of developing a game-based 3D virtual learning environment to support the kind of science learning envisioned by NGSS. Middle school students will use MHS to learn about water systems and build competencies in scientific argumentation. Our process includes methods for developing a game narrative, a virtual world, NPCs and game/learning mechanisms to enable player activity and learning opportunities. MHS must satisfy player requirements for having an engaging and fun experience and for having the flexibility to learn from errors and failure. MHS must also satisfy student requirements for exposure to new content, meaningful activity, and progressions through the curriculum.

MHS is being developed through a set of evaluations that support decision-making about design and development choices and eventually lead to a field test to assess outcomes. Our plans for evaluation will hopefully contribute to the evidence base for game-based approaches to science learning.


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