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Designing Scientific Argumentation into the Mission HydroSci Game Based Learning Curriculum

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Abstract

This paper provides an introduction to the argumentation system being developed as part of the Mission HydroSci (MHS) learning game. We will report results from the early stages of development over three iterative phases of design work. The results of these phases suggest progress toward richer argumentation scenarios, which support scientific learning and the Next Generation Science Standards (NGSS). We will describe how the system supports richer argumentation interactions in three specific ways: 1) dynamic evidence collected by the player in problem-based simulation experiences, 2) complex argument generation, and 3) an intelligent assessment system, which allows for specific player feedback. We will discuss our design progression and how these game mechanics evolved as well as provide implications for supporting argumentation development in learning games.

Introduction

Mission HydroSci (MHS) (Laffey et al., 2016) is a game-based, 3D virtual learning environment and incorporated curriculum that supports middle school-level science learning. MHS is being developed in the Unity game development engine for use in distance and blended learning environments. Research and development efforts are supported with grants from the US Department of Education. The MHS curriculum is anticipated to take 12 to 15 hours of game play and one of the two core curricular objectives is to deeply engage students in scientific argumentation, scaffolding their ability to argue scientifically and integrating the practices of argumentation (Osborne et al., 2013) with core earth science ideas related to water systems.

Though argumentation has been integrated into the core of science curriculum, literacy, and practice, few games have been specifically developed to impact students' ability to perform argumentation. Next Generation Science Standards (NGSS) stress that students engage in scientific practice to learn and apply the science knowledge they are gaining (Ford, 2015; Grooms, Enderle, & Sampson, 2015); Common Core State Standards also fall in line with NGSS, emphasizing argumentation as core literacy (Kuhn & Moore, 2015). A few recent innovative efforts have been made to support argumentation learning in games. Bertling and her colleagues (2015) demonstrated that their Mars Gen One: Argubot Academy improved student engagement and structural argumentation skills during gameplay. Other game such as Argument Wars and Citizen Science (Mechtley, 2015; Schrier, 2015) also showed potential to improve students' deliberation and civic engagement. These games typically conceptualize argumentation as part of dialogue between the player and non-player characters (NPCs) to solve problems or issues in the game environments; and provide structured scaffolding and feedback to support argumentation skills development. Despite their success in promoting certain aspects of argumentation, students are given pre-selected evidence sets and structures, which reduces complexity, and therefore loses the authentic scientific thinking and practice necessary to foster argumentation strategies. While playing such games, students often employ naïve strategies such as process of elimination, which is not possible outside of the game–based environments that feature them. There are strong needs to devise game mechanics to truly capture the authenticity, dynamics, and engagement involved when people practice scientific argumentation in realistic settings.

Against this background, we set our design goal to foster knowledge and skills that transfer outside of the game into realistic argumentation scenarios. In the following sections, we will share our design and research process in which we iterated three phases of design and development in order to facilitate richer argumentation interactions and foster deeper argumentation strategies. We examine how the three game mechanics listed above have been realized and evolved in order to mitigate the use of the process of elimination and provide appropriate feedback to students.

MHS Argumentation System Overview

Our decision to combine scientific argumentation with a game that teaches water science was motivated by the NGSS focus on using argumentation as a scientific practice (Ford, 2015; Grooms et al., 2015). Integrating argumentation into a game–based environment brings with it certain affordances as well as design constraints. The affordances include the ability to use fantasy to create any desired problem–based scenario, such as preventing the New Orleans's levees from failing or exploring the Nile. These scenarios are not just labels for different feature sets, but rather become visually rich, data–filled, interactive environments. These environments provide both contextual support and motivation to explore, collect data, and engage with the narrative and characters.

Constraints that accompany game–based environments involve maintaining the gameplay loop of player exploration, action and feedback. The feedback portion of this loop requires game–based assessment for a seamless gameplay experience. For our design and development teams, this meant we could not include any text entry, which required human interpretation of player answers. These constraints prevent written response and student debate, which are two of the more common forms of argumentation practice students engage in during traditional classroom lessons.

Design of the Argumentation System

This section describes phases in the design, development, and testing of the MHS Argumentation System from September 2014 to April 2016 and includes a brief summary about the iterative design process, prototype development and evaluation of the system at each phase. In each phase, we reviewed prior design work, developed a prototype, and conducted usability testing with representative users employing methods such as think-aloud techniques and interviews (Someren, Barnard, & Sandberg, 1994).

Phase-1: Dialogue Based System

The first phase of development focused on grounding the argumentation in context. Accordingly, players were allowed to create their own water systems (e.g., watershed) and place sensors in a 3D terrain simulation environment in order to collect measures of different environmental features, such as the total amount of rainfall and the area of a continent (see Figure 1). Players then used dynamically generated evidence to advance an argument with a claim and supporting reasoning statements.

Video games traditionally use dialogue systems to deliver interactive narratives or conversations. In our initial design efforts to ground the argumentation scenarios in context, we conceptualized an argument as a special type of conversation with a non-player character (NPC). To foster such conversations, we created an antagonist NPC who challenged the player with argumentation-framing questions. After the player had dynamically collected evidence in their terrain simulator, the antagonist NPC would guide them through argumentation by first prompting them to make a claim, then asking them to choose the relevant evidence, and finally asking them to choose a reasoning statement (see Figure 1). This argumentation was delivered through the dialogue system so that each choice was required to be made sequentially and had to be correct before the player was allowed to move on to the next.

The usability testing results indicated that this dialogue-based argumentation system combined with a dynamic evidence collection mechanism was successful in terms of creating initial engagement and seamlessly integrating instructional scaffolding features. However, the dialogue-based delivery of the argument was not pedagogically visible; so players failed to extract an argumentation structure out of the interaction. In addition, we found that the limited response options, sequential progression, and corrective feedback ("you need to reconsider your answer") allowed students to use the process of elimination to create passing arguments. For example, players could loop back to the list of response options while randomly clicking on any possible choice.

Figure 1. This is our initial proof of concept for the game. Panel 1 shows the 3D terrain simulator where players construct a custom continent in real time. Players are able to place various sensors in the environment in order to take different measures, which become evidence cards for use in argumentation. Panels 2, 3, and 4 show the argumentation taking place in our dialogue system. Panel 2 shows the student selecting a claim, Panel 3 shows a player selecting evidence, and Panel 4 shows a player choosing their reasoning.

Phase-2: Tree Based System

During our second phase of design and development, we focused our efforts on visualizing argumentation structure while preventing players from using the process of elimination as a strategy. In our second prototype, we created a decision structure similar to the popular board games Clue and Mastermind. Rather than presenting each component of an argument (e.g., claim, evidence, and reasoning) to the player as sequential, individual decision points; we allowed the player to construct a visual representation of the entire argument, and then submit it as a whole. This solution space is exponentially more complex for the player to randomly explore and forces the player to carefully consider which components to use in combination rather than to use the process of elimination to determine each individual argumentation component.

This restructured argumentation system was presented outside of the dialogue system in a custom user interface designed specifically for argumentation (see Figure 2), which consisted of a three height–level trees, a claim at the root node, evidence at the leaf nodes, and reasoning statements on the middle level. Players were able to choose an argumentation tree structure, which would determine the number and placement of branches on the tree. The players had all of their claims, reasoning statements, and evidence visually represented as drag–and–drop objects, which could be placed on the various nodes of the tree. In this system, we defined successful patterns a–priori based on each possible tree and component configuration. We used a simple pattern–matching assessment strategy to determine which feedback to provide to the player. The feedback is intended to point out general flaws in the player's argument such as, "You have redundant evidence" or "Your evidence is irrelevant to the claim you chose." In this first scenario, the player could choose to use fewer branches in their argumentation tree or choose different evidence. In the second scenario, the player could choose a different claim or choose different evidence.

The usability testing results indicated that this tree-based argumentation system was successful in terms of making explicit argumentation structures. However, players perceived the visual representation to be similar to "school work," which lowered their emotional engagement. Players also reported difficulties in selecting and fixing a tree structure before fully exploring options for claims, evidence, and reasoning statements. A third issue students had was understanding which elements would remain if they changed the tree structure after going partway through argument construction.

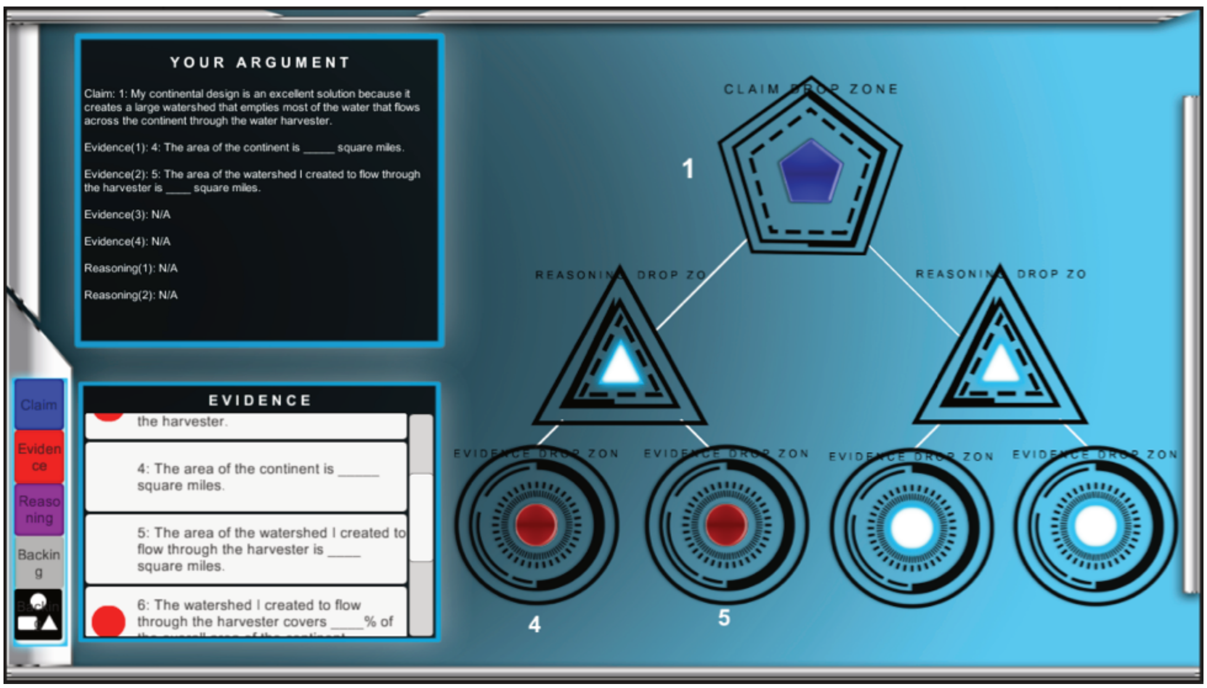

Figure 2. This figure shows our second prototype of the Argumentation system. All student interaction takes place on this screen. The top left panel constructs player arguments in paragraph form. The bottom left toolbox contains all drag-and-drop components: claims, evidence and reasoning, as well as the tree selector. The main panel shows the tree structure with the player's current argument.

Phase-3: Claimer System

The third phase of design addressed problems that we detected during the second design iteration. In our new attempt, we initially focused on the aesthetics of the system. The goal was to make sure that the look and feel of the system didn't immediately remind students that they were in school. In efforts to make the system feel more fun, the first change was to remove the very academic–looking trees. Instead, we created a user interface similar to a solar system with the claim represented as the sun, reasoning statements as planets, and evidence statements as moons. This new structure reimagines the visual representations of connections between claim, evidence and reasoning while still adhering to its underlying model. The new interface solves the difficulties that were inherent in the second-phase prototype. In this new interface, players do not need to select an argumentation structure, but instead they were 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, by implementing the largest tree and not representing individual drop zones, which alleviated the players' need to "fill the empty spots". This new system required a more complex assessment strategy than the second prototype. Instead of pattern matching, we 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. The usability testing for the new system is planned for May 2016.

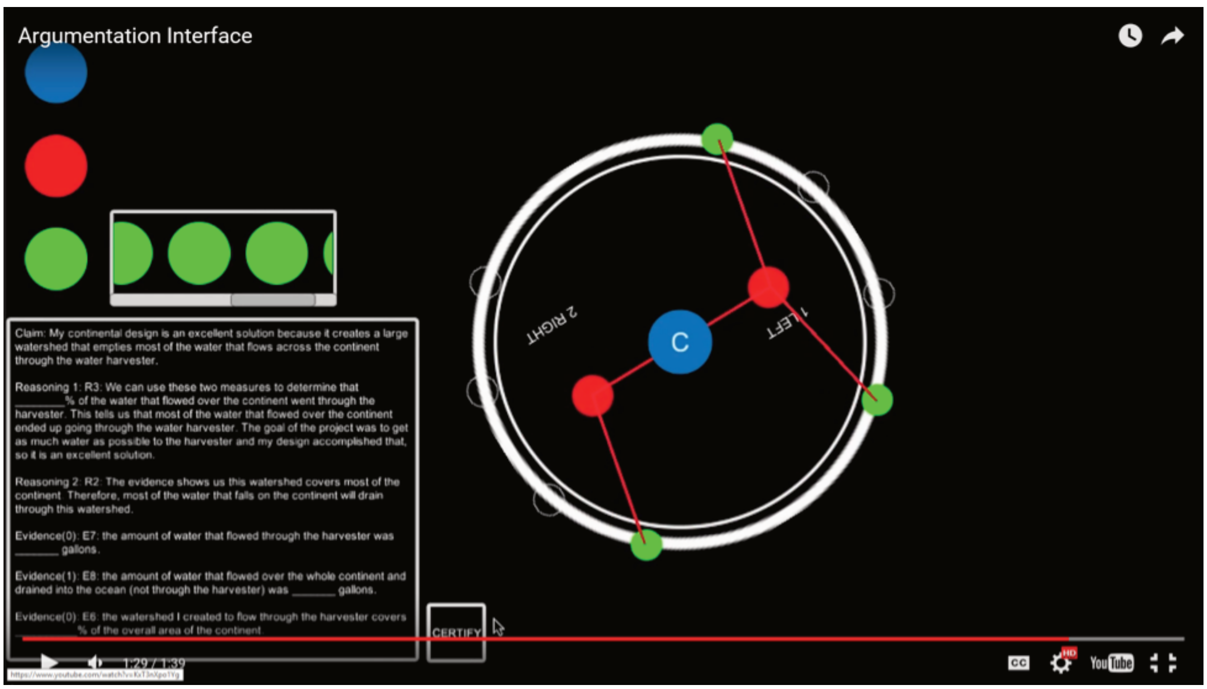

Figure 3: This figure shows our latest version of the Argumentation system. The player is no longer able to choose a tree, and there is much less clear "drop zones" for the player to fill up. The red lines connecting the various components only show up after the player has submitted their argument. The claim is the central element in the system, and reasoning statements are the red circles in the middle. Finally evidence pieces are placed on the outer ring to support different lines of reasoning.

Implications for MHS supporting Argumentation

Due to the dynamic evidence and more complicated assessment necessary, the claimer system is more difficult to design content for, but creates more authentic, dynamic, and engaging argumentation experiences for the player. Throughout usability testing, we have learned that the problem based nature of gameplay benefit players in terms of authentic scientific inquiry, and the rich, 3D data filled environments allow us to capture great detail surrounding this engaging interaction. We have learned that argumentation support also needs a cognitively challenging yet aesthetically creative representation in order to foster argumentative thinking beyond mechanical composition. We especially emphasize an embedded assessment system that prevents corrective responses, process of elimination, and other naïve argumentation strategies. We believe the claimer system has promise for transferring useful scientific argumentation skills into real world settings because this system requires the most critical thought from the student. The rich narrative gameplay experience provides a stimulating context for the player to ground their understanding in. The complex solution space where students choose all the components of an argument before submission addresses the process of elimination problem. Finally, the regular expressions can create very dynamic experiences with static components by providing custom feedback to any argument the player creates.

Future challenges remain, such as scaffolding evidence collection over an entire gameplay experience. One potential solution we are considering is giving students access to specific evidence–collecting sensors in the earlier units of the game, and then requiring players to re-use and synthesize evidence sources in more complex ways during later units. Another challenge is fostering counter argumentation, which involves more complex interaction and feedback. While there is still much to do and learn before we have a final design and development of MHS our process includes iteration, user testing and teamwork to find creative solutions. Developing innovative mechanisms that can playfully enact important scientific practices is key to developing learning games and advancing the potential of games in education.

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