# Using a Computer Game to Introduce Scientific Argumentation to Students

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Presented as a poster paper at NARST 2015, Chicago, IL

April 12, 2015

Abstract

This paper reports a design-based study that aimed to develop curriculum materials that could be used by high school biology teachers to introduce students to the practice of scientific argumentation with a game-based approach. We report a case of teacher use of the curriculum materials through two iterations of revision. We describe teacher instruction and provide evidence of student learning during each iteration. Implications for research, curriculum development, and game development are discussed.

*Keywords*: game-based science learning, argumentation, curriculum

Using a Computer Game to Introduce Scientific Argumentation to Students

Current reforms in U.S. science education include a focus on engaging students in practices such as scientific argumentation (NGSS Lead States, 2013; NRC, 2012). More broadly, calls from the science education research community to teach argumentation in science classes (e.g., Newton, Driver, & Osborne, 1999) make research of this practice relevant to those in states that do not adopt the *Next Generation Science Standards* (NGSS) and to those in countries in addition to the U.S. This paper addresses the need for research on curriculum materials and instructional approaches that can be used to introduce argumentation to students.

In addition to changes brought about by the adoption and implementation of the NGSS, there has recently been interest in exploring possibilities for using computer games to achieve a variety of science learning goals (Honey & Hilton, 2011). However, most of the research thus far on game-based science learning has focused on limited learning outcomes with an emphasis on learning scientific content (Li & Tsai, 2013). This paper addresses a need to study the use of game-based approaches for additional science learning goals by describing how a teacher used a game to introduce the practice of scientific argumentation to students.

## Literature Review

Our research is informed by work in the areas of supporting scientific argumentation and game-based science learning. We briefly describe key literature in each of these areas in the subsequent sections before presenting our study that seeks to unite these two areas of research.

First, it is important to clarify our use of the term scientific argumentation. Two practices described in the *Framework for K-12 Science Learning* and incorporated in the NGSS are “constructing explanations” and “engaging in argument from evidence.” While these practices complement one another, scholars have disagreed about the definitions of explanation and argumentation and the degree to which they should be separated in classrooms (Osborne & Patterson, 2011; Berland & McNeill, 2012; Osborne & Patterson, 2012). For clarity, we use the term scientific argumentation to describe activities in which students do three things: (a) state a claim that answers a question, (b) provide evidence to support their claim, and (c) use scientific principles to show how their evidence supports their claim. This operationalization of argumentation is based on the claim, evidence, reasoning (CER) framework (McNeill & Krajcik, 2012), which was adapted from Toulmin's (1958) model of argumentation in order to be more accessible to classroom teachers. Because of the variety of terms used in previous research, our review of the literature includes research on explanation and argumentation.

**Scientific Argumentation**

In recent years, research has provided valuable insights on supporting scientific argumentation in classrooms. This research has included examining the effects of teacher instruction while introducing scientific argumentation to students (e.g., McNeill & Krajcik, 2008) and studies of effective ways to scaffold the development of scientific arguments (e.g., Kang, Thompson & Windschitl, 2014; McNeill, Lizotte, Krajcik & Marx, 2006; Sandoval & Reiser, 2004). McNeill and Krajcik (2008) delineated four teaching practices associated with effectively introducing scientific argumentation[1] including defining scientific argumentation and the C, E, R components, providing an explicit rationale, modeling an argument, and connecting to everyday uses of argument.

Researchers have also studied features of curriculum materials and learning environments that are useful for scaffolding students' development of scientific arguments. Kang et al. (2014) reviewed five types of scaffolds embedded within assessment prompts, which included (a) using

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[1] The original text uses "scientific explanation", however, we chose to use "scientific argumentation" for internal consistency with our operationalization of the term.

contextualized phenomena, (b) checklists, (c) rubrics, (d) sentence frames, and (e) prompting students to draw explanatory models along with written explanations. They concluded that, while all five scaffold types were linked with the quality of students' explanations, "providing contextualized phenomena had the greatest impact on the quality of student explanations" (p. 674). Additionally, Sandoval and Reiser (2004) found that a digital learning environment could be used to help students structure and evaluate scientific explanations. Their computer-based *Explanation Constructor* served as an epistemic tool that provided conceptual scaffolds to guide students' attention to key aspects of the scientific phenomena being described and made accessible data and figures that students could include as evidence in their explanations.

**Game-Based Science Learning**

In a synthesis of research on gaming in science education, Honey and Hilton (2011) stated that computer games "have potential to advance multiple science learning goals…" (p. 15). Despite this potential, Honey and Hilton also stated that the "evidence for the effectiveness of games for supporting science learning is emerging, but is currently inconclusive" because "to date, the research base is very limited" (p. 54). The majority of studies currently making up the research base have focused on student learning of science content knowledge and concepts (Li & Tsai, 2013).

Given the relatively limited research on game-based approaches to teaching science, what do game-based approaches afford that may warrant additional research? Squire and Jan (2007) suggested that game-based approaches "situate learners in complex thinking tasks that are driven by authentic questions, incorporate multiple tools and resources, rely on learning by doing, guide learners through a path of events and into a way of thinking, and require complex performances to demonstrate mastery" (p. 8). In their study of an augmented reality game, Squire and Jan

(2007) concluded that the structure of the game enabled students to engage in argumentation. They suggested that "educators might pursue scientific argumentation as an important direction for educational gaming, developing extra curricular resources around the experience designed to explicitly teach argumentation and facilitate transfer" (p. 23).

## Curriculum Unit and Game

This study was based on teacher enactment of the high school unit *Why Dread a Bump on the Head?* and the associated computer game, *The Golden Hour*. The unit and game were developed through an iterative design process that was shaped by feedback from a scientist, teachers, and students, as well as enactments in authentic classroom settings.

*Why Dread a Bump on the Head?* is a seven lesson unit through which students learn about the neuroscience of traumatic brain injury (TBI). In the first three lessons, students read case studies to learn about different causes and symptoms of TBIs, conduct a sheep brain dissection to explore brain anatomy and physiology, and study CT scans to identify different types of brain injuries. Lessons 4 and 5 focus on the cellular level as students learn about neurons and investigate apoptosis and necrosis of neurons after a TBI. In Lessons 6 and 7, students research TBI using publicly available data and communicate their findings to the general public.

The first three lessons of *Why Dread a Bump on the Head?* incorporate *The Golden Hour*, which provides an interactive and contextualized way for students to learn about the science of TBI and to practice scientific argumentation. Through the game, students take on the role of an advanced medical student to help diagnose and treat a patient who may have experienced a TBI. *The Golden Hour* is separated into three scenes: (1) Emergency Medical Services (EMS), (2) CT Scan, and (3) Neurosurgery. As students play through each scene, they learn neuroscience concepts and collect information about the patient. At the end of each scene, students submit a report of their findings to the lead physician (a character in the game). Through a dialogue modeled on the CER format for argumentation, the physician scaffolds students in using the data they collected to answer the question "What should be done next for the patient?" (Figure 1). Students are first prompted by the lead physician to make a recommendation (i.e., a claim), then to support their decision with evidence collected during the main scene, followed by reasoning for how the evidence supports their claim. Students answer the physician's step-by-step questions by selecting from multiple choice responses. If a student selects an incorrect response, the physician provides immediate feedback stating why the answer was incorrect and asks the student to make another choice. After completing the interactive dialogue with the lead physician, students write a scientific argument in the form of a medical recommendation for next steps for the patient.


*Figure 1*. A screenshot from *The Golden Hour* depicting dialogue based on the CER framework. Dialogue from in-game characters appears at the upper-left corner, and the player can choose a response from the options at the bottom of the screen.

This study focused on Scene 1 of *The Golden Hour*, where students measure the patient's vital signs and consciousness and use these data as evidence to determine next steps in medical treatment of the patient. Figure 2 displays the dialogue players have with the lead physician at

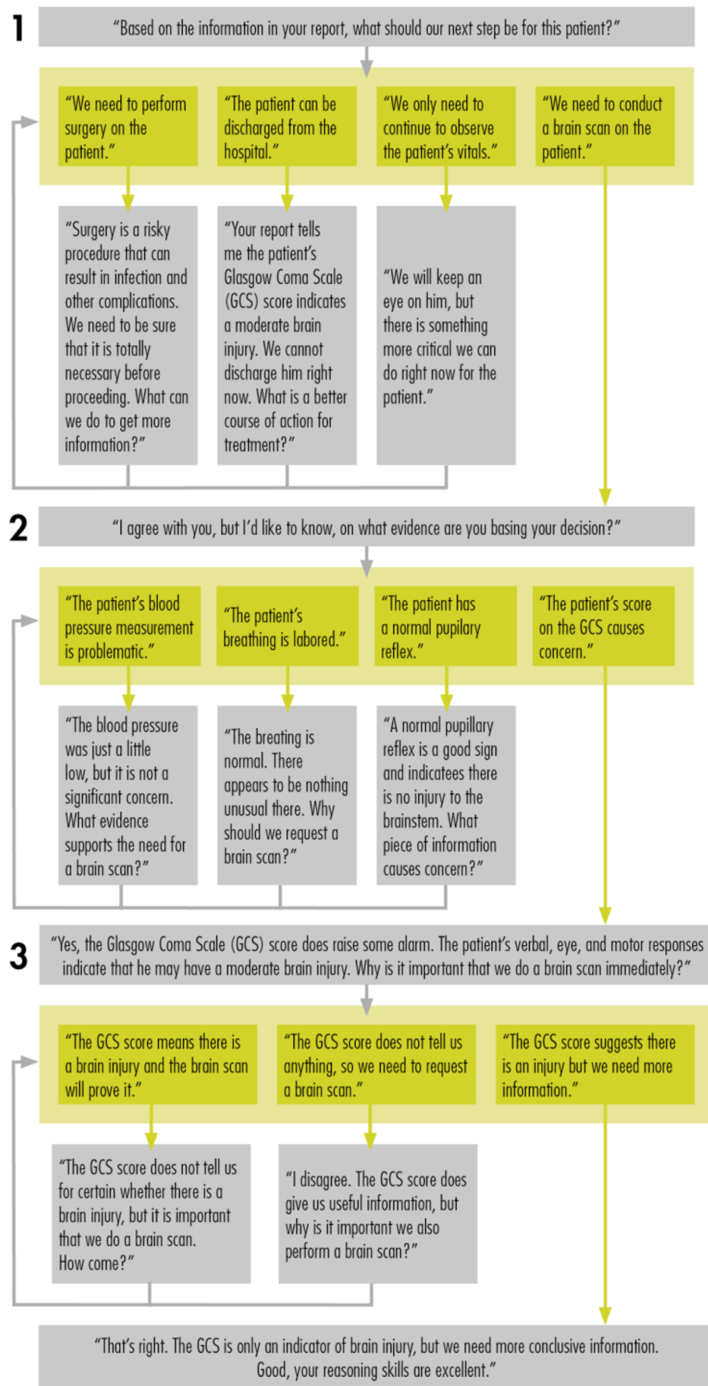


*Figure 2.* Flowchart of the dialogue between the lead physician and the player at the end of Scene 1. Text blocks in grey are speech from the physician and gold text blocks are dialogue options presented to the player. Throughout the dialogue, the physician prompts the player to choose the best (1) claim, (2) evidence, and (3) reasoning.

the end of the scene. The dialogue is intended to model the CER framework and scaffold students' development of scientific arguments by prompting students to select a claim and provide evidence and reasoning.

## Research Questions

Drawing from the literature on introducing students to argumentation and game-based science learning and classroom enactment of *The Golden Hour* and associated curriculum materials, we describe two iterations of how a teacher used curriculum materials that featured a computer game to teach students how to make scientific arguments. The present study addresses two research questions: (a) How does a high school science teacher introduce scientific argumentation using curriculum materials that feature a computer game?, and (b) How might differences in written scaffolds across two iterations of the curriculum materials influence the quality of student arguments?

## Methodology

This study took place as part of a larger design-based project focused on developing a computer game integrated with a curriculum unit on TBI. We describe the details that are relevant to the research described in this paper. The design-based approach emphasized the development of curriculum materials and refinement of the materials based on their use in authentic classroom settings. In this paper, we looked at a case study of how one teacher used the curriculum materials and *The Golden Hour* to introduce students to scientific argumentation through two iterations of materials in two consecutive years. A summary of our methodology is provided in Table 1.

Table 1

*Summary of Methodology*

| | Year 1 (Iteration 1) | Year 2 (Iteration 2) |
|---|---|---|
| Teacher | One teacher was followed for two consecutive years. She<br>● had 10+ years of teaching experience,<br>● attended professional development workshops for the curriculum unit, and<br>● used the curriculum unit with *The Golden Hour* game | |
| School context | High school located in a small urban community<br>● About 48% of the school's students identified as low-income | |
| Student participants | Anatomy & Physiology<br>● elective course<br>● mostly upperclassmen students<br>● 49 students | Anatomy & Physiology<br>● elective course<br>● mostly upperclassmen students<br>● 39 students |
| Enactment materials | ● Curriculum lessons<br>● *The Golden Hour* game | ● Curriculum lessons<br>● *The Golden Hour* game<br>● Student sheet with CER scaffolding |
| Data collection and analysis | ● Teacher enactment data (audio recordings and classroom observations)<br>○ Researchers transcribed audio files and used the transcripts to identify themes with a framework to characterize teacher instruction (adapted from McNeill and Krajcik (2008))<br>● Student artifact (students' written arguments/medical recommendations)<br>○ Two researchers scored student work using a task-specific rubric (adapted from a rubric developed by McNeill and Krajcik (2012)), and statistics were calculated in SPSS | |

**Participants and School Context**

For this study, we selected one teacher to participate as a case to study. This teacher was selected because she attended professional development workshops on using the curriculum unit, and she planned to use the curriculum materials in her classroom. Her enactment was of particular interest because she was the first teacher to use the unit with the computer game, and she used the curriculum materials for two consecutive years through two iterations of materials. The teacher enacted the first three lessons of *Why Dread a Bump on the Head?* and used *The Golden Hour* in Anatomy and Physiology, an elective course that enrolled mostly upperclassman students. The teacher was an experienced educator, having taught for more than ten years. The study took place at a high school located in a small urban community with approximately 48% of the school's students identified as low-income. Data were collected from students across the teacher's classes who provided parent consent and student assent. Forty-nine students participated in the first year of the study, and thirty-nine students participated in the second year of the study.

**Data Collection**

We used a mixed-methods case study approach. Two categories of data were collected and analyzed: (a) teacher enactment data, and (b) student artifact data. Teacher enactment data consisted of audio recordings of the teacher and classroom observations that were collected during enactment of the lessons (over two days of instruction). We transcribed and coded the teacher audio data, initially looking for emergent themes that described how the teacher introduced scientific argumentation to students. After identifying themes, we were able to adapt an existing framework (McNeill & Krajcik, 2008) to analyze the teacher data. We found three categories that could be used to characterize instruction, and they included (a) how claim, evidence, and reasoning components were defined, (b) whether a rationale for argumentation was provided, and (c) whether argumentation was modeled with an example.

Student artifact data consisted of students' medical recommendations from the end of Scene 1 of *The Golden Hour*. The written prompts for this task changed significantly between

Iteration One and Iteration Two enactments in how they scaffolded construction of the medical recommendation, or scientific argument. In Iteration One, students were asked to use a blank sheet of paper to write their explanation. In Iteration Two, students were provided with a sheet that included (a) the question prompt students were expected to answer, and (b) a table organizer to scaffold students' construction of a CER explanation. The organizer contained three columns, one for each of the components, as well as an additional space at the end to combine the three components to write their final complete medical recommendation.

For student artifact data, we collected and examined students' completed medical recommendations from all participating students across multiple class periods for each year. All student work was independently scored by two researchers using a rubric adapted specifically for this argumentation task from a rubric developed by McNeill and Krajcik (2012). Scorers had an inter-rater reliability of 86%, and all discrepancies were resolved by discussion.

## Results

In this section we describe teacher instruction and summarize student artifact data during two iterations of curriculum enactment. Iteration One corresponds with first year of enactment and Iteration Two corresponds with the second year of enactment. Teacher instruction descriptions are from two days of instruction from one representative class period for each year. The class periods that were selected were from the middle of the school day so that the teacher already had enacted the lesson at least once previously during the day. The focus is on the teacher's introduction of the CER framework for argumentation in relation to *The Golden Hour*. For student artifacts, examples that are representative of the mean score for that iteration are provided and discussed.

## Iteration One

### Teacher instruction.

***Defining.*** In Iteration One, after students completed Scenes 1 and 1.5 of *The Golden Hour*, the teacher explained the CER framework for scientific argumentation. She began by telling students that they needed to write their recommendation to answer "what is the best treatment for the patient?" Though initially she referred to the medical recommendation and did not explicitly say "claim," when presenting an example CER a few minutes later in instruction, she then further defined a claim as "a statement or a conclusion that answers the original question we have."

Evidence was defined as "the scientific data that supports your recommendation" and students were told that "the evidence needs to be appropriate for your claim." The "sufficiency" aspect of evidence was not as explicitly addressed as the "appropriate" aspect, but the teacher did mention to "include enough data so [they] have enough information to really convince someone…" The teacher further explained evidence within the context of the game by saying, "The evidence would be the data that you collected about the patient's condition, his vital signs and so on."

Reasoning was explained to students in Iteration One as follows: "So, what is your reasoning? How do you connect your claim with the data you've collected? In your reasoning statement, you're going to tell why your data count as evidence to support that claim. So, it's a process of applying the scientific knowledge to solve that problem of what treatment is needed for [the patient]."

***Rationale.*** In Iteration One, the teacher provided a vague rationale for writing scientific arguments by telling students that their task in writing the medical recommendation was to "convince someone that [their] suggested treatment would be the best treatment for the individual."

***Modeling.*** In Iteration One, the teacher talked students through a CER example with the claim, "Polar bears can live in the arctic because they have adaptations for the environment." The evidence to support this claim was a series of statements similar to the first: "Polar bears have webbed paws that let them swim through the water to catch seals." Finally the reasoning was provided as "Adaptations are characteristics that allow an animal to survive in its environment; getting food and staying warm are both necessary for the animal to live." The individual C, E, and R components were identified in the example, but strengths and weaknesses were not discussed.

**Student artifacts.** During Iteration One students wrote their medical recommendations on blank paper. The following examples show student responses. These examples were selected because they earned scores that were close to the mean score of the group.

***Artifact 1.*** I recommend the patient get a CT scan. His airway and breathing is clear enough for him to get the procedure although his blood pressure is low, this and his vital signs should be monitored. The reasoning for the CT scan is because his GCS is moderate which shows he's stable and he has no external injuries therefore we can conclude the problem has to be internal.

***Artifact 2.*** I recommend the patient have a CT scan done. Evidence that supports this recommendation is he had a GCS score of 10, which isn't especially low. All his vitals were normal. He did have a slightly low blood pressure, so I would recommend you monitor that. His pupillary reflexes are fine, so we know there wasn't an (*sic*) severe brain trauma caused by the accident.

***Artifact 3.*** Given the information we have about the accident and the patient's current state, I recommend he be kept in the hospital overnight under close watch and discharged in the morning as long as all is well. His GCS score was moderate and all vital signs appeared normal. Because of this, we can safely conclude that nothing is seriously wrong in this head injury and he should be back to normal soon with rest.

***Discussion.*** The authors of artifact 1 and artifact 2 voiced similar claims about the need for a patient to have a CT scan. All students also included some data that they collected as evidence such as blood pressure values or GCS scores. However, students seemed to have a difficult time coordinating how the data they presented supported their claim.

**Iteration Two**

**Teacher instruction.** During Iteration Two, the teacher verbally explained the C, E, R components and also supplemented her instructions with two paper handouts that she added to the curriculum, which included (a) a simple rubric that outlined the three components and provided a scoring system and (b) a written example that included a definition of each component and a sample CER. Students were encouraged to review the two handouts for more information on how to write their arguments. Therefore, both the teacher's verbal explanation and written supplements are described below.

***Defining.*** In Iteration Two, the teacher explained the C, E, R components when introducing *The Golden Hour*, just before students began playing the game. She began by stating that they will need to answer the question "What should be done next for the patient?" using a claim, evidence, and reasoning. The claim was defined as "a concise statement that relates to the questions." The handouts further defined a claim as "a concise statement" that "relates directly to the question and hypothesis," "focuses on most important features of the experiment" and that is "a conclusion about a problem."

For the evidence component, the teacher asked students to reflect on and restate the data that they collected about the patient. The handouts included "several data sources used to explain claim, including observations and accurate measurements," 'clear connections to question and hypothesis," and "scientific data that is *appropriate* and *sufficient* to support the claim."

Finally, the reasoning was explained by the teacher when she said "you're going to show how that evidence answers that claim." The handouts expanded on this by identifying reasoning as "a justification that shows why the data count as evidence to support the claim and includes appropriate scientific principles," "illustrates understanding of how experiment fits into the 'big picture,'" and "incorporates background knowledge, and makes connections to science concepts studied in class, to draw conclusions about experiment."

***Rationale.*** During Iteration Two, while introducing the CER framework and providing instructions, the teacher provided no rationale to the class as a whole for why they were constructing a scientific argument.

***Modeling.*** During Iteration Two, students received a handout of an example argument with the following claim: "The rate of pumpkin plant growth increases as the temperature increases." This example was based on a scientific experiment and included evidence such as "Over the course of the week, we observed that the experimental plant was healthier looking, had more leaves, and grew taller than the control plant." This was followed by reasoning such as "Pumpkin plants are sensitive to the temperature of their surroundings" and "Maybe pumpkin plants are able to do photosynthesis faster at warm temperatures, so they are able to grow more."

The individual C, E, and R components were identified in the example, but strengths and weaknesses were not discussed.

**Student artifacts.** During Iteration Two students wrote their medical recommendations on a sheet that included the question prompt and a table organizer for the C, E, and R components. The following examples show student responses that were selected because they earned scores that were close to the mean score of the group.

***Artifact 4.*** Claim: We should conduct a CT scan on his brain.

Evidence: The patient scores GCS causes concern, eye score 2, verbal 3, motor 5, both pupils reacted, vitals are stable.

Reasoning: The GCS scores suggest there is a brain injury and the brain scan will prove it. The patient is stable until the moment.

Medical recommendation: We should conduct a CT scan as soon as possible because his GCS score was high. We should continue to monitor his stats.

***Artifact 5.*** Claim: I think that the patient needs a CT scan of the brain.

Evidence: My evidence is the GCS score. The GCS score was a total of 10. That means that it’s moderate.

Reasoning: My reasoning is that we need more conclusive information about the head trauma. It’s stable enough for the patient to survive the CT scan since his GCS score is moderate.

Medical recommendation: I recommend that this patient gets a brain scan. I recommend that since the patient have an head injury we need to know more about the injury so we can know how to treat the patient and if he needs surgery or not.

***Artifact 6.*** Claim: Needs to conduct a brain scan.

Evidence: Patient score on the GCS score causes some concerns.

Reasoning: The GCS score suggests that there is a brain injury but we need more information. The patient's condition is stable enough for a brain scan.

Medical recommendation: A scan is need on the patient because patient's score on the GCS score causes some concerns. The GCS score that there is a brain injury but we need more information and the patient's condition is stable enough for a brain scan so we can do the brain scan.

***Discussion.*** Similar to the artifacts from Iteration One, all students had a similar claim about the patient needing a brain scan. All students mentioned GCS scores as part of their evidence, although they provided varying levels of details and in some cases even started to include their interpretations. Students did a better job at specifying reasons why the GCS score evidence supported their claims, but they did not completely connect evidence to ideas they mentioned about the patient being stable.

## Student Artifacts: Score Comparison

Beyond comparing examples of student work, the distribution of scores for all students is displayed in Figure 3. The group of students ($n$ = 49) from Iteration One had a mean score of 4.39 points, and the group of students ($n$ = 39) from Iteration Two had a mean score of 7.15 points. Based on the scoring rubric, there was a maximum possible total of 10 points. The standard deviations were 3.36 and 2.60 points, respectively. A $t$ test was used to compare the average scores of the two groups and indicated $t(86) = 4.23$, $p < .001$, indicating that means from Iteration One and Iteration Two students were significantly different.

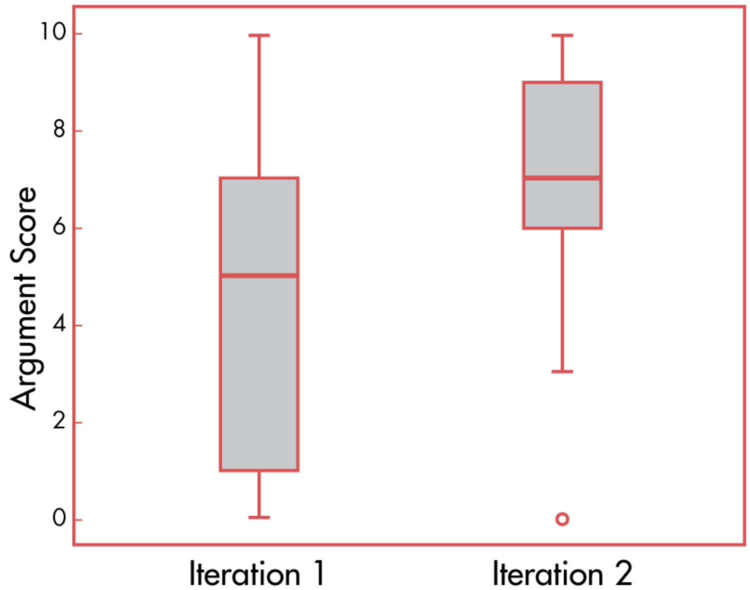


*Figure 3.* Box plots of student scores from Iteration One and Iteration Two. This figure shows a relative increase in student scores across the distributions and a narrowing of the range of scores during Iteration Two.

## Discussion and Significance

This study described how a science teacher introduced argumentation to students using a computer game that provided students with contextualized opportunities to develop scientific arguments. We discuss our findings about teacher instruction and student artifacts in the sections that follow.

### Teacher Instruction

Within the lesson plan for Lesson 1 of the TBI unit (the lesson that was the focus in this paper), little information was provided to support teachers in introducing scientific argumentation to their students. The lesson plan simply states, “Explain to students that all good scientific explanations must have these three components. For any scientific explanation, you must first make a sound claim, provide evidence that supports that claim, and explain the reasoning that connects the evidence to the claim.” While the lesson plan instructs teachers to familiarize students with the C, E, R components, little detail and guidance is provided on how to do so effectively. When designing the curriculum materials and *The Golden Hour* game, students’ interaction with the game was expected to be students’ primary method of introduction to argumentation. The game was designed to engage students in a scenario that contextualizes scientific argumentation and therefore provides an implicit rationale and real-world example for scientific argumentation. Additionally, the dialogue was intended to interactively model the CER framework for scientific explanation, by walking students through the components and providing feedback along the way.

The enactment data, however, indicated the importance of supplementing the game with explicit teacher instruction on scientific argumentation. This study showed that the teacher valued providing an introduction of scientific argumentation and the CER framework before students wrote their medical recommendation in the game. This is evidenced by the teacher’s supplementation of the existing curriculum materials with more explicit definitions of the C, E, R components, modelling CER through examples, and providing a rubric for scientific argumentation. This finding suggests revision of the lesson plan to include a more robust introduction of scientific argumentation and the CER framework.

Findings from existing literature also support explicit instruction of argumentation and the CER components. McNeill and Krajcik (2008) showed that teacher’s instructional practices when introducing scientific explanations can influence student learning of the scientific practice. One finding in particular was that providing an explicit rationale for scientific explanation could result in greater student learning of the practice, however, teachers may often overlook this component of instruction (McNeill & Krajcik, 2008). In this case study also the teacher provided little to no rationale for writing scientific arguments. Though the contextualization of argumentation within the game provides some implicit rationale for students, these findings suggest the importance of revising the lesson plan to support teacher instructional practices to make the rationale explicit.

Providing additional information in the lesson plan to support teachers in introducing their students to scientific argumentation and the CER framework could aid in the instruction of the scientific practice in two ways. First, while this revision would provide valuable support to all teachers, it would be especially helpful to those who do not attend the professional development workshops for these materials or those who are not already familiar with the CER framework for scaffolding scientific argumentation. For example, the lesson plan can guide teachers in making the rationale for scientific argumentation more explicit, something that was missing from the enactments in this study. Second, the curriculum revision would include materials that better align with the structure of the argumentation task in *The Golden Hour.* For example, in this study, the teacher provided students with a rubric that made references to an "experiment." This could potentially confuse students because the medical recommendation they must write in *The Golden Hour* is not based on an experiment. Revised materials with a rubric and example arguments that are more consistent with the task could better support teachers and students.

## Student Artifacts

While the game itself did not change between Iteration One and Iteration Two (other than minor bug fixes), the quality of students' explanations improved during Iteration Two. While caution should be taken to avoid interpreting a causal claim for the improved student scores, the game in and of itself did not result in student arguments of similar quality. Rather, aspects of the teacher's introduction and scaffolds external to the game may have influenced the quality of student explanations. Consistent with findings from Kang et al. (2014), the rubric provided in Iteration Two may have helped students. Also, the prompt in Iteration One had characteristics of a faded scaffold, which was less appropriate when students were first introduced to argumentation (McNeill et al., 2006). The prompts within the curriculum materials in Iteration Two were not faded and instead scaffolded the development of separate components of argumentation. Future research should investigate how students progress through the three scenes of the game using prompts that are faded with each consecutive section.

**Implications for Curriculum Revision**

To organize our thinking about the development and continued refinement of the curriculum materials and game based on the design research described in this study, we created a conjecture map (Sandoval, 2014) which is shown in Figure 4. Our high level conjecture for the learning environment we were designing was "Contextualization and appropriate scaffolds help introduce students to argumentation." This conjecture was embodied in the materials we developed including lesson plans for teachers, student sheets, *The Golden Hour* game. Findings from the study prompted us to look more closely at how best to provide appropriate scaffolds. The student artifacts from Iteration One suggested that students may need more structured supports for developing arguments using the CER framework. Therefore, we developed a student sheet with stronger scaffolds which students used in Iteration Two. Future revisions may also include fading scaffolds for argumentation as students progress through the three scenes of the game. Our ideas about how to support teachers in introducing students to argumentation were also refined through the process, and these future revisions are reflected in the conjecture map. Teacher instruction data from Iterations One and Two showed us that teachers, and thus students, could benefit from detailed and relevant information about how to introduce the CER framework for argumentation and support this task.

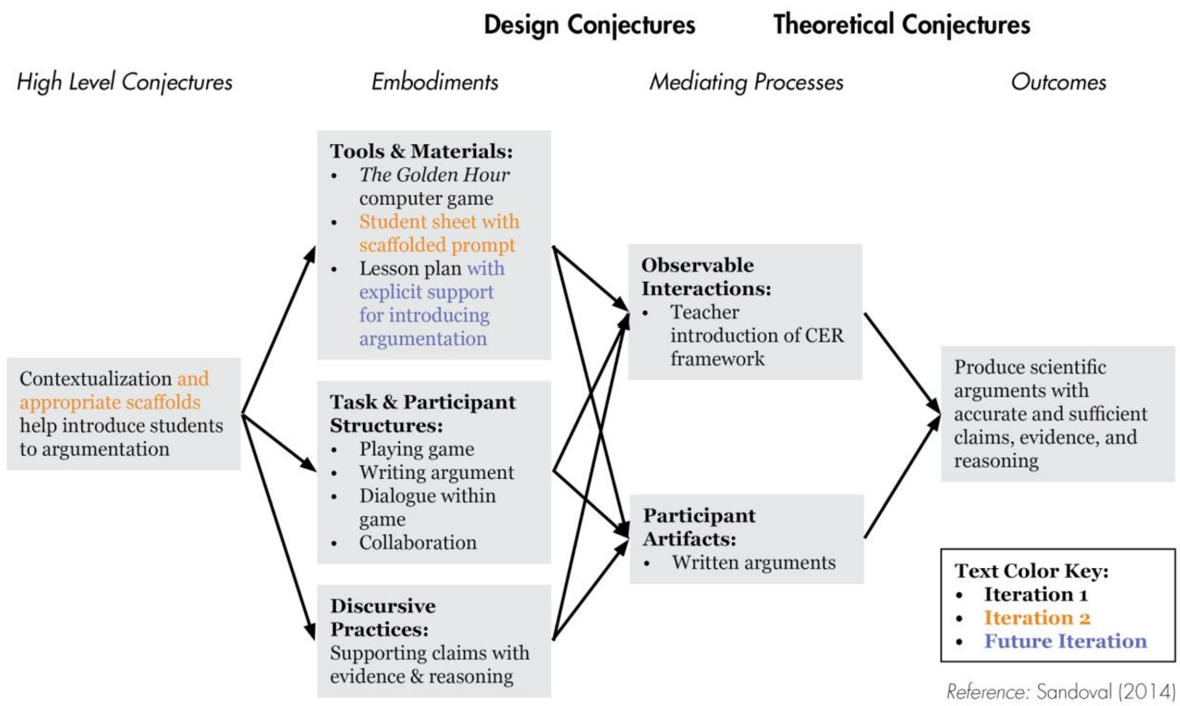


*Figure 4.* A conjecture map that shows development in our thinking about the game and curriculum materials described in this paper. Black text shows our original conjecture map, orange text shows revisions after Iteration One, and blue text shows future revisions after Iteration Two.

## Conclusion

The *NGSS* highlight the importance of integrating practices with learning of content. As adoption of *NGSS* expands, educators will need effective, interactive, and diverse ways to engage students in these practices. This study explored how a teacher introduced argumentation, a key practice outlined in the *NGSS*, to prepare students to make arguments scaffolded by an interactive computer game that contextualized learning. The findings add to the literature on different ways to support students in argumentation. Yet the findings highlight that scaffolded digital environments such as computer games may not be sufficient to introduce students to argumentation. Curriculum developers, game developers and teachers should focus on how curriculum materials such as written scaffolds used in conjunction with digital learning environments such as computer games can maximize the quality of student explanations. Future work can examine additional ways to support teachers while introducing argumentation and the affordances of scaffolding with computer games. Future research can also explore causal links for differences in outcomes for high achieving and low achieving students.

**Acknowledgements**

The research and curriculum materials described in this publication were supported by a Science Education Partnership Award (SEPA; Award No.: R25 RR024251-03 and R25OD011144) from the National Center For Research Resources (NCRR) and the Division of Program Coordination, Planning, and Strategic Initiatives of the National Institutes of Health (NIH). The content is solely the responsibility of the authors and does not necessarily represent the official views of NCRR or NIH. We thank all the Project NEURON members who were involved in developing the *Why dread a bump on the head?* curriculum unit and *The Golden Hour*. We are also grateful to Claire Scavuzzo and Emily Serblin for assistance with data analysis.

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