Developing Science Literacy through the Heat Game: An Online Role-Playing Game

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Abstract

The decline of young peoples' interest in science and technology education in western countries is causing concern worldwide. To help change this situation, teachers need to take a leadership role in designing innovative approaches for engaging students with science learning in schools. This teacher-researcher action research study examined science literacy learning opportunities that emerged for grade 7/8 students through engaging in an approach to science curriculum based on video games. The approach, called the Heat Game, is designed to simulate for grade 7/8 students a real-world context for their science and technology work. Though online communication that augments project-based lab work, teacher and students role-play scientists and engineers working together in a futuristic scenario to learn about heat transfer and design energy efficient housing for their city. This research study focuses on the conversation between one student playing the role of Dr Spacey (junior physicist) and the teacher playing the role of Dr. Boyle (expert physicist). It examines opportunities for the development of Dr Spacey's science literacy through this online communication. Findings demonstrate that the Heat Game afforded Dr Spacey opportunities to increase her science literacy by developing awareness of science situated meanings of words and phrases, science ways of representing information and by developing understanding of aspects of the nature of science including: the importance of evidence and repeatability in science, scientists' ways of reporting, and peer review. The implications of the findings for this teacher's professional practice and for curriculum design in general are discussed.

Science literacy is a term used to describe the public understanding of science and helping students develop their science literacy is the generally accepted goal of science education in schools (DeBoer, 2000). International concern regarding a decline in young peoples' interest in science subjects (Becker, 2010; Bennett & Hogarth, 2009; EU, 2008; OECD, 2006; Sjoberb 2010) is fueling a drive for the development of engaging approaches to support students' science literacy acquisition (Sjoberb 2010). This paper focuses on one such approach called the Heat Game (Author, 2014). Based on principals of learning in scenario type videogames that young people engage in for fun outside school (Black & Steinkuehler, 2008; Gee 2007; Lankshear & Knobel, 2006; Nelson, 2005; Shaffer 2006; Squire 2005; Squire & Jan, 2007), the Heat Game provides an opportunity for middle school students to role play science professionals online and develop their science and environmental literacy through conversations with virtual experts. While a previous paper (Author, 2014) focuses on how students develop their environmental literacy through the Heat Game, this paper focuses on ways that students develop their science literacy.

Students need to develop the kind of science literacy that enables them to assess and discuss the significance and validity of knowledge claims presented to the general public about real life concerns (Hodson, 2003, 2008). Schwartz, Lederman & Crawford, 2004 point out that in order to develop this kind of science literacy students need two kinds of experiences. On the one hand they need to develop science literacy from the *inside* by experiencing the kinds of processes and practices that science professionals use inside their profession to construct science knowledge through participation (Lave & Wenger, 1991; O'Neill & Polman, 2004; Roth, 1995) and on the other hand they need to develop understanding of the Nature of Science (NoS) by viewing it from the *outside* (Driver, Leach, Millar & Scott, 1996; Lederman, 2007; McComas, 2004). The

Heat Game is designed to provide students with opportunities to develop their science literacy from the *inside*. Follow-up reflection questions on their work in the Heat Game offer students opportunities to develop science literacy from the *outside* (NOS).

The design of the Heat Game is based on the ideas of Gee (1996, 2004) who views the acquisition of a literacy such as science literacy as the development of a “social language” that is part of an “identity kit” that individuals who are insiders in a particular “Discourse community” take on. Individuals who are insiders in the Discourse community acquire a literacy by being part of a social network of like-minded individuals with similar identities, such as a scientist professional identity. The identity kit allows the individual to take on a particular social role that others will recognize (such as ‘lawyer in court’ or ‘doctor in surgery’ or operationally environmentally literate person in the world). According to this view, words, symbols and devices such as charts and graphs have particular meanings (Lemke, 1990; Wellington & Osborne, 2001) that are “situated meanings” in the context of the social language (Gee, 2004; Street, 1995).

In describing how people learn in video games Gee (2007) points out that video games can offer opportunities for players to take on new identities and develop new literacies. For example in *World of War Craft* players can take on identities as professional soldiers, and through interacting in that role with virtual expert soldiers within the elaborate scenario that the game provides, they can develop the literacy of the *World of War Craft*.

Modeled on such videogames, the Heat Game is designed to create opportunities for students to take on identities as science professionals, and interact in these roles with virtual expert scientists within a science scenario to conduct science activities and develop their science literacy from the *inside*.

To developing their science literacy from the *outside*, following completion of their work in the Heat Game they reflected on their activities guided by reflection questions that drew upon the work of Aikenhead & Ryan (1992). Aikenhead & Ryan, (1992) conducted extensive work to discover understandings and attitudes of Canadian students regarding the nature of science and the relationship between science, technology and society (STS).

Methodology

This is a teacher-researcher action research study (Elliot, 1991; Kremmis & McTaggart, 2000) in the tradition of reflective professional practice (Schon, 1983; Manfra, 2009). It is grounded in the view of teachers as “knowers and thinkers” (Cochran-Smith & Lytle, 1999, p. 15), who can conduct research in their own classrooms to bring about change and add to the development of theories for best practices in education.

Participants. The participants in this study were nine students who comprised the full cohort of a grade 7/8 class (aged 13-15 years) at a Montessori school in a small city in Ontario; seven girls and two boys. The researcher in this study was the teacher of the class. S/he had experience as a science researcher, had completed a doctorate in science and had published in peer reviewed science journals. In addition s/he had fourteen years experience as an elementary teacher.

Context. Over a six-week period, students worked on the Heat Game during normal science and technology class-time (2.5 hour/week) as well as many more hours of additional time by choice (classroom time when other work was completed and during lunchtime). In the Heat Game students take on one of three junior professional identities (physicist, engineer, environmental scientist) and work together, in character, in teams to conduct science activities in the lab, apply their knowledge to address a technological challenge and help solve an environmental problem. In character, via e-mail and blog, the students interact with virtual experts who are role-played by the teacher. The science is the physics of heat transfer and the testing of devices to reduce heat transfer, the technological challenge is to design energy-efficient housing, and the environmental problem is climate change. The end result of the students' work is presentations that students prepare for city council.

Constructed following the recommendations of Bibla (2007) for rich assessment tasks, the Heat Game begins with a power point presentation that introduces the scenario, and goal of the game: "The year is 2020. Energy costs have sky-rocketed due to diminishing fossil fuel resources and the expense of introducing renewable energy source technology. City Council desperately needs energy efficient house designs." Students then learn of their role in the project, "You are one of a team of three scientists: an environmental scientist, a physicist, and an engineer. The task for you and your team is to design energy-efficient housing and prepare a presentation and speech that you will perform for City Council to convince them to give your team the contract."

The objectives of the curriculum unit are embedded in the Heat Game through the requirements of city council. "City Council requires your presentation to include: a house plan and a list of the methods/devices you suggest to cut down heat transfer and reduce energy use; an explanation of your design choices in terms of the physics of heat transfer, engineering, environmental and societal impact, budget, comfort and ease of living." The students are introduced to the Virtual Experts though backstories provided on the blog , "On line you will receive help from The Virtual Experts. You can connect with them through your team e-mail account and blog".

For each class period, when the students arrive in the lab, they check the blog and their team e-mails for messages from The Virtual Experts. They work in their teams independently (with technical assistance from their teacher) to conduct their investigations and inquiries; design houses and e-mail findings and design ideas, comments and questions to the virtual experts.

To design their energy efficient houses in the Heat Game students use *The Sims* an extremely popular strategic life-simulation computer game (Wright, 2000). In *The Sims*, players normally use architectural design tools to construct “Dream” homes. In the Heat Game students modify features of *The Sims* to create their energy-efficient house designs.

At the end of the day the teacher (working in multiple characters as virtual experts) answers blog and e-mail correspondence and prepares further suggestions for next steps for students (including providing suggestions for lab. experiments and offering sources for on-line library research).

The Virtual Experts characters that the teacher creates behave as senior colleagues deeply interested in the outcome of the project. Each house design project ‘belongs’ to the team of students who are free to choose the direction they take.

Follow up reflection on the nature of science. The reflection questions were modified from the VOSTS instrument created by Aikenhead & Ryan (1992). VOSTS (Views on Science Technology Society) is a comprehensive series of statements about the nature of science and STS written in language accessible to high school and middle school students. These questions provided opportunities for students to reflect upon the work they had done in the Heat Game. The choice of statements was guided by the work that students actually conducted in the Heat Game. An example is “Do you think that students can add to scientific knowledge?”

Data sources. At the end of the Heat Game, all blog posts, comments and email messages between the teacher (in character as the virtual experts) and the students (in the character as junior professionals) were collected and organized into conversations based on the activities discussed within them. Twenty such conversations were collected, six to eight conversations per team. In this paper we examine one representative conversation.

Reflection Correspondence. The students' responses to modified VOSTS (Ryan &Aikenhead, 1992) were collected through e-mail.

Artifacts. Artifacts including student work on google documents and powerpoints for presentations were collected.

Data Analysis. The data analysis method used to examine how students developed science literacy was based on Gee's approach to analyzing discourse (Gee, 2005, 2011). First conversations, and the responses to the reflection questions and statements, and artifacts were coded for the speakers' use of situated meanings of words and phrases that are appropriate to the science context. Next the conversations and responses to reflection questions were examined for students' demonstrated understanding of science practices. Finally conversations and responses to reflection questions were examined for students' demonstrated understanding of the nature of science.

Findings

The findings we report in this paper concern one exemplary online conversation that occurred in the Heat Game between a student playing the role of Dr. Luna Spacey, junior physicist and the teacher playing the role of Dr. Patrick Boyle, expert physicist. This conversation occurred over a period of ten days and it was contained within twenty-one online exchanges, ten e-mails, three blog posts and seven blog comments. Dr. Spacey spent five hours in the lab on four different occasions throughout the time period. The reflection questions analyzed were addressed in writing by the teacher to the student who embodied Dr. Spacey at the end of the Heat Game.

The conversation and associated activities is first described followed by findings regarding Dr. Spacey's developing science literacy including science situated meanings, understanding of science practices, and understanding of the connections between science, technology, society and the environment.

Overview of the conversation and associated activities. The online role-playing conversation began when Dr. Boyle (teacher) sent Dr. Spacey (student) an e-mail asking for help. He asked her to try out some protocols for science demonstrations that he used in his teaching to see if she could get them working better since he was short of time before his class. Dr. Spacey selected one of these protocols to work on, entitled "Understanding the difference between temperature and heat." In this protocol, two bolts of different sizes (both made of the same material) are heated in boiling water. Each bolt is transferred to a separate container of an equal volume of room temperature water, and the temperature of that water is measured at regular intervals. The smaller bolt does not heat the water as much as the larger bolt, since the smaller mass has less heat energy to transfer to the water. The point of the demonstration is to illustrate that the amount of heat energy depends on more than just the temperature of a substance, it also depends on the mass of the substance (as well as the specific heat capacity of that particular substance).

Dr Spacey performed the protocol twice. The first time she did not get the results she was expecting so she adjusted the protocol and tried again. She e-mailed Dr Boyle to tell him about her findings both times and give him advice regarding the set up of the demonstration. She omitted some of the details Dr. Boyle needed to repeat the procedure and he asked her to get him those results, which she then presented on the blog.

After her report was published on the blog (Figure 1), Dr. Spacey received a comment (from Dr. Boyle) on her blog post asking her how this work might help in the design of an energy efficient house for sustainable living; the overall aim of the project. Dr. Spacey was drawn towards finding something in her report that she could link to this technological problem and real world need. Dr. Spacey responded by explaining that the experiment has led her team to the decision to downsize their house since that would reduce the amount of energy needed to heat it. They decided to reduce the size of their house from greater than 5000 sq. ft. to 648 sq. ft (see screenshots in Fig. 8) because it takes a smaller amount of heat energy to maintain a temperature of 20C in a smaller house and help reduce global warming.

Figure 1. Dr. Spacey's modified procedure for Dr. Boyle. A. (top left) the bolts; B. (top right) the bolts being heated to 100C; C. (bottom left) the bolts in the test-tubes of water; D. (bottom right) one of the test-tubes of water with the bolt added placed in an insulated cup and containing a thermometer for measuring water temperature at specific time intervals (this last step was repeated for both test-tubes).

Developing science literacy in the Heat Game: Science situated meanings. Situated meanings used in the conversation between Dr. Spacey (student) and Dr. Boyle (teacher) were first identified. Dr. Spacey began by using meanings from her everyday Discourse of these words and phrases while Dr. Boyle used meanings from his science Discourse. During the conversation, Dr. Spacey came to adopt the science Discourse meanings.

An example concerns the word ‘size.’ At first Dr. Spacey referred to the metal bolts used in the experiment as of “extremely different sizes” (Figure 2 lines 1&2).

and the results were a bit better. I used bolts that were extremely
different sizes. I used test tubes and a smaller amount of water instead of

Figure 2: Screenshot of part of Dr Spacey’s post.

She responded by measuring the lengths of the bolts (in centimeters) and sent that information to Dr. Boyle in a chart.

Details	Ex1	Ex2
Bolt size	Large: 11cm Small: 5.5cm	Large: 8.5cm Small: 2cm
Bolt type	Galvanized	Non-Galvanized
Water volume	Cups: 150ml	Test tubes: 50ml

Figure 3: Screenshot of Dr Spacey’s chart.

Dr. Boyle (teacher) responded by asking for the mass of the bolts explaining that he needed to know this because the bolts that he is using in his lab could be thinner .

Hi Dr Spacey,
I'm wondering about the bolts what is their mass? I am getting frustrated because when I try to repeat the experiment I don't get the same results! Now I thinking my bolts may be thinner. The best was to know that we are heating up the same amount of matter is if the bolts have the same mass. Could you please weigh your bolts and post a comment to let me know there mass?

Figure 3: Screenshot of a comment on Dr. Spacey’s post

Further, he explained that it is the mass that tells us how much matter the bolt contains and this is what is important in the protocol. Dr. Spacey posted a comment on the blog that gives the size of the different bolts as masses, which is the appropriate situated meaning of size for the social language within the Discourse of science.

I have sent some pictures that i hope will be posted soon but until then i guess I'll just have to answer by describing things. **the mass of the non-galvanized bolts** (the ones you should be using) are as follows.
large bolt - 59g
small bolt - 6g

Figure 4: Screenshot of Dr. Spacey's comment

Through this exchange Dr. Spacey came to use the appropriate situated meaning when speaking about difference in size.

Other adopted situated meanings were "heat energy" 'galvanized' and 'non-galvanized' for describing the type of metal bolt used in the experiment and "volume" for describing the amount of water.

Another way that Dr. Boyle passed on situated meanings was when he defined concepts. For example when Dr. Boyle was responding to Dr. Spacey's explanation of how her experiment can be applied to the problem of designing energy-efficient housing, he re-stated the results of Dr. Spacey's experiment and in so doing he explained the distinction between temperature and heat.

I guess the way I look at it is the amount of Heat depends not only on the temperature but also on the mass of matter that is at a particular temperature. The large bolt and the small the bolt were at the same temperature when you put them in the test tube but the large bolt had more heat energy because it had a larger mass. I guess that's why it heated the water to 29C insteas of 23C.
A very nice demonstration Dr. Spacey. Thank you again
Dr B.

Figure 5: Screenshot of Dr. Boyle's comment to Dr. Spacey's blog post

He explained that the amount of heat energy in a substance depends not only on the temperature of the substance but also on the mass of the substance (as well as on the specific heat capacity of the substance). He was providing her with a more science-Discourse-appropriate way of stating what she found in her experiment.

Later in the follow up reflection questions after the Heat Game, the student who embodied Dr. Spacey demonstrated that she retained understanding of some of these situated meanings. For example when asked “What conclusion did you draw from doing your experiment?” she replied, “People think temperature and heat are the same thing but they are not the same thing at all.”

Developing science literacy in the Heat Game: science practices. An aspect of science literacy that Dr. Spacey (student) developed through her conversation with Dr. Boyle (teacher) concerned the fundamental need in science for writing reports so that results could be reproduced. Dr. Spacey was asked to provide information needed to repeat her experiment (Figure 6).

Dear Dr. Spacey,
I am a student of Dr. Boyle's and I have been attempting to repeat your experiment since you achieved good results with your modifications to Dr. Boyle's procedure. I have not reproduced your results and I think it is because there are a couple of items that are not clear in your procedure. First what volume of water did you use in your test tubes? What was the mass of the bolts you used? Could you please e-mail this info. so that it can be posted on the BLOG. so that I can repeat your experiment and get equally impressive results?
Thank-you from a student

Figure 6: Screen shot of comment requesting details

This introduced Dr. Spacey to the reason behind careful reporting in science: reports must be written in such a way that procedures can be repeated exactly in another location because in science discourse, experimental results are considered valid when they *can* be repeated by following the published procedure, and scientists often check each other’s work before sending it for publication.

Another aspect of science reporting was the organization of experimental information into the style of report appropriate to science communication. The original protocol that Dr. Spacey received from Dr. Boyle (teacher) included a chart for collecting data. When Dr. Spacey first provided results to Dr. Boyle she used a modification of this chart. The next time that Dr. Spacey provided results she chose to use a chart again even though this is not requested by Dr.

Boyle (Figure 3). This suggested that she was acquiring the understanding of the use of charts as the appropriate form for representing science results. Later Dr. Boyle asked Dr. Spacey to take pictures of her experiments. Dr. Spacey took pictures and Dr. Boyle chose those that illustrated the steps of the protocol (Figure 1). By so doing Dr. Boyle modeled for Dr. Spacey the manner in which scientists use photographic representations of the steps in their protocol to show other scientists what they did.

The student who had embodied Dr. Spacey again expressed her developing science literacy regarding understanding science processes in the response to reflection questions at the end of the Heat Game. This can be seen in her response to the reflection question, "Can students contribute to science knowledge?"

1. Well just because we're students
2. doesn't mean we can't make discoveries
3.I mean, we're young but we're not unintelligent
4. We could be doing an experiment that we thought up
5. and discover something new
6. Then we could send it to a professional scientist
7. Who would do the experiment again
8. And then publish it
9. And give us our credit for thinking it up
10. So theoretically we could be contributing to much more science knowledge
11. than you think we are.

In this passage she exhibited aspects her understandings of the practices of science professionals in a variety of ways: scientists do experiments to discover something new about the world (lines 4&5); scientists do not work in isolation, they communicate with each other (line 6); scientists repeat each other's work to find out if the results can be reproduced (line 7); scientists peer-review each other's work before it is published (line 8); and scientists get credit for publications (lines 9&10).

Developing science literacy in the Heat Game: Relationships between science and technology and the environment. A third aspect of science literacy that Dr. Spacey developed is the understanding of the connection between science and technology. In the Heat Game, after Dr. Spacey posted her results of her experiment on the Blog she was asked in a blog comment if she could think of a way to apply what she had found out to the task of designing an energy efficient house.

Hi Dr Spacey,
I wonder could you relate the results of your experiment to our project to Design Housing for Sustainable Living? How do you see this relationship? I am interested in designing a truly energy efficient house and I think this can help me.

Figure 7: Screenshot of a question for Dr. Spacey posted as a comment on the blog.

Dr. Spacey responded to say that the experiment suggested the team should downsize their house.

This experiment is telling us that we want to build a smaller house for sustainable living. My reasoning for this is that with a smaller house you have a smaller amount of space that needs heating during the year. Which means that it won't cost as much to heat a smaller house. With this information you could theoretically build the perfect house for the Johnson Family. They want a low cost for energy bills in their house. Heating takes up energy. With a smaller house you need less heat which means you need to use less energy.

This connection led Dr. Spacey's team to create a small house for sustainable living.

Figure 8: Screenshot of Dr. Spacey's response

Figure. 8 Screenshots of the house designs (*Sims, Maxis*) from Dr. Spacey's team. House 1(on the left) had an area of more than 5000 sq. ft whereas the downsized house 2 (on the right) had an area of 648 sq. ft.

When Dr. Spacey and her team presented to city council they explained that in their opinion "downsizing is the single most important thing we can do to reduce energy use."

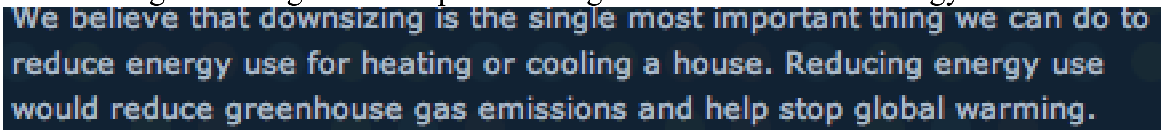
We believe that downsizing is the single most important thing we can do to reduce energy use for heating or cooling a house. Reducing energy use would reduce greenhouse gas emissions and help stop global warming.

Figure 9: Screenshot of Dr. Spacey's team speech to City Council.

Discussion

The aim of this action research study was to help a teacher learn something about how her students developed their science literacy through the Heat Game by focusing on one representative conversation. Evidence presented suggests that through developing a professional identity and corresponding as a colleague with an expert professional in a simulation of a science world, the student who embodied Dr. Spacey had opportunities to acquire aspects of science literacy including science situated meanings of words and phrases, awareness of science practices, and understanding of the manner in which science, technology are connected to each other and to the environment.

This preliminary trial of the Heat Game and follow-up reflection questions demonstrates that it can be an effective approach for helping students achieve curriculum goals and expectations, and develop the kind of science literacy where they not only understand how knowledge is generated through scientific inquiry and applied to technological innovation, but also understand something of the nature of science. In the future, similar games could be constructed for other units of curriculum and it is hoped that through their use students could come to better understand science and appreciate its significance in their lives.

This was the first iteration of the Heat Game and the study made evident to the teacher several aspects that she would like to change. One example of a change that the teacher would like to make in future iterations of the Heat Game is in the choice of the activities. One example is this ‘protocol adjustment’ activity that Dr. Spacey engaged in. Although Chinn and Malhorta (2002) do list protocol adjustment as an authentic science activity, based on current curriculum guidelines (OCST, 2007; NGSS, 2013), an open-ended science inquiry activity would be a more appropriate choice.

In future iterations of the Heat Game the teacher would like to recruit real scientists and engineers to the role of Virtual Experts to make the simulation a more effective representation of a science world. Organizations in Canada such as *Virtual Researchers on Call* VROC (2014) have already demonstrated success with enhancing learning opportunities for students through connection with real scientists.

To continue with this work the obvious next stage is to test the project in a larger setting. The intricacies of running the project for a larger group of students will no doubt provide challenges. Through repeated iterative cycles of design and trial and redesign it is hoped that a project suitable for this larger setting will be developed.

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