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Developing Awareness of Connections Between Science, Technology and the Environment through Participation in a Game-Like Approach to Curriculum

Desenvolvendo a consciência das conexões entre Ciência, Tecnologia e Ambiente pela participação em uma abordagem do currículo como jogo

Carol Rees

Thompson Rivers University
BC, Canada
crees@tru.ca

Abstract

If we are ever to achieve the goal of redirecting technological development along more environmentally and socially responsible lines we need to provide students with opportunities to examine the processes of science and technology, the possible costs and consequences of this work, and the choices available to us. The purpose of this study is to examine students' developing environmental literacy in the *Heat Game*. The *Heat Game* is a game-like approach to curriculum designed to support students developing their environmental literacy while addressing curriculum requirements for a grade 7 unit, *Heat in the Environment,* in Ontario, Canada. Based on principles of learning in video-games, the *Heat Game* recreates a simulation of a science and technology setting wherein student-participants role-play junior professional scientists communicating online within a community of scientists. In their roles they work to solve a virtual challenge to design energy-efficient housing, and reflect on possible environmental and societal consequences of their designs. This study, which is part of a larger design-based research study of The *Heat Game,* uses discourse analysis to examine online role-playing conversations generated within the game as well as online correspondence between students and their teacher after the game. The study demonstrates that through actions and online conversations in the *Heat Game* students developed their environmental literacy, including understandings of the relationships between science, technology and the environment and the consequences of choices we make. In addition the study provides support for the ideas of Gee (2007) regarding how we can use the principles of learning in video games to create opportunities for students to develop a literacy; in this case environmental literacy.

Keywords: Environmental literacy; STSE education; discourse analysis; learning through video games; middle school education.

Resumo

Se um dia quisermos alcançar o objetivo de redirecionar o desenvolvimento tecnológico ao longo de linhas mais ambiental e socialmente responsáveis, precisamos proporcionar aos alunos oportunidades para examinarem os processos da ciência e da tecnologia, os possíveis custos e consequências deste trabalho, e as opções disponíveis para nós. O objetivo deste estudo é examinar o desenvolvimento da alfabetização ambiental dos alunos no *Heat Game*. O *Heat Game* é uma abordagem do currículo como jogo concebido para apoiar os alunos a desenvolverem a sua alfabetização ambiental enquanto aborda simultaneamente as exigências curriculares para uma unidade temática, calor no ambiente, em Ontário, Canadá. Com base nos princípios de aprendizagem em vídeo-games, o *Heat Game* recria a simulação de um cenário de ciência e tecnologia em que os alunos-participantes dramatizam cientistas profissionais em comunicação on-line dentro de uma comunidade de cientistas. Em seus papéis, eles trabalham para resolver um desafio virtual de projetar habitações energeticamente eficiente, e refletir sobre as possíveis consequências ambientais e sociais de seus projetos. Este estudo, que é parte de uma pesquisa maior sobre o estudo do projeto do *Heat Game*, utiliza a análise de discurso para analisar as conversas on-line dos participantes dentro do jogo, bem como a correspondência on-line entre os estudantes e seu professor após o jogo. O estudo demonstra que através de ações e conversas on-line os alunos desenvolveram sua alfabetização ambiental, incluindo a compreensão das relações entre ciência, tecnologia e ambiente e as consequências das escolhas que fazemos. Além disso, o estudo fornece suporte para as ideias de Gee (2007) a respeito de como podemos utilizar os princípios da aprendizagem em videogames para criar oportunidades para os alunos desenvolverem a alfabetização; neste caso alfabetização ambiental.

Palavras-chave: alfabetização; educação CTSA; análise do discurso; aprendizagem através de videogames; ensino fundamental.

Introduction

We live in a time when we can no longer ignore the environmental crises (e.g. climate change, environmental degradation, toxic chemicals in the environment, illness and disease) that result from our dominant mindset that positions us as separate from the natural world (SARKER, 2012). Science Technology Society and the Environment (STSE) education aims to engage students' to develop understanding of the societal and environmental consequences of our science and technological actions (AIKENHEAD, 2003). STSE education can help students take social action and develop environmental stewardship (HODSON, 2003).

The *Heat Game* that is the focus of this study is a role-playing game designed to provide students with an opportunity to develop their environmental literacy through role-playing environmentally literate science professionals, taking virtual actions, and communicating online with Virtual Experts in order to develop the kind of environmental literacy that includes environmentally conscious perspectives and awareness of the connections among science, technology, and the environment.

The purpose of this study is to examine how Grade 7/8 students' environmental literacy develops through the *Heat Game* using Discourse Analysis (GEE, 2005) of their online correspondence.

The study addresses the following research questions:

1. In what ways do students demonstrate identities as environmentally literate persons (ELPs) in the *Heat Game*?

2. In what ways do students demonstrate awareness of the connections between science, technology, and the environment and awareness of the consequences of the choices we make?

Background

Based on the ideas of Gee (1996) a literacy, such as environmental literacy, is a social language (GEE, 1996) that individuals can acquire through being part of a social network of like-minded people who share particular values, beliefs and attitudes, and ways of thinking, acting, and communicating. This study examines the acquisition of students' environmental literacy in the *Heat Game* using Disinger and Roth's (1992) definition of environmental literacy. According to Disinger and Roth (1992) the particular values, beliefs and attitudes, and ways of thinking, acting, and communicating that environmentally literate persons share, include the following:

1. evaluating the impacts and consequences of actions,
2. gathering and synthesize pertinent information,
3. choosing among alternatives,
4. advocating action positions, and
5. taking actions that work to sustain or enhance a healthy environment.

Following Gee's ideas, The *Heat Game,* is designed to support students acquiring environmental literacy by providing them the opportunity to take on the role of environmentally literate persons in a simulation of a social network of like-minded individuals. Students take actions appropriate to that role, and communicate with environmentally literate individuals within this social network. Gee (2007) offers the example of the video game *World of Warcraft* wherein players take on the role of a professional soldier and through interacting in that role within the elaborate simulation that the game provides, they develop their *World of Warcraft* literacy.

Though studying games such as *World of Warcraft*, Gee (2007) has elucidated principles of learning that can be applied to constructing effective learning games for educational settings. These principles are incorporated into the design of the *Heat Game*. The principles include the following: a high level of *interactivity* and *agency* for players to experience, *strong identities* with compelling narratives and "back-stories" for characters that make learning *embodied and affective*; learning is *collaborative and distributed* between the participants and virtual expert professionals; *problems are well ordered* and *pleasantly frustrating* to solve because the challenge is at the outer limit of the participant's "regime of competence" (GEE, 2007). *Cycles of expertise* are offered so that players can practice and improve with *low consequences of failure*. Information is provided *just in time* when players most need it to complete their tasks. These learning principles have been used as the basis

of other educational games including *Mad City Mysteries* (SQUIRE; JAN, 2007), and the epistemic games of Shaffer (2006). The *Heat Game* is modeled on the games of Squire and Jan (2007) and Shaffer (2006).

Description of the *Heat Game*

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 laboratory and apply their knowledge to address a technological challenge and help solve an environmental problem (REES, 2014). The science topic involved 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. In character, via e-mail and blog, the students connect with virtual experts who are role-played by the teacher. Through these on-line exchanges as well as real and simulated deeds, students experience a science and technology world peopled by professionals focused on solving an environmental problem. The project ends with presentations that students prepare for a simulated City Council and speeches that students actually present to the real City Council of their hometown.

The description of the game follows the work of Bibla (2007) who identified five features important in curriculum planning: Goal, Role, Audience, Scenario, Performance.

The *Heat Game* is introduced with a PowerPoint presentation that provides 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 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 (your Audience) to convince them to give your team the contract.”

In order to win, house designs must satisfy City Council’s requirements. “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. On line you will receive help from The Virtual Experts. You can connect with them through your team e-mail account and blog.”

When the students arrive in the lab in each class, they check the blog and their team e-mails for messages from The Virtual Experts. The teams work independently (with technical assistance from their teacher) to conduct their lab investigations and inquiries. Using *The Sims* they create their house designs. *The Sims* is 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 energy-efficient house designs.

Teams communicate their results, comments, and questions to the Virtual Experts via e-mail. At the end of the day the teacher (working in character as multiple virtual experts)

answers blog and e-mail correspondence and prepares further suggestions for next steps for the students in the laboratory and offers sources for on-line library research.

In the role of the Virtual Experts the teacher acts as senior colleagues who are deeply interested in the outcome of the project. Each house design project 'belongs' to the team of students, who are free to choose their own direction. The relationships between virtual expert professionals and students are designed to mimic those between science professors and their graduate students.

Methodology

This study is part of a larger design-based research study (Design Based Research (DBR) Collective, 2003) of the *Heat Game*. DBR involves cycles of game design; generation of hypotheses about game-elements that might be more effective; redesign and hypothesis refinement, where the appropriateness of game-design-changes comes from observing the educational outcomes developed by the students who practice the game in each cycle (DBR COLLECTIVE, 2003). The present study uses Discourse Analysis according to the methods of Gee (2005) to focus on the development of students' environmental literacy in online exchanges within and following the *Heat Game.* The theoretical foundation of Gee's Discourse Analysis is that language is used for multiple purposes, including the demonstration of belonging (identity) to a particular social group such as a group of Environmentally Literate persons. In Gee's words language primarily serves, "to support the performance of social activities and social identities and to support human affiliation with cultures, social groups, and institutions," (GEE, 2005, p.1)

In this study we first examined ways that students establish an environmentally literate identity in online correspondence within the environmentally literate social group in the *Heat Game* and then, at the end of the *Heat Game,* examined students' developing environmental literacy; in particular their understandings of connections between science, technology, and the environment.

Participants

The participants in this study were nine students (seven girls; two boys) who comprised the full cohort of a grade 7/8 class (aged 13-15 years) at a small private school in a small city in Ontario, Canada. Over a six-week period, students participated in the *Heat Game* during normal science & technology class-time (averaging 4 hours/week) as well as many more hours of additional time by choice (other classroom time when other work was completed, during lunchtime, and after school). The science teacher was the researcher for the study.

Data Collection

Three data sets were used in this study: 1) Students' and teacher's e-mail and blog correspondence within the *Heat Game*; 2) Students' work on Google documents produced in preparation for their presentations to City Council at the end of the *Heat Game;* 3) Students' responses to follow-up statements addressed to them after the *Heat Game* was

finished. Examples of these statements modified from Ryan and Aikenhead (1992) are: “Scientists should not be held responsible for the harm that might result from their discoveries”. “Science and technology can be relied upon to fix pollution problems in the future”.

Data Analysis

Data were first coded by relevance to environmental literacy and connections between science technology and environment, then for indications of the characteristics of ELPs (DISINGER; ROTH, 1992), as follows:

1. evaluating the impacts and consequences of actions,
2. gathering and synthesizing pertinent information,
3. choosing among alternatives,
4. advocating action positions,
5. taking actions (virtually and/or in the real world) that work to sustain or enhance a healthy environment.

Findings

1. Students demonstrate identities as environmentally literate persons (ELPs) in the *Heat Game*.

Indications of students exhibiting ELP identities were first found at the beginning of the *Heat Game* when those students playing Environmental Scientists first introduced themselves to the Virtual Expert Environmental Scientist, Dr Rita Carson in their introductions on the *Heat Game* Blog (see Figure 1 screenshot).

Anonymous said...

Hello my name is Dr. Kendra Acre and i attended university at Harvard. My experience is i have been into the enviroment all my life. This is one of the things that i did in high school i was in an enviromental club and later on i became the leader of that club. As you probally know i wrote a book and it is called leading the enviroment it is about what kind of things that can help our enviroment. Some of my hobbiesthat i like to do is to go for long walks with my dog and also go out and pick up garbage because it makes me feel like i am doing somthing good with my life.

March 21, 2007 at 8:18 AM

Figure 1 Student Identifies as the Environmental Scientist for her Team (screenshot)

In this Blog comment the student playing the role of Dr Kendra Acre, (the environmental scientist for team C) demonstrates her creation of a fictional ELP identity for herself by establishing her interest in the environment all her life (line 1-2), and how this impacted her choices of the actions she has taken (lines 2-5) - (OELP characteristics #3, 5):

Throughout the course of the *Heat Game* students demonstrated their ELP identities through their activities as seen in the example in Figure 2.

In this post (Figure 2) the student role-playing Dr Lola Justice (the environmental scientist for team B) demonstrates her ELP identity when she mentions the gathering and synthesis of pertinent information (ELP characteristics # 3), and later, in the decision of her team to incorporate a green roof into their house design (Figure 3) – (ELP characteristics # 5). As well as the green roof illustrated in Fig 3, this first house design of Heat Team B incorporates a solarium, a passive solar design and a thermal chimney. Students modified functions on *Sims* to incorporate these design features.

Students maintained their ELP identities even when talking to each other more informally on the Blog through comments (Figure 4).

Dr Peff-Puff, engineer for Team A, demonstrates her ELP identity when she asks Team B for information (ELP characteristic # 2) about how they modified the Sims features to create the greenhouse roof for their house, commenting that, “it is a great energy saving feature” (line 1) and asking if “it acts like a greenhouse (line 2).”

At the culmination of the *Heat Game* all three teams demonstrate ELP identities when they evaluate the impacts of their actions, gather information, chose energy efficient alternatives and talk about their virtual actions within the *Heat Game* (ELP characteristics 1,2, 3,5), to the real engineering and environmental experts from their city who make up the mock city council. An example of a presentation slide is shown in Figure 5.

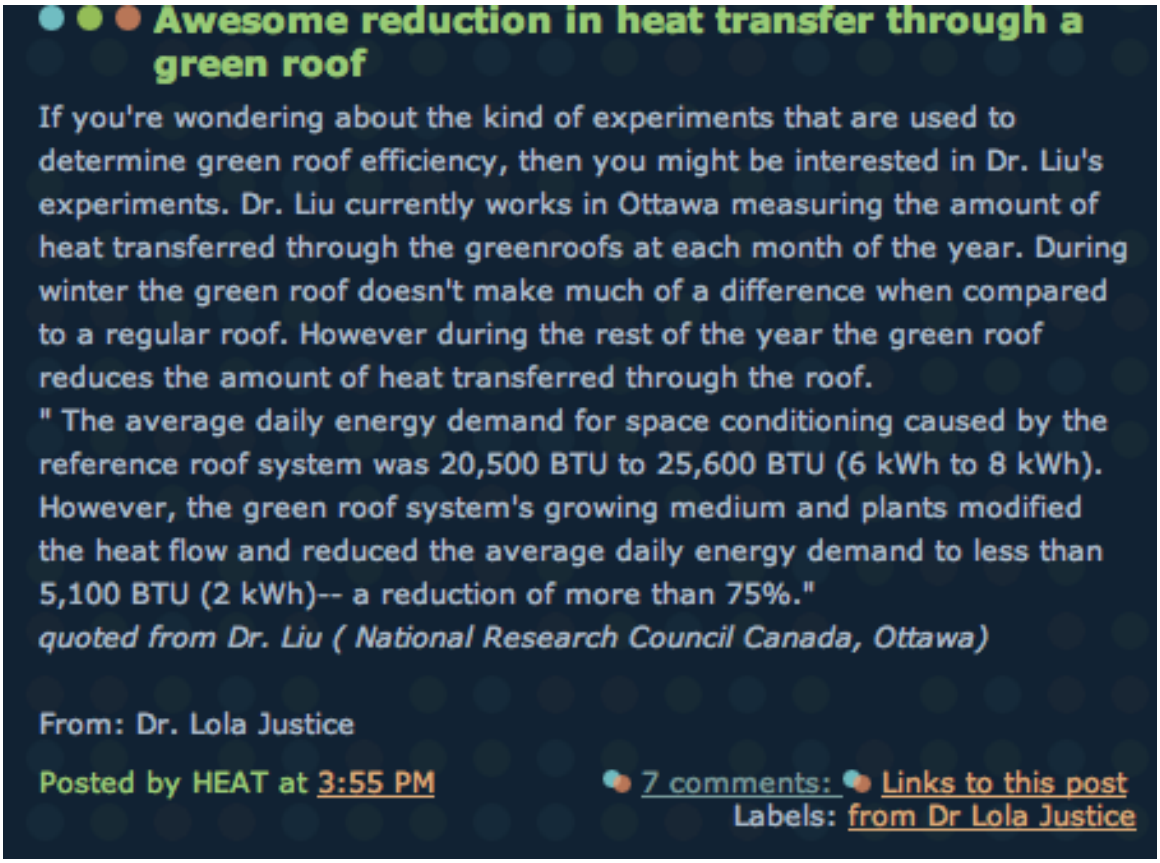

Figure 2. Post on the Blog (screenshot)

Figure 3. The First Energy Efficient House Design by Heat Team B (screenshot).

Dr. Peff-Puff said...

hye guys!
nice house, i was just wondering how you get those glass sloping roofs on sims. It is a great energy saving feature and does it act like a greenhosue and keep all the heat in?
hehe Dr. Peff-Puff

April 30, 2007 at 5:05 PM

Anonymous said...

Dear Dr.Peff-puff You need the new sims seasons in order to get a greenhouse roof and yes it does keep the heat in.
From F.A.M

May 2, 2007 at 7:55 AM

Figure 4. Teams Exchange Information (screen shot)

Their PowerPoint presentations included pictures of their *Sims* houses, an explanation of their technological choices to reduce heat transfer, and how their choices impact the environment. Students received very supportive feedback from the mock City Council.

Following this experience they went on to present shorter speeches for the real City Council of their hometown. In their speeches they all exhibited ELP identities when they recommended to City Council that it should incorporate students' findings in future building plans (ELP characteristic # 4). Their speeches were televised and reported in the local newspaper, one City Councilor made a speech about the importance of the students' work and how City Council would follow-up and consider the students ideas in future plans. Given all of this positive feedback it is not surprising that students maintained their ELP identities in the weeks following the *Heat Game*.

Figure 5. Excerpts from the PowerPoint of Drs. Peff-Puff, Leets, and Huggatree (Screenshot)

2. Students demonstrated awareness of the connections between science, technology, and the environment and awareness of the consequences of the choices we make.

The previous section shows that when students were role-playing in the *Heat Game* they demonstrated identities as environmentally literate persons (ELPs**).** They also demonstrated awareness of the connections between science, technology, and the environment and awareness of the consequences of the choices we make. For example in Figure 5 Drs Peff-Puff, Leets, and Huggatree demonstrate awareness of the connection between technology and the environment in their description of their house, when they say, "this will reduce energy use and energy costs and it will cut down on the production of greenhouse gases and help stop climate change."

After completion of the *Heat Game* students also demonstrated their thoughts about the consequences of the choices we make, in their responses to the statements addressed to them by the teacher.

For example when the students who had embodied Drs. Peff-Puff, Leets and Huggatree in the *Heat Game* were asked to comment on the statement, "Scientists and engineers should not be held responsible for the harm that might result from their work", they responded as follows:

> "Some projects are much worse for the environment and not necessarily needed. If the scientists and engineers had to think about if it was going to have a negative

> effect on the environment, they would have to think about if they actually needed it and if they didn't the project may be terminated."

The students are indicating their belief that scientists and engineers have decisions to make about the possible consequences of their actions in their projects. Finally, when asked to respond to the statement, "Science and technology can be relied upon to fix pollution problems in the future", the students who embodied Dr Justice and Dr Hudson replied as follows:

> "[…] we the people are the ones responsible for pollution and we are the ones who have to cut down. In the future there may be devices that might help but we don't see that time coming along any time soon."

These students are indicating that it is "we the people" who need to take responsibility for those actions that can have negative impacts on the environment.

Conclusions

This study demonstrates, using Discourse Analysis (GEE, 2005) that by engaging in the *Heat Game,* students had the opportunity to take on roles as environmentally literate persons and develop their environmental literacy. Through their virtual actions in the *Heat Game,* students built awareness of the connections between science, technology and the environment and the consequences of the choices we make. Following the *Heat Game* they maintained their environmental literacy when they addressed the real City Council of their hometown and when they explained their perspectives to their teacher.

Shaffer (2006) comments that his "epistemic games," allow students to take on the mindset of a particular professional group so as to see the world from their point of view. Based on the principles of learning in video games (GEE, 2007) and the games of Squire and Jan (2006) and Shaffer (2006) the *Heat Game* offers students an opportunity to look at life from the perspective of environmentally literate persons and develop awareness of the connections between science, technology and the environment.

In future iterations of the *Heat Game* it is intended that real experts will become involved as mentors. Exciting plans for future developments include incorporating ideas from studies of *PlantingScience* (Scogin, 2014), a program developed by the Botanical Society of America that uses online mentoring with real experts in the field of Botany.

Continuing studies of the *Heat Game* are exploring identities exhibited by students taking on the roles of physicists and engineers, how students develop their science literacy through the *Heat Game*, and features of effective online mentoring that the teacher exhibits (GARRISON, 2011).

References

AIKENHEAD, G.S. "What is STS Science Teaching?" In: SOLOMON, J.; AIKENHEAD, G.S. (Eds.), **STS Education**: International Perspectives in Reform. New York: Teacher's College Press, 1994.

AIKENHEAD, G.S.; RYAN, A. The development of a new instrument: 'Views on Science-Technology-Society' (VOSTS). **Science Education**, vol.76, p.477-492, 1992.

BIBLA, S.; GRASP A **Tool for Developing Environmental Literacy**. Toronto: Toronto District School Board, 2007.

DESIGN-BASED RESEARCH COLLECTIVE. Design-based research: An emerging paradigm for educational inquiry. **Educational Researche**r, vol.32, p.5-8, 2003.

DISINGER, J.F.; ROTH C.E. Environmental Literacy. **ERIC Clearinghouse for Science, Mathematics, and Environmental Education**, 1992 Available at <http://www.ericdigests.org/1992-1/literacy.htm > (Accessed 11, October, 2013).

GARRISON, D.R. **E-learning in the 21st century**: A framework for research and practice [second edition]. New York: Routledge, 2011.

GEE, J.P. Good video games and good learning: collected essays on video games, learning and literacy. New York: Peter Lang, 2007.

GEE, J.P. **Social Linguistics and Literacies**: Ideology and Discourses. London: Routledge, 1996.

_____. **An Introduction to discourse analysis.** [Second Edition]. London: Routledge, 2005.

_____. **Situated language and learning**: a critique of traditional schooling. London: Routledge, 2004.

HODSON, D. Time for action: science education for an alternative future, International Journal of Science Education, vol.25, n.6, p.645-670, 2003.

REES, C.A. Analyzing actions and interactions in a game-like approach to curriculum based on video game research. In: National Association for Research in Science Teaching (NARST) international conference, 2014. **Proceedings…** Pittsburg, U.S.A, 2014.

SARKER, S. **Environmental philosophy**: From theory to practice. Chichester, West Sussex: Wiley-Blackwell, 2012.

SCOGIN, S. Motivational support and student inquiry engagement: a self-determination theory perspective on online scientist-mentoring. In: National Association for Research in Science Teaching (NARST) international conference, 2014. **Proceedings…** Pittsburg, U.S.A, 2014.

SHAFFER, D.W. **How computer games help children learn.** New York: Palgrave Macmillan, 2006.

SQUIRE, K.D., JAN M-F. Mad city mystery: developing scientific argumentation skills with a place-based augmented reality game on handheld computers. **Journal of Science Education and Technology**, vol.16, n.1, p.5-29, 2007.

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