Game Effectiveness of Power Ville in Promoting Science and Engineering Design

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Game Effectiveness of *Power Ville* in Promoting Science and Engineering Design

ABSTRACT

This paper presents a virtual reality (VR) game, *Power Ville*, which aims to infuse cyberinfrastructure (CI) learning experiences into the pre-engineering classrooms and to promote science and engineering design. The design and implementation of the game are described in detail with the focus on the CI features, metacognitive strategies, context-oriented approaches as well as their seamless integration into core game play.

INTRODUCTION

K-12 education is facing the challenge of educating all children to meet higher standards in areas of science, technology, engineering, and mathematics (STEM). For instance, schooling remains highly departmentalized, stratified and continues to teach subjects in isolation, with little or no attempts to draw connections among the STEM disciplines [1]. Schools have not kept pace with the transformative technological revolution to bring much needed cyberinfrastructure (CI) learning experiences into secondary classrooms due to the lack of resources and training for teachers. All of those have direct, negative impact on students' choice and interest in STEM.

To address this challenge, our project [2] proposes a scaffold approach that develops and implements a virtual reality (VR) game system, called *SustainCity*, to infuse CI learning experiences into classrooms of secondary education. This paper, in particular, presents one of the games, *Power Ville*, with the focus on its design, implementation, and assessment. The game incorporates the access to visualization, simulation, modeling and collaboration tools, creating an interactive and collaborative learning environment for students to digitally explore science and engineering concepts via virtual analysis and design.

OVERVIEW OF POWER VILLE

Cooking a dinner, heating a house, lighting a street, and running a factory - all of these need power. Energy is thus at the heart of everybody's quality of life. How to generate and use energy that satisfies increasing energy needs while combating climate changes at the same time becomes an unprecedented challenge for a sustainable city development. The goal of the *Power Ville* VR game is to educate students about four energy choices (coal, wind, solar, and nuclear) and the impact of those choices on the environment of the city. To implement this goal, the game incorporated the CI tools, which are gaming, simulation and networking, and the three metacognitive interventions.

Goal identification is of importance in game playing to motivate players and promote a deep understanding of content [3]. In *Power Ville*, each player is introduced to the game by visiting the city hall and talking to the Mayor of the city as shown in Fig. 1a. The conversation asks the player to take the task, as a consulting engineer, to conduct and report a thorough analysis on the most suitable form of energy for the future of the city with the given city budget and energy demands. Meanwhile, the player is urged to visit different facility buildings and talk to individual power system experts for vital information regarding the pros and cons of various energy sources. Succeeding in this role requires that the player understand and apply the knowledge about power and energy systems learned in both the classroom and the game environment, together with the writing skills to collect appropriate evidence and compose a persuasive piece of writing. In fact, the game is designed in the way that automatically composes a final report for the player by using every justification the player provides in the question prompts (Fig. 1b) at different game stages.

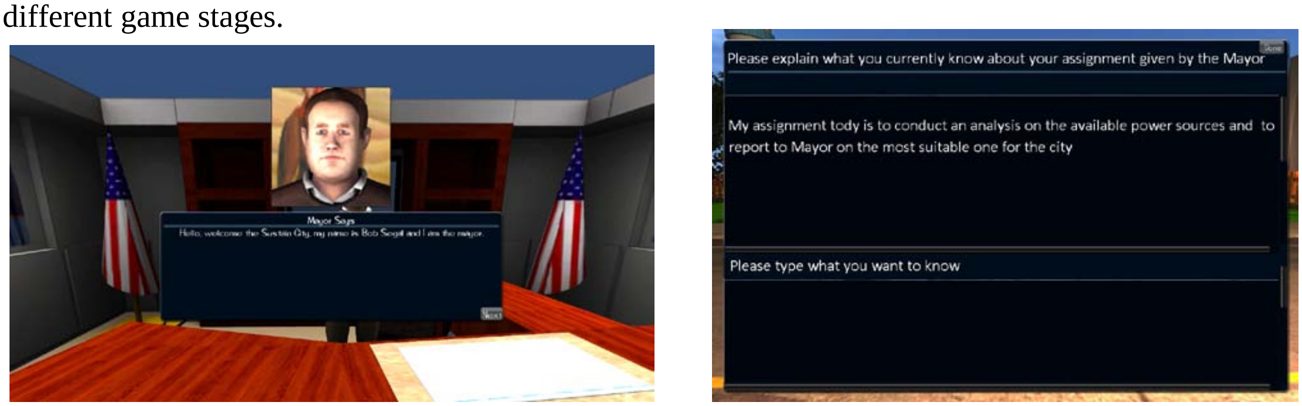
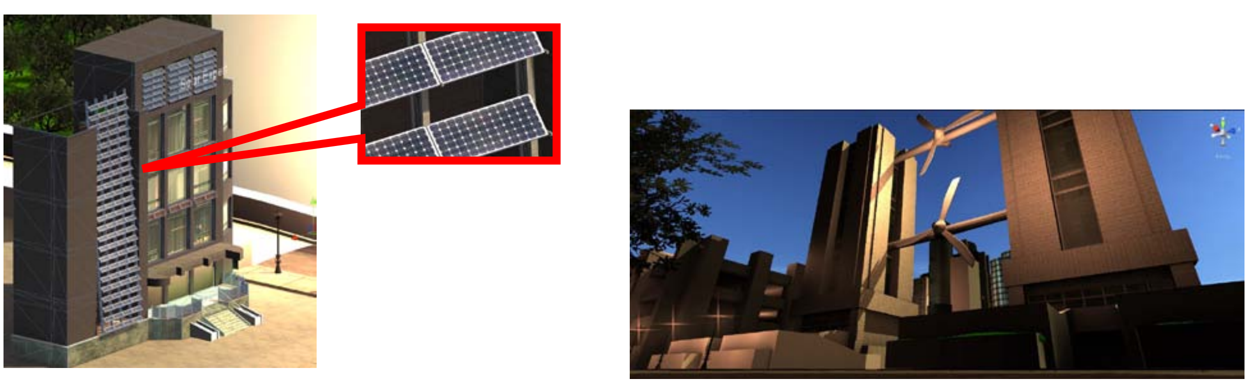


Fig. 1: (a) Chat with Mayor for the assignment; (b) a question prompt after a player visited the Mayor's room

After players exit the city hall, they must talk to different power system experts located in offices spread across the city. The game environment is designed for easy navigation as each office building has identifiable and unique landmarks. For instance, the solar-power building contains racks of solar-panels and the wind power building has large turbines that tower over the streets below (Fig. 2). In addition, the *Road Map* tool, one of the metacognitive interventions, is always available on a game menu for players to retrieve the next task in the must-do list and to show the cost and the peak energy output of a particular power source (Fig. 3). The game menu is launched through the TAB key. After players interact with individual experts, watch a video, and do a quiz, or play a mini-game on the energy production process they are exploring, they are prompted to write about stories from characters they talk to. These notes are recorded in What I Know - What I Want to Know - What I have Solved (KWS) chart. Players can launch KWS via the game menu to modify their notes (Fig. 4). As the logs for each player, particularly the What-I-Know section of the KWS, are automatically used to compose his or her final report, the player has to craft the notes using the most compelling support for their argument.



(a) (b)

Fig. 2: the symbolic design for all buildings in the game (a - Solar building; b - Wind building)

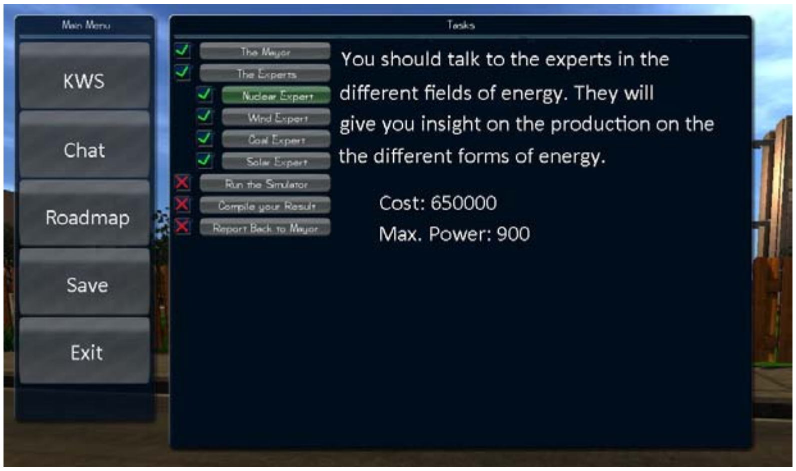


Fig. 3: The roadmap in *Power Ville*

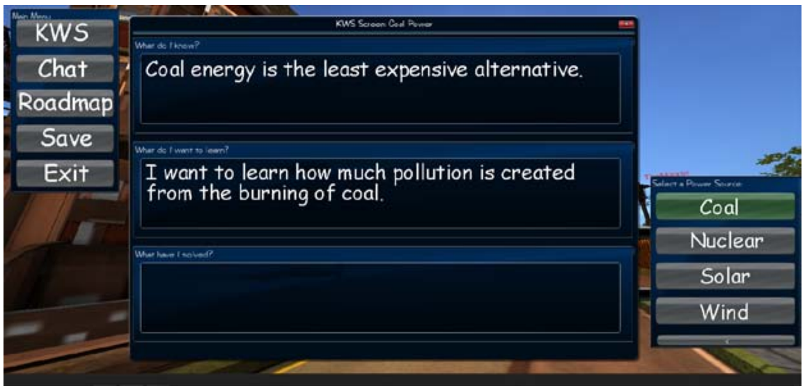


Fig. 4: the student's inputs to the prompt is recorded in his/her KWS

Soon after visiting all experts and making their way to their apartment, players are provided with two other CI tools, *Simulator* and *Optimization*, to help formulate their answers as to the best energy source for the future of the city. The *Simulator* allows players to select each of four different power sources with a given demand as well as other source-dependent constraints, such as sun exposure for solar power and wind speed for wind power. It then visually outputs the total amount of CO2 emissions and the total environmental impact of the chosen power source. As shown in Fig. 5, the simulation run of the coal power source indicates the footprint of the power generation and warns the player the potential of coal being depleted as a non-renewable energy. The *Optimization* tool, on the other hand, provides students the experiences of computer-supported problem solving. In particular, the tool scopes the city into different areas which can be powered by different sources of the player's choice. Whenever the player makes such a decision, the information tally on the screen is then dynamically updated with respect to the amount of power that can be generated versus the demand and the amount of budget required versus available. The updates clearly show how the decision helps or hinders to achieve the optimization goal.

Fig. 5: The interactive simulator in *Power Ville*

IMPLEMENTATION AND ASSESSMENT

The initial pilot of *Power Ville* was conducted in *Principles of Engineering (POE)* course as part of their laboratory activities at Burlington County Institute of Technology – a vocational school in New Jersey. An online survey, administrated by the International Society for Technology in Education (ISTE), was then given to the 15 students upon their completion of the game.

One of the important findings from the survey is that some additional scaffolding may be necessary for students to get the most benefit from the game experience. For instance, the metacognitive tools were generally usable for students without much assistance, but the students reacted differently to Road Map, KWS, and chat. Road Map was the most popular. About half the students used KWS, but were not sure of its value. One student commented, "*I felt like the KWS was a bit unnecessary; however, if you were to create a notebook to take notes during the videos I believe that it would be used*." In fact, the note-taking function is present; but the student did not find it. Similarly, few students used chat (although, possibly because of personal computing experience, most predicted they would use it for future problem-solving). One student felt that KWS was "*redundant if you have chat*," as if the KWS structure of questions and the ability to ask questions were interchangeable. A larger issue is to help students understand that KWS is a simplified, specific instance of a general problem-solving framework that they will need to use throughout their careers in addressing novel challenges.

Minor interface adjustments might make KWS and chat more accessible and integrated, or the instructors might need to do some modeling of collaborative problem solving. For example, chat is currently designed to be launched through onscreen menu. A "You Got a Message" type of note will pop up on the top right corner of the game GUI whenever a group member initiates chat with the player. The current design raised a lot of suggestions from the students during their play

as how to "tweak" the interface to improve its accessibility. For instance, a scrolling chat box at the bottom of the screen would be much better than going through hierarchical menu options.
The popularity of Road Map as a resource compared to KWS may be related to students having more experience with linear labs and projects, and thus being more familiar with this type of guidance. The students reported little experience with either tool prior to playing *Power Ville*. The larger question is how *Power Ville* and future games might be crafted to increase the emphasis on open-ended problem solving and the need to use appropriate tools for that purpose.

In terms of CI tools, videos and simulations were considered valuable by most students. Their impact on student learning was also partially reflected in student responses to other open-ended questions. For instance, students were able to provide important justifications when prompted to discuss energy sources with an advocate of a particular approach, such as "*You have to factor in the cost, the power it supplies, and the effectiveness over X amount of years." "The best way to select an energy source is to focus on being environmentally friendly first. Then find the most cost effective that will produce enough energy for your needs."* Students also commented on the most important things they learned through the game such as "*The most important thing that I learned was to be environmentally friendly rather than being the most cost and energy efficient*", and "*How money can decide on what energy source you can have to run your city*". Although about a third of the stu1dents had prior programming experience, the programming in the game was deemed hard, and was the tool most likely to require teacher assistance. Given that programming is to play a larger role in subsequent games, we plan to design additional instructions and/or internal resources to support use of this tool.

Overall, there was considerable variation in responses to most questions, indicating that the items were appropriate in addressing a range of student backgrounds and attitudes. Some felt the game was too elementary, others found it enlightening about aspects of energy generation. All but one student felt that the game was more realistic than textbook problems, although no students felt it was truly like an authentic job assignment. When asked how, after playing the game, they might discuss power options with an advocate for one or another energy source, students came away with a variety of opinions. A third of the students emphasized that "it depends" on balancing a variety of factors. Another third had pro-environmental or pro-energy-production positions. Others had more nuanced points of view, such as the need to have more than one energy source, or the need to find out what the people affected value most.

After game revisions, two additional student pilots were conducted in summer 2012 as part of outreach activities. One implementation was with 10 Project Lead the Way (PLTW) students from a New Jersey high school. The other was in a summer outreach program at Rowan University for students from various high schools. In both cases, the game was implemented in the same computer lab at the university. Tables 2 and 3 display results of the *Power Ville* survey for all 50 respondents. (Because the survey and game were revised after the first pilot, 2011 responses are not aggregated with 2012.)

Most students were familiar with video games, playing them at least once a week. Most described themselves as "somewhat" familiar with all the power sources addressed in *Power Ville*, with nuclear power being the energy source most likely to be "very familiar." (The nature of the students' understanding was not defined. It is possible that "familiarity" only indicates how often they have heard about the power source, with nuclear power being in the news most often because of the partial meltdown of the Fukushima plant in Japan.)

Similar numbers of students felt the game scenario was somewhat realistic and interesting, although the remaining students were more likely to find the game realistic than they were to think it was interesting. Compared to a textbook, students had generally favorable attitudes toward the game. They were more likely to find the game more fun and interesting than a textbook, and more likely to describe the learning outcomes as similar.

Table 2: *Power Ville* Prior Experience

	N	*At least once a week*	*> than 1/week*	*Rarely/Never*
How often do you play video games?	47	72%	13%	15%
Before playing *Power Ville*, how familiar were you with the following power sources and their production processes:	*N*	*Very*	*Somewhat*	*Not Very*
Nuclear Power	50	42%	52%	6%
Wind Power	50	34%	62%	4%
Solar Power	50	34%	62%	4%
Coal	50	16%	74%	10%
To what extent did the assignment in the game seem like a realistic engineering problem?	50	29%	59%	12%
How interested were you in the game scenario?	50	18%	59%	24%
Compared to working this same problem out of a text book:	*N*	*More than a textbook*	*About the same as a textbook*	*Less than a textbook*
How interesting was the problem?	49	57%	35%	8%
How much fun was the process?	49	57%	37%	6%
To what extent did you have the resources to solve the problem?	49	47%	37%	16%
How much did you learn?	49	33%	51%	16%
To what extent did you increase your understanding of environmental and economic impacts of different power sources?	49	27%	57%	16%
To what extent did you increase your interest in pursuing a career in power systems engineering?	49	27%	55%	18%

Of the online tools, Road Map had the most consistently positive responses: It was rated easiest to use, most useful, and most used within the game. If respondents were to keep only one of the tools, they were most likely to choose Road Map. This was consistent with the raters in the first pilot. Similarly, KWS had the least positive ratings on the same attributes. Students used online chat less than Road Map, although they had the most experience with chat and believed they were most likely to use it in the future (Table 3).

Table 3: *Power Ville* Cognitive and Metacognitive Tools

Please rate the usability of the following game tools:	N	Unassisted on 1st attempt	Unassisted on 2-5 attempts	With peer help	With teacher help	Did not use
Road map	49	76%	12%	2%	2%	8%
Online chat with your group players	49	61%	8%	2%	2%	27%
Simulator	48	60%	17%	17%	4%	2%
KWS	49	39%	8%	4%	2%	47%
Programming code	49	20%	24%	24%	16%	14%

In the game, you gathered information on power sources by talking to the Mayor and energy experts in the information acquisition state. How often did you use the following tools during this stage?	N	4+ times	2-4 times	1-2 times	Never
Road map	49	37%	24%	29%	10%
Online chat	49	24%	18%	18%	39%
KWS	49	10%	14%	22%	53%
In the game, you analyzed information through simulation and programming coding for your final report in the analysis and decision-making stage. How often did you use the following tools during this stage?	N	4+ times	2-4 times	1-2 times	Never
Road map	49	27%	35%	18%	20%
Online chat	49	18%	14%	12%	55%
KWS	49	6%	12%	24%	57%

How helpful were the following tools for you to accomplish the assignment in the game?	N	Very	Somewhat	Not Very
Videos on different energy sources	49	53%	43%	4%
Road map	49	51%	43%	6%
Simulator	49	43%	41%	16%
Programming code	49	24%	47%	29%
Online chat with your group players	49	20%	27%	53%
KWS	49	14%	22%	63%
Mini-quizzes	49	12%	53%	35%

	N	Road map	Videos on different energy sources	Online chat with your group players	Simulator	Mini-quizzes	KWS	Code
If you could keep only one of these tools in the game, which one would you select?	49	45%	18%	14%	16%	4%	2%	0%
If you could eliminate one of these tools in the game, which would you remove?	48	0%	0%	8%	0%	27%	38%	27%

Have you used tools like this before in solving problems in school?	N	3+ times	Once or twice	Never
Online chat with your group members	49	22%	27%	51%
Road map	49	12%	18%	69%
Simulator	49	10%	35%	55%
Programming code	49	10%	22%	67%
KWS	49	4%	27%	69%
How likely are you to use these tools on your own in engineering / other subjects?	N	3+ times	Once or twice	Never
Online chat with your group members	43	53%	33%	14%
Simulator	43	37%	47%	16%
Road map	43	33%	44%	23%
Programming code	43	30%	49%	21%
KWS	43	21%	33%	47%

A short scenario asked students to explain to a partisan for one or another power source what a city needs to take into account when making energy decisions. Twenty-nine students responded to this prompt. Most of them (17) drew the lesson (or had an existing assumption that) cost, efficiency, and environmental aspects had to be balanced. Six emphasized cost or efficiency (cost per unit). The remaining responses were spread across advocates for environmental concerns or nuclear power. Three responses were off-topic.

CONCLUSION

This paper presents an educational game, *Power Ville* that is on environmental and economic impact of four energy choices (i.e., coal, solar, wind and nuclear). The integration of metacognitive interventions, problem-solving strategies and learning into core game mechanics is described in detail. The assessment provides encouraging results as the students loved the game as an interactive and fun deliverable method of learning. The valuable insights on how students perceived the metacognitive tools suggested some necessary refinement for students to get most benefit from the game experiences.

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