AC 2012-3380: EDUCATIONAL EFFECTIVENESS OF VIRTUAL REALITY GAMES PROMOTING METACOGNITION AND PROBLEM-SOLVING

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Educational Effectiveness of Virtual Reality Games Promoting Metacognition and Problem-Solving

ABSTRACT

There is an increasing awareness among engineering faculty that our students lack effective reading and problem-solving strategies, which poses significant barriers to their learning. This paper presents an approach that infuses metacognitive reading and engineering problem-solving strategies into Electrical and Computer Engineering (ECE) curriculum, through a series of virtual reality games. The educational process of integrating both metacognition and problem-solving in a fun learning environment is then demonstrated through a sample game, *Mystery of Traffic Lights.* The evaluation of its deployment in *Digital I* course at Rowan is also presented. The assessment confirms the utility and usability of metacognitive tools in engineering design, and also provides valuable insights for the iterative game refinementvn.

INTRODUCTION

Reading is a critical skill for students to perform well academically. However, many students are poor readers, or have difficulty understanding expository texts [1]. The serious problems in students' comprehension ability pervade content areas like engineering. That is a reason that we often hear from our students, "what does this problem ask?" when given a problem to solve. The lack of understanding hinders our students to further apply knowledge, make inferences, and correctly and efficiently solving problems.

According to the International Reading Association, levels of literacy can be described as three levels [2]: (a) Basic literacy – the ability to decode, recognize, and comprehend printed signs, symbols, and words; (b) Proficient Literacy – the ability to extend ideas, make inferences, draw conclusions; and (c) Advanced Literacy – the ability to use language to solve problems and to extent cognitive development. If we would take a closer look at the proficient and advanced literacy, we would see the perfect overlaps between the skills that engineering faculty strives to teach in problem-solving and that are defined in levels of literacy. Research has shown that providing students with explicit reading strategy instructions improves their comprehension and learning [3]. However, most of the research development has focused on science literacy in K-12 education. There is a need to understanding engineering students' knowledge of and use of reading strategies, and its impact on academic performance.

Motivated by these remarks, this project, as part of an NSF-IEECI grant, designs a virtual reality game system that infuses metacognitive reading strategies and real engineering problem-solving into fully packed Electrical and Computer Engineering (ECE) curricula at Rowan and Tennessee State University (TSU). The pilot study is conducted in the context of two ECE knowledge domains: *Digital design* and *Circuit Analysis*. This paper, in particular, focuses the digital theme of the games. The evaluation of the game deployment in *Digital I* course at Rowan is presented. More specifically, the assessment aims to answer the following questions:

- Did the games deliver sufficient metacogntive and problem-solving content?
- If so, what is the utility and usability of them?
- Was the student learning in general improved by the gaming experience

OVERVIEW OF *DIGITAL ADVENTURE*

Digital Adventure is one of the two themes being chosen for our game development that fits any introductory digital design course in ECE, electrical engineering, and computer science curricula [4]. The target courses at Rowan and TSU have an important laboratory component (e.g., 2.5 hour laboratory period every week for the *Digital I* course at Rowan), where our games are deployed as a replacement to the traditional lab experiments. The overarching goal of these games is to provide an attractive and motivating environment for students to tackle engineering design in general, and to impart essential reading and reasoning strategies to promote improved problem-solving skills, in particular. More specifically, the broad objectives of the games are to:

1. *Improve students' active reading and thinking of ECE concepts* by exposing them to a selection of metacognitive reading strategies through carefully designed game activities demonstrating ECE principles.
2. *Strengthen students' ability to apply general principles to solve multi-step problems* by immersing them in the process of analytical reading, synthetic thinking, and heuristic problem-solving through authentic and engaging play in the virtual reality games

The group of games in *Digital Adventure* is designed to connect engineering discovery with students' daily life experience where abstract digital design fundamentals are transformed to lively concepts that students can feel. In addition, students are exposed to object-oriented Hardware Description Language (HDL). The game system is then capable of retrieving students' HDL design solutions and invoking ModelSim simulation software for validation. Here, we exemplify this educational process in one game, *Mystery of Traffic Lights*, to showcase the seamless integration of reading strategies and engineering content in a fun game setting.

The Mystery of Traffic Lights – The application of digital logic in a traffic light control is a practical and real-world example that students can associate in terms of its functionality and importance. The design, as a typical sequential machine, can be very daunting, with all functional and timing requirements, as well as race, hazard and synchronization conditions that could occur, and should be designed against.

Designed from a first-person perspective, the game starts at the major intersection of a small town, where an engineer character, Jack, is standing there frustrated by the busy and messy traffic due to malfunctioning traffic lights. He then invites students to help him redesign the controller with the right logic for the current traffic flow (Fig. 1). The player's role as a traffic engineer is then established through this dialog. Setting up a meaning role for each player motives him or her to have a deep understanding of content. Succeeding in this role requires the player to know about state machine diagram, state table, and behavior HDL, etc. – the content knowledge learned in a traditional classroom, and to apply them into this contextual reality. Our game provides the player an environment that makes academic content a necessary tool and positions the learner as a hero who can make a world of difference.

Research indicated that students learn better in a guided learning than discovery learning. However, in a common game environment, players are often left alone with responsibility to explore and to figure out problems themselves. To really bridge the gap between entertaining and education, a "Road Map" reading strategy [5] is designed in the game as shown in Fig. 2. The road map is composed of a set of milestones and actions, providing students an expert view of what takes to solve a problem. The road map can then be deactivated and re-activated through

the menu bar on the right, allowing the player to revisit the road map as many times as needed in navigating through the problem-solving process.

Fig. 1: The introductory scene of *Mystery of Traffic Lights*

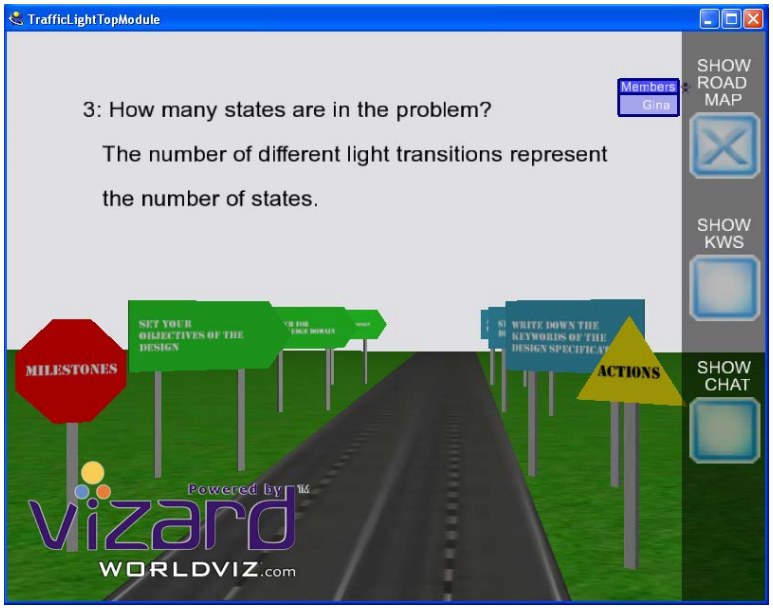

Fig. 2: The road map is enabled in the game

Problem solving demands problem solvers to be constructively responsive, thoughtful, and engaged. The more students are aware of their constructive thinking processes, the more they can control, and the better they can solve the problem. To facilitate students' self-monitoring and self-regulating their problem-solving in the game, the What I **K**now-What I **W**ant to Know-What I Have **L**earned (KWL) reading strategy [6] is adapted to provide students a virtual notebook called KWS, where S stands for What I Have Solved. Through KWS, students can continue to synthesize their design ideas in a 3-column datasheet as they advance from one game stage to another (Fig. 3).

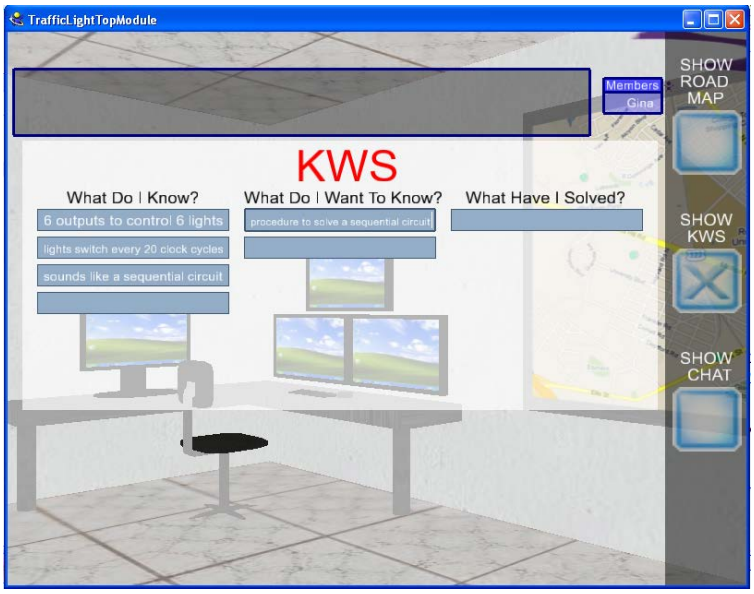

Fig. 3: The KWS is enabled in the game

To enable the network functionalities that allow students to play with their on-line group members where ideas and knowledge are shared, our design chooses a client/server architecture. Only the instructor has the access to the server program, where he/she can set up the group size and password. At the client site, when a player logs in, his/her login ID then becomes visible to other players in the group. Then, he/she can initiate a conversation with the online group members by clicking the "Show Chat" on the game interface. As shown in Fig. 4, two persons (i.e., Gina and Mike) in the same group are online and chatting each other. The discussions, as well as each player's actions, are recorded in the system as exemplified in Fig. 5, and are only accessible to instructors and researchers, providing a good resource to analyze student performance and game effectiveness in promoting learning.

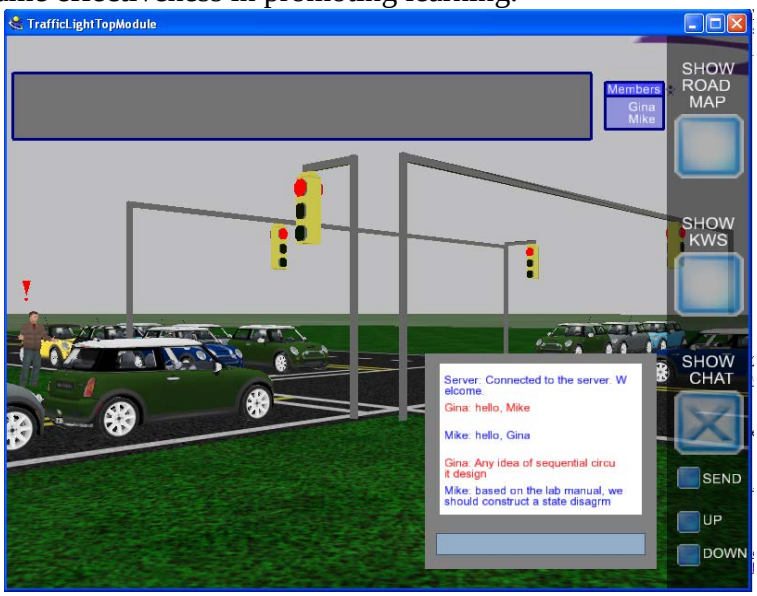

Fig. 4: The chat is enabled in the game

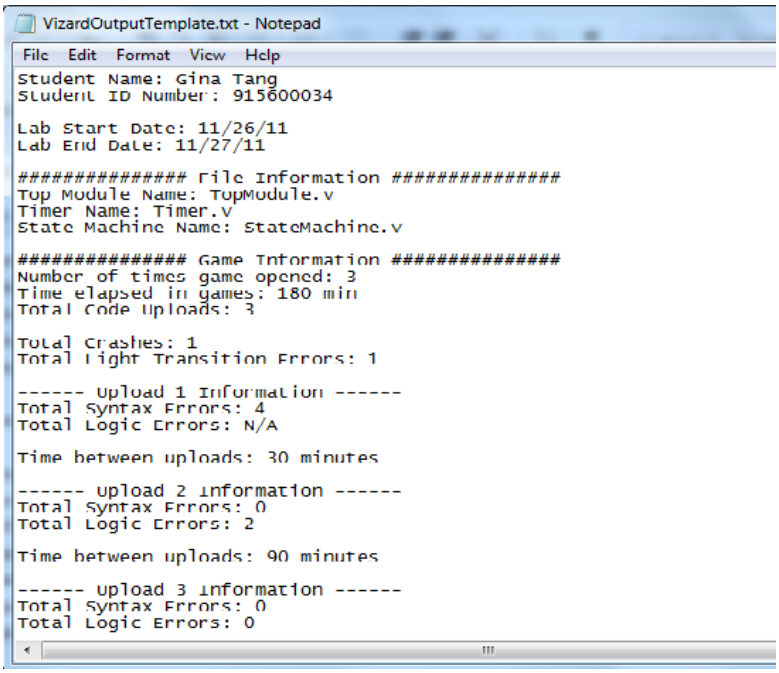

Fig. 5: The log file that tracks students' activities in the game

ASSESSMENT

In Fall 2011, *Mystery of Traffic Lights* was piloted in *Digital I* course at Rowan. Extensive evaluations through student surveys and focus group interviews were conducted. The assessment particularly looked into students' interest and motivation in game learning, how the metacognitive tools to student learning, and whether the learning in general is improved by the gaming experiences. Notable results indicated that VR games were interesting and motivational, especially with a story line. Among the focus group interviews, all participants except one liked the game approach. The one who didn't like the game might be considered as an outlier, because he does not like to play any video games outside of class as indicated during his interview. A pre- and post- conceptual survey was given to 18 students in the experimental group and to 21 students in the control group to rate their proficiency on 19 core concepts of *Digital I* (scores ranged from zero to five (unfamiliar to proficient)). An independent sample t-test revealed no difference between experimental and control groups at pre-test ($p=0.774$) but a significant difference between these groups at post-test ($p=0.028$). The results demonstrated that students in the game learning believe they have greater proficiency with the course concepts. As far as the metacognitive tools are concerned, students voiced their different views of what the game system should provide. Some felt that the current road map was just right to provide necessary assistance in identifying domain knowledge. In a survey given to 20 students in the experimental group about their game behaviors, 10 of them chose road map as the most helpful tool in navigating the game labs, since road map, in their words, "*gives an idea of what information to use when I am lost*", "*hints necessary concepts*", and "*provides formulas to carry out whatever tasks I must*". Without a direct purpose for and required responses from students to the KWS intervention, students were not focused on the learning modeled in such support as deeply as we had hoped. Out of the 20 students, 15 chose KWS as the least useful tool since "*I don't usually track my progress in such a way as the one (KWS) presented in the games*", "*I like to write the problems down in my notebook*", and "*typing about circuits (in KWS) is too difficult*". Chat, although

perceived as a useful tool, was deemed unnecessary by the students as they played the game in the same lab with their group members.

CONCLUSION

This paper presents a pedagogical approach that develops a series of virtual reality games to integrate metacognitive reading and problem-solving strategies into ECE curriculum. The integration and its effectiveness in learning are demonstrated through *Mystery of Traffic Lights.* The assessment provides encouraging results as the students loved the game as an interactive and fun deliverable method of learning and believed they developed a deeper understanding of their content knowledge. 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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