AC 2011-768: INTERACTIVE VIRTUAL REALITY GAMES TO TEACHING CIRCUIT ANALYSIS WITH METACOGNITIVE AND PROBLEM-SOLVING STRATEGIES

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Interactive Virtual Reality Games to Teaching Circuit Analysis with Metacognitive and Problem-Solving Strategies

ABSTRACT

There is an increasing awareness among engineering faculty that engineering students lack effective metacognitive and problem-solving strategies, which poses significant barriers to their learning. The research basis of this work is that providing students with explicit strategy instructions improves their comprehension and learning. This paper presents such a work that develops a virtual reality theme-based game system where circuit analysis is the theme and engineers solving real-life problems are the scenes. Deploying the games as a replacement for the traditional laboratory setting of the four target courses, this approach immerses students in actual engineering design challenges where a selection of metacognitive and problem-solving strategies is unfolded. With no additional software and hardware required, the game system can be installed, configured, and run in any personal computer, making this development cost effective and easily transportable.

INTRODUCTION

Engineering Circuit Analysis (*e.g., Network I* and *II* offered at Rowan University) is so-called "gateway" course within the curricula of Electrical and Computer Engineering (ECE). It is foundational in that many of the upper level courses have a heavy reliance on the application of the concepts from them, and therefore poor performance often discourages students from continuing to pursue ECE as a career track. Instructors try to strike a balanced presentation of challenging concepts, facts, and learning strategies, but it seems that students always feel that there are too many detailed, progressively complex theories with few "real" engineering examples to relate. The lack of proper comprehension and problem-solving tactics adds additional frustration to students when they are asked to transform technical materials into forms that demonstrate their understanding and to apply knowledge in a variety of problem settings. Thus, it is crucial to design a fun learning environment that promotes strategic, constructive, and big-picture reading, thinking and problem solving.

With the advancement in digital technology, games have come a long way to be much more than visualization. They are interactions within immersive digital worlds that promote learning through authentic and engaging play. Since many of today's students have grown up with games of ever increasing sophistication, infusing out-of-school literacy into a classroom setting becomes extremely important.

Motivated by these remarks, this project, as part of an NSF-IEECI grant, investigates a non-intrusive approach that infuses metacognitive strategies into fully packed ECE curricula at Rowan and Tennessee State University (TSU). In particular, the pilot study designs theme-based games that feature metacognitive strategies and ECE fundamentals in real engineering problem-solving to replace the traditional laboratory setting of four targeted courses, *Network I and II* at Rowan and *Circuit Analysis I and II* at TSU. With minimal modifications to the existing course materials, the game format provides students with a learning structure and an incentive to develop their skills at their own pace in a non-judgmental, competitive and often fun environment. The interaction together with visual and audible information serves as parallel channels to the learner, increasing the efficiency of learning.

METACOGNITIVE INTERVENTIONS

Awareness and monitoring of one's learning processes with a repertoire of strategies that they apply when and as required by different learning circumstances are increasingly recognized as critical for successful learners. Such awareness and monitoring processes are often refer to as metacognition –" the processes in which the individual carefully considers thoughts in problem solving situations through the strategies of self-planning, self-monitoring, self-regulating, self-questioning, self-reflecting, and or self-reviewing" [1]. The contention of this research is that metacognitive awareness on the part of students can be improved through systematic and direct instructions on strategic thinking. To support that, three important metacognitive interventions, as detailed below, are carefully designed into the interactive game activities.

- Road Map training – Learning roadmap provides study guides that endow pupil with the capability to find the relevant information and to capture the concepts in the study materials [2]. In this project, a study guide is a set of suggestions designed to lead students through a problem solving process by directing attention to the key ideas and suggesting the application of skills needed to solve the problem successfully. As exemplified in Fig. 1, the road map is composed of a set of milestones and actions, providing students an expert view of what it takes to solve a problem. This caters extremely well to the majority of students that adopt sequential learning. Stressing the big picture of the trip and the relevant facts to the larger whole is an important addition to address the minority of global learners who might otherwise be frustrated by the traditional methods.

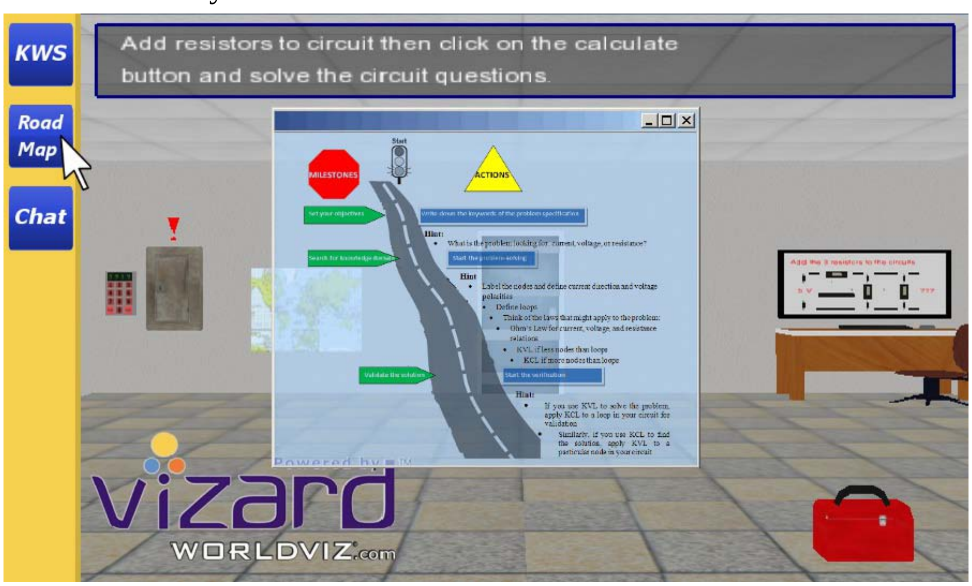

Fig. 1: A sample road map enabled in *Escape*

- What I **K**now-What I **W**ant to Know- What I have **S**olved (KWS) training – KWS is adapted from a well known reading strategy, What I **K**now-What I **W**ant to Know- What I Have **L**earned (KWL) [3]. It typically provides a 3-column chart structure as exemplified in Fig. 2, to activate students' prior knowledge by recalling what students know about a problem (K), to motivate students to read/think by asking what they want to know (W), and finally to review what part of the problem has been resolved and what is yet to be solved (S). In this project, questions are deliberately presented in a coherent manner throughout the game to assist students in deciding what they already know about the problem and what needs to be explored further. Doing so forces students to conduct the sophisticated kind of thinking required for drawing inferences and developing interpretations.

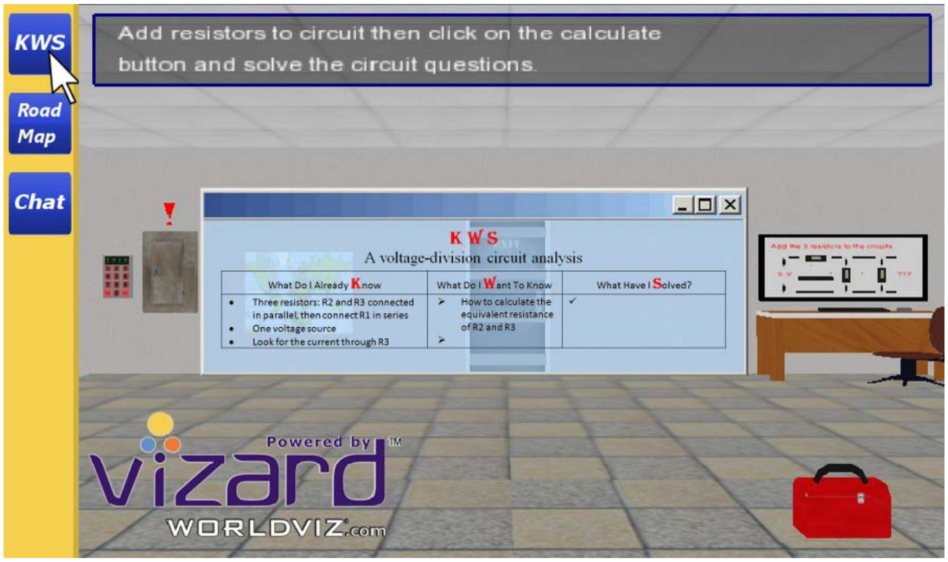

Fig. 2: A sample KWS enabled in *Escape*

- Think-Aloud-Share-Solve (TA2S) training – As Vygotsky pointed out, learning is an inherently social and cultural rather than individual phenomenon [4-6]. The interactions among peers produce intellectual synergy of many minds to bear on a problem, and the social stimulation of mutual engagement in a common endeavor. This technique requires students to (1) think individually about possible solutions to a problem; (2) share ideas (e.g., the KWS worksheet) with their partners; and (3) consolidate their knowledge to eventually solve the problem cooperatively. TA2S is a variation of the collaborative learning strategies, Think-Aloud [7, 8] and Pair Problem-solving [9], which is implemented in the game system through online chatting.

GAME THEME AND DESIGN

In this section, this educational process is exemplified in three experiments of different complexity, one with detailed illustration to showcase the seamless integration of fun, metacognitive interventions and engineering problem-solving in a well-balanced engagement and learning process, and the other two with a brief outline of the setup and pertinent engineering principles.

<u>Escape:</u> Designed from a first-person perspective, the game starts in a dark room where the player character wakes up and realizes that he is locked in the classroom (Fig. 3 (a)). While he is seeking a way out (e.g., typing the door key), a talking computer in the room asks him to conduct several DC circuit analyses to be able to retrieve the correct door code (Fig. 3(b)). Meantime, the talking computer provides some design guidance in a road map as seen in Fig. 1, showing the key DC circuit fundamentals. The road map can then be deactivated and re-activated through the menu bar on the left, allowing the player to revisit the road map as many times as needed in navigating through the problem-solving process. While the player walks through the map and

advances from one stage to another, he continues to synthesize their design ideas in a 3-column KWS datasheet as shown in Fig. 2. The game becomes even more fun when the player plays with his on-line friends where ideas and knowledge are shared as shown in Fig. 4. It is in such communication that much of the learning occurs and an optimal solution results. The discussions, as well as each player's actions, are recorded in the system and are only accessible to instructors and researchers, providing a good resource to analyze student performance and game effectiveness in promoting learning.

(a)

Fig. 3: (a) The player is locked in the room; (b) While the player is seeking a way out, the talking computer suggests him/her to click the computer

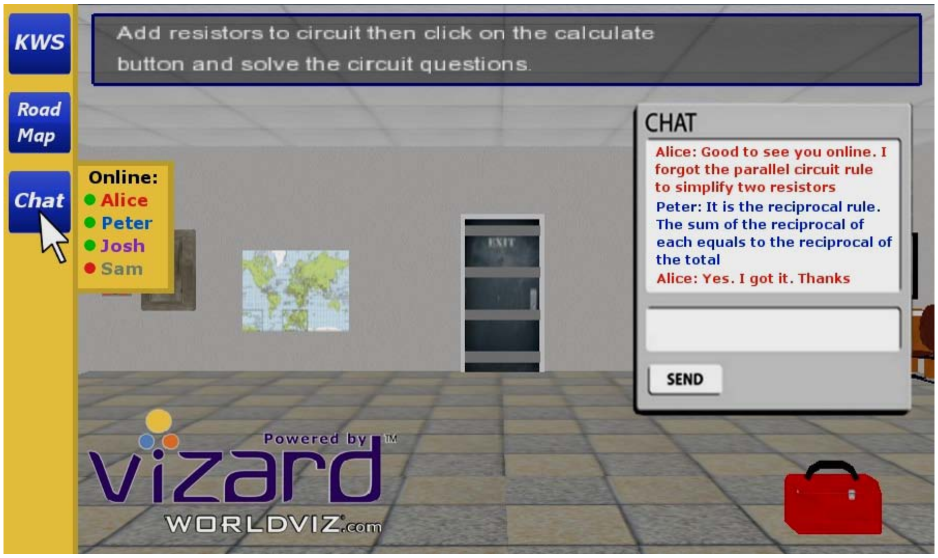

Fig. 4: The online chatting enabled in *Escape*

<u>The Weakest Link</u> – This game allows students to detect and identify the weakest link in the electric grid network. The weakest link in the network is overloaded and is on the brink of bringing the network down. The city officials suspect that the weakest link is a malfunctioning transformer. In a race against time, the city invites smart engineers to detect the malfunctioning transformer. This game utilizes concepts related to design of transformers, power systems analysis, maximum power transfer, three phase circuit design, and filter analysis, etc.

<u>Need for Power</u> – Due to spiraling oil prices, there has been a growing interest in electric cars. This game will provide students the ability to design and run a simulated electric car around a track. *Need for Power* has much in common with the *Need for Speed* series [10] as well as *Gran Turismo 4* [11], which was the second best selling video game of 2005. This game straddles the boundary between rigorous engineering simulation and an accessible video game that could guide students through engaging and authentic engineering problems. The character in the game, Zachary, is a budding entrepreneur who wants to build a successful electric car which will compete in the popular NASCAR competition. Unlike a traditional video game, the students, who are willing to help Zachary, will not have the luxury of steering wheels, gearshifts, accelerator, or brake pedals to get the car to move. Instead, they must write Matlab code to design the DC motor for the car and issue basic driving commands in controlling the amount of power supplied to the DC motor (e.g., how much to step on the electric and brake pedal; which gear the transmission should be in, and the orientation of the steering wheel, etc.). The car simulation runs in real time, displaying the behavior of the car in full 3D graphics. Through the game interaction and intervention, the students gain valuable experience in building a real-life engineering product, including analysis of design specifications, resource (power) management, and integrated design and testing.

CONCLUSION

Three series of games with the focus on metacognitive and problem-solving strategies in teaching circuit analysis are under development and being implemented in four targeted courses at Rowan and TSU, respectively. The learning materials as well as their organization optimize student learning and help them develop a strong foundation to carry over for subsequent coursework

ACKNOWLEDGMENT

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BIBLIOGRAPHY

[1]. Hyde, A. and Bizar, M. *Thinking in context*, White Plains, NY: Longman, 1989.
[2]. Oliveira, M. and Serrano, J. A., "Learning roadmap studio: new approaches and strategies for efficient learning and training processes," http://www.elearningeuropa.info/files/media/media16938.pdf
[3]. Ogle, Donna M. (1992). KWL in action: Secondary teachers find applications that work. In E. k. Disher, T. W. Bean, J. E. Readence, & D. W. Moore (Eds.), Reading in the content areas: Improving classroom instruction (3rd ed., pp. 270-281). Dubuque, IA: Kendall-Hunt.
[4]. Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Cambridge, MA: Harvard University Press.
[5]. Vygotsky, L. S. (1981). The genesis of higher mental functions. In J. V. Wertsch (Ed.), The concept of activity in Soviet psychology (pp.144-188). Armonk, NY: Sharp.
[6]. Vygotsky, L. S. (1986). Thought and language. Cambridge, MA: MIT Press
[7]. Blakey, E. and Spence, S., "Developing Metacognition," *Educational Resource Information Center (ERIC)*, http://www.education.com/reference/article/Ref_Dev_Metacognition/
[8]. Kim, B., Park, H., and Baek, Y., "Not just fun, but serious strategies: using meta-cognitive strategies in game-based learning," *Computers & Education*, 52, 2009, pp. 800-810.
[9]. Narode, R. B., "Pair Problem-Solving and Metacognition in Remedial College Mathematics," *Technical Report*, http://www.eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/1c/53/3b.pdf
[10]. Need for Speed: www.needforspeed.com.
[11]. Gran Turismo: www.gran-turismo.com.