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Evaluation of Interactive and Inter-connected Software in Undergraduate Renewable Energy Courses

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Abstract

As the investment in renewable energy technologies is growing globally, it is important for academic institutions to educate the future engineers and scientists in this field. This paper discusses the ongoing development and evaluation of an educational software that was developed with an interactive and interconnected approach to educate undergraduate students in the concepts of renewable energy, specifically fuel cells. Three out of the five main modules of the software have been mostly developed. The two evaluations conducted so far show promising results in terms of improving student motivation and knowledge in the subject matter.

Introduction

The global scientific publication output is growing exponentially, and the growth rate between 1980 and 2012 was reported to be ~3% annually[1]. Coincidentally, with the advent of more sophisticated and diverse technology in the world, the amount of resources available to educators to perform their duty is ever increasing[2]. The newer generations of students are people who have grown up with a lot of technology around them, which influences the teaching-learning process[3]. The use of computer-assisted multimedia in teaching is shown to have a positive impact and improve the students' satisfaction in learning[4, 5]. With the assistance of videos, animations or simulations, the instructor can help students understand abstract concepts. Especially in science and engineering courses, where the concepts involved can be complex and sometimes impossible to demonstrate via an experiment due to the time scales, length scales of the processes or even safety concerns. Although the concept of learning styles is much debated[6-10], more and more educators have started adopting technologies like Smartboards, computer simulations, videos, animations, e-books, interactive e-books, online learning module templates, online grading tools, video games[5], etc. The percentage of students enrolled in online courses went from 9.6% in Fall 2002 to 32% in Fall 2011[11]. Going beyond the traditional lecture-notes methodology, is not only becoming an option but also necessary in the cases where the courses are offered exclusively online or have an online component. Therefore, there is a need to develop learning resources using technology that could be used as supplemental material in class or outside of the class over the web.

The United States submitted a report to the United Nations Framework Convention on Climate Change in March of 2015, stating the country's goals to reduce CO_2 emissions by 17% in 2020 compared to the emissions in 2005[12]. This implies that the reliance on renewable energy will go up drastically in the near future, and there correspondingly will be a need to educate the workforce in renewable energy, whether it is educating engineers and scientists who will conduct research and development in this field, or technicians who will deploy the technology and run maintenance on-site. The fuel cell market in particular sees a lot of commercial growth. It's estimated that in 2015, 350 megawatts worth of fuel cells was deployed when compared to less than 100 megawatts in 2010[13]. There are a number of resources available to teach students about fuel cells, which include: books, fuel cell trainer kits, fuel cell demonstrative toys, and online resources like the ones offered by the U.S. Department of Energy[14]. Yet, there is no educational software that is interactive and interconnected available for teaching the concepts of fuel cells to undergraduate students in science and engineering majors. Here the term interconnected means that the different modules and sub-modules (from application to science contents) that the educational software is divided into, are interconnected to make logical patterns in how a student may navigate the educational contents without having to follow a linear pattern.

Status of Software Development

The primary objective of the software is to educate undergraduate students in science and engineering majors on the topic of fuel cells. Although the intention of the software is to serve as supplemental material to accompany a lecture series or a course, it is designed to cover all major aspects about fuel cells sufficiently such that it can used on its own. The software can be opened in any internet browser when a user is given access to it and the software contents are made using Adobe Flash animations, videos, text, and audio. The software consists of five major modules, the modules in turn contain sub-modules comprising of 'slides' which could be animations, videos or text with/without audio. Each slide was made with a simplistic and creative approach making it easy for the student to understand the concepts, while ensuring scientific accuracy at the same time.

The five major modules are: (i) Introduction, (ii) Applications, (iii) Fuel cell systems, (iv) Cell level, and (v) Fuel cell science. The design concerning the development of the modules was discussed in depth in the 2015 ASEE paper[15]. Figure 1 captures the main interface of the software and also stills from some of the animations. The user interface is designed using Adobe Flash with hyperlinks to connect the modules and sub-modules with each other. In some of the slides there are hyperlinks designed to show some content when the user can use the mouse pointer to hover over it. These features make the software, both interactive and interconnected. This offers a unique experience where a user can navigate the educational contents in a linear fashion (module by module sequentially) or in a manner that suits their interest or curiosity and gives the user a top-down understanding of fuel cells from the perspective of single cells to the whole system to the fundamental science.

Before any of the specific slides were made, the components and structure of the modules were outlined methodically. The first three modules are for the most part finished. In addition, a number of animations and videos for the other two modules are also completed.

A few new animations as compared what were shown in [15] can be seen in Figure 2. The figure shows the interface and one of the animations from the *Fuel Cell Systems* module. This module consists of sub-modules called Fuel Cell Stack, Fuel processing sub-system, and Power electronics, Thermal management sub-system and Water-management sub-system. The screen

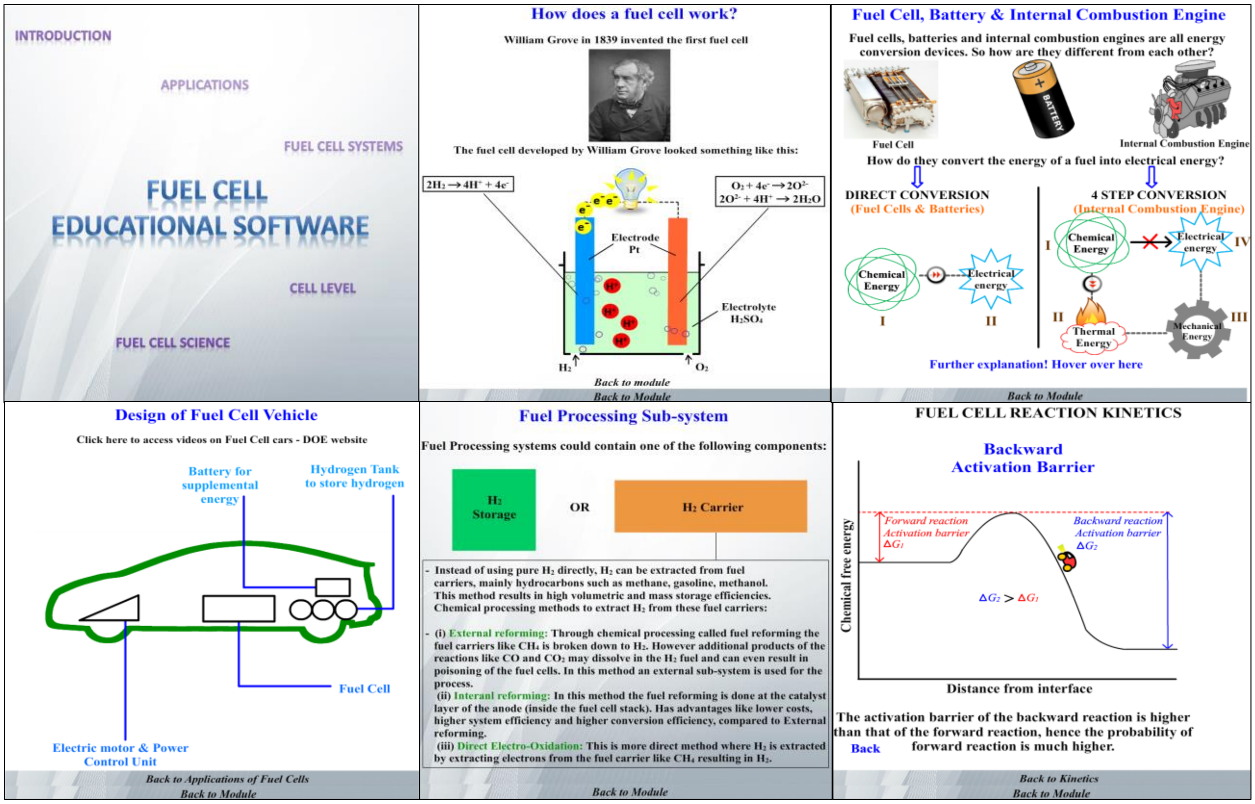

Figure 1. A few screenshots of the fuel cell educational software showing the main user interface and some of the animations in the software.

shot from the Fuel Cell Stack sub-module shows the planar design of fuel cell stacks sub-system. Also included in the figure are the screen shots illustrating thermodynamic concepts and charge transport concepts from the Fuel Cell Science module.

Software evaluation/assessment

Evaluation status and approach

So far there have been two evaluations conducted to test the effectiveness of the software in live undergraduate engineering classrooms at a large university in the south-east of the United States with sample size of 144 and 135 during Fall 2014 and Spring 2015 respectively. In addition, there is one evaluation planned for Spring 2016 at the home university and another evaluation to be conducted in Summer 2016 at a different university. The sample size for these future evaluations are expected to exceed 200 students each. To assess the software's effectiveness it is important to measure both knowledge and learning motivation, before and after the software intervention. Therefore, pre- and post-intervention surveys and knowledge-based quizzes were designed, that can be easily accessed by the students as an online form on their computers or tablets or smartphones. While the Fuel Cell Knowledge quiz checks how well the student

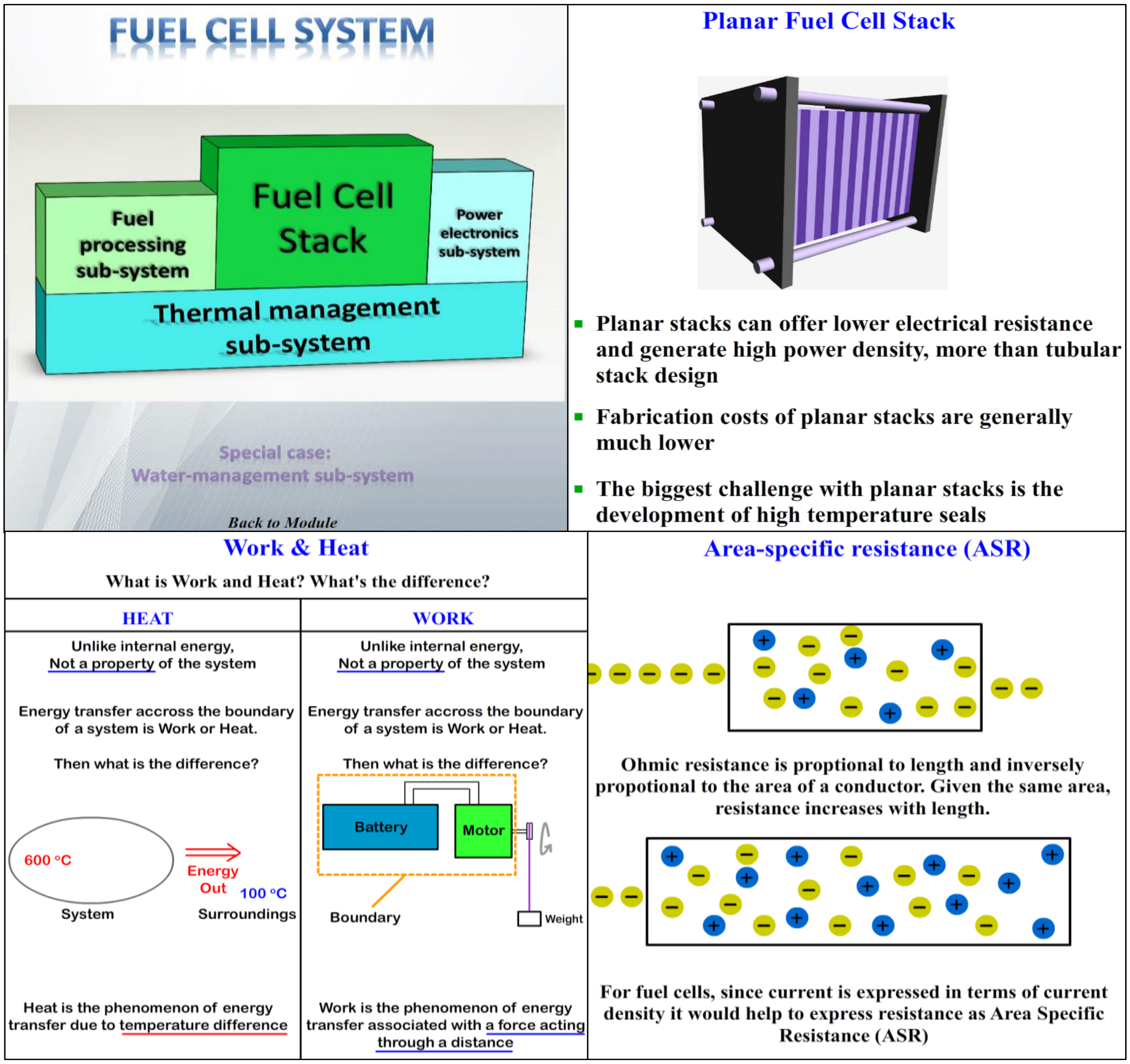

Figure 2. Screen shots from the Fuel Cell System module and the Fuel Cell Science modules.

understood the educational content being taught, the Student Learning Motivation survey based off the ARCS (Attention, Relevance, Confidence, and Satisfaction) model[16] and the Kolb Learning Style Inventory[17] gathers information about the student's learning motivation and learning style. Demographic information was also collected. The surveys were approved by the IRB (Institutional Review Board) office at the home university and the IRB consent form was read and presented to students prior to conducting the evaluations. After the pre-intervention survey and quiz, the students were taught using the software for approximately 50 minutes and then post-intervention data was collected.

Results from the evaluations

The demographic data from the first evaluation showed that in the sample size of 144 students, there were 17 females (121 male), 131 students in the age range 20-29 years and 7 above 30 years; 9 students with learning disabilities; 88 Caucasian, 27 Hispanic, 5 African American; and 137 students were seniors and the rest juniors. Initially, data analysis was carried with repeated measure MANCOVA with motivation and the knowledge test scores as the dependent variables. Since there seemed to be no influence by gender or ethnicity on the dependent variables ($p>0.05$), the model was changed to MANOVA after removing ethnicity and gender from the model. It can be inferred from the results that the software is effective since the students' learning outcomes improved considerably with $F_{(1, 121)} = 242.42$ ($p < 0.001$) while controlling for the motivation of students, the mean knowledge score went up by 14.46 points from ($M = 8.22$, SD = 4.25) before the software intervention to ($M = 22.68$, $SD = 4.35$) afterwards, and also the students' motivation increased 2.09 points from ($M = 67.01$, $SD = 13.01$) before to ($M = 69.10$; $SD = 14.13$) after the intervention.

From the second evaluation, in a sample size of 135 students, there were 36 females (99 male), 125 students in the age range from 20-29 years and 10 above 30 years; 7 students with learning disabilities; 80 Caucasian and 33 Hispanic; 132 were seniors and 3 juniors. The results of the analysis from the second evaluation followed a trend comparable to that from the first evaluation. The learning outcomes improved with $F_{(1,134)} = 235.94$ ($p < 0.001$) while controlling for the motivation of students, the mean knowledge score went up by 14.47 points from ($M = 11.80$, $SD = 5.67$) to ($M = 21.59$, $SD = 4.86$), and finally the mean motivation score also rose from ($M = 70.54$; $SD = 13.51$) to ($M = 71.92$, $SD = 13.15$).

For the third evaluation that is scheduled in Spring 2016, apart from collecting the student knowledge and motivation data, there is also a plan to conduct a control group study.

Conclusion and future work

In this paper, the current status of development and assessment of an interactive and interconnected educational software to teach undergraduate science and engineering students about renewable energy, specifically fuel cells, was presented. Of the five main modules that constitute the software, three modules are mostly completed while the other two modules are partially completed. From the two evaluations conducted in two different engineering courses, it was shown that the students' knowledge and learning motivation improved proving the effectiveness of the software. Two more evaluations are lined for the year of 2016, one at the home university and another at a different university. It is intended that in the long run this educational software would become part of one or more fundamental courses in undergraduate engineering or science, such that it will not only motivate students to take up renewable energy as a specialization so that they could seek employment as engineers, technicians and researchers but also help spread awareness about renewable energy technologies.

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