AC 2012-5294: WORK-IN-PROGRESS: TOWARDS THE DEVELOPMENT OF A MODEL FOR BENEFICIAL USE OF EDUCATIONAL TECHNOLOGY THROUGH A PHOTOVOLTAICS ENGINEERING WEBSITE

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Work-In-Progress: Towards the development of a model for beneficial use of educational technology through a photovoltaics engineering website

Abstract

Photovoltaics (PV) engineering is an emerging field within the schools of engineering. To meet the needs of a new field, learning resources need to be developed for students to utilize in order to effectively engage with the content. The purpose of this work in progress is to discuss an established photovoltaics website (pveducation.org) that is being augmented towards becoming an effective PV education resource. With 3000 hits per day, pveducation.org engages learners in PV across the globe at a post-secondary content level. The authors of the site have recently enlisted educational and cognitive psychologists to enhance the website by infusing facets of educational technology. We intend to describe pveducation.org and provide an overview of the role educational technology has played in enhancing the website through the use of scaffolding and the inclusion of active-interactive tools. We contend that through this process the website can aid in the proliferation of effective learning of PV across the globe, and potentially aid new and well established engineering domains as they begin to embrace e-learning technology as learning resources.

Introduction

Over the last 20 years, the field of Photovolatics (PV), the research, design, and construction of devices that harnesses and convert the sun's energy into electricity, has seen 40% annual compound growth.[1] To maintain that growth world-wide, skilled engineers who are familiar with PV design, manufacturing, and materials are essential. In the US, the development of and growth in the PV manufacturing sector will require an exponential growth of the number of engineers we train in PV manufacturing and materials. The need for individuals capable of performing within the PV market is obvious, and ultimately increasing.

Not only is PV an emerging field, it is an interdisciplinary one as well, as it is comprised of numerous engineering and science domains. These domains include, but are not limited to materials science, electrical engineering, industrial engineering, sustainability, and physics. Unfortunately, few, if any truly interdisciplinary degrees or concentrations in Photovoltaics exist in the US to meet the demand for individuals able to engage in industry – only one well-articulated undergraduate degree program exists in the world and it is in Australia at the University of New South Wales.[2] Most courses taught in photovoltaics lack necessary educational resources to promote effective learning environments for students – few textbooks, professors, and facilities exist to truly integrate the curriculum.

At Arizona State University (ASU), few educational resources exist for students that participate in PV courses. Although ASU has expended a large number of resources building the largest PV power generation facility at a university campus in the US (10 megawatts of installed PV)[3] and has recently obtained a joint DOE/NSF funded research center in PV called Quantum Energy and Sustainable Solar Technology (QESST: NSF # EEC-1041895), currently only two advanced undergraduate elective courses are taught in solar energy.[4] Second, there are no educational lab facilities to reinforce concepts - well-structured labs can be complementary to courses in engineering.[5] And lastly, textbooks are topic specific (e.g. Pierret, 1996, which is a resource on semiconductor science,[6] but doesn't include information about solar radiation or PV power plant design). Providing students with additional resources related to a given topic can aid struggling learners significantly,[7] particularly in PV. Because of the limited resources at ASU in PV education - typical of most research 1 institutions in the US, students have few means to aid their learning of PV.

Well-structured educational resources can provide students with the means to be more successful in their learning.[8-11] For example, from an interdisciplinary engineering approach, instructors have utilized different and additional activities and mediums to provide more opportunities for learning for their students. These activities include, but are not limited to the integration of different content through laboratory experience, contact with experts in the field, and collaboration with peers.[12]

Educational technology provides a platform to enhance and support positive learning outcomes that goes beyond traditional education resources.[9-11] Numerous studies have recently been conducted that include the infusion of technology and/or online tools to act as resources that can enhance learning gains (e.g. Ellis, 2007, and Curry, 1999), especially in engineering.[9] These educational technology resources have been shown to encourage learning, and promote well-rounded opportunities for students to learn.[9] Further, educational technology can provide a more efficient learning environment when aiding coursework.[13] Therefore, additional education resources for the learning of PV can be enhanced even more by providing learners with resources based on educational technology resources.

The purpose of this work-in-progress is to describe how Arizona State University is taking steps to create additional education resources for students engaged in photovoltaics through the use of an educational website. To do this, we describe the website, what some educational technology tools are, and how we are adapting them for existing content in a PV website. This photovoltaic web-based environment is a test-bed for the infusion of educational technology to promote and develop effective additional educational resources, potentially informing emerging and interdisciplinary fields of engineering in the future.

Education Technology

With the proliferation and exponential growth of computers and mobile technologies, access to much of the world's information is cheap, easy, and fast.[14] Technology becomes an indispensable part of our lives globally as it informs and provides a platform to improve the ways we communicate, learn, and teach. Since the very first introduction of computers, educational technologists have been working to leverage technology to enhance teaching and learning. Generally, learning has been positively impacted by the technological revolution.[15] The combination of significant developments of powerful devices, networks, the Internet, software, and Web 2.0, to name a few, and the focus on effective implementation of tools for learning has changed the face of education dramatically.[16]

Educational technology uses computers and technology to aid in the learning process, but also the systematic organization and presentation of knowledge to the learner.[17] It plays an important role in enriching, improving and individualizing instruction delivered to students - serving not only those with access to formal instruction, but also those that have limited accessibility to enriched learning environments. [18] To do this, educational technology should infuse affective tools and consist of an infrastructure that enables learning that motivates and inspires learners, regardless of background, language, or disability.[18]

Due to its application-based environment, engineering education has provided a good test-bed for some of the best educational technology practices (e.g. Bourne, 2005,& Ellis, 2007) through online simulations and coursework.[12, 19] In engineering education, educational technology tools are commonly used to (1) engage and empower learning experiences for both engineering degree and non-engineering degree learners, (2) provide personalized learning, (3) enable continuous and lifelong learning for an array of specialized topics, (4) and offer up-to-date content anywhere, anytime, and to anybody.[20] Engineering classrooms have infused educational technology through web-based course modules that enhance instruction,[19] and also through animations and simulations.[13]

Pveducation.org

Pveducation.org was originally developed as a CDROM resource, providing learners interested in photovoltaics access to an electronic photovoltaics text book. It fulfilled a niche; a succinct and comprehensive resource for photovoltaics content was originally hard to come by. Since its original form, the content has been uploaded and integrated into a website. Recently, the website has acted as a web-based text-book for photovoltaics courses across the US. For example, it is being used for PV courses at the University of Delaware, Massachusetts Institute of Technology, and Arizona State University. Typically, professors assign specific webpages to supplement course content. The content is organized around photovoltaics; guided by the principles governing and used for the development, design, and understanding of photovoltaic science and engineering. The content is organized into eight chapters and the website is structured so that the subject matter builds upon content presented in previous chapters. For example, the content covered in Chapter Four: Solar Cell Operation requires an understanding of content covered in the previous section, Chapter Three: PN-Junction.

The pveducation.org website is a well-established and used educational website on photovoltaics. We recently analyzed the traffic of the website by looking at the number of unique page-views of the website and found that over 400,000 page-views occurred last year alone. Additionally, we also looked at the geographical locations of where these page-views were occurring. As a result, we found that the website attracts people from across the United States and the world. The majority of website users within the US are from Arizona, California, New York, and Colorado. Outside of the US, the website is primarily accessed by users in the UK, Australia, and Taiwan, but is also accessed by numerous other countries. Frequently accessed chapters are Chapter Two: Properties of Sunlight, and Chapter Three: PN Junction. In light of this information, these chapters have been the primary focus for all new educational technology implementations.

Over the last six months, revisions to pveducation.org have focused less on content development and instead have taken a stronger educational technology design focus. Two practices in education technology being utilized are active-interactive tools, and scaffolding of content. The following sections will describe what these practices are, how they are being infused into pveducation.org, and what directions are being taken to leverage a PV course with the website.

Active-Interactive

Chi, 2008 characterizes active learning as the process of doing something to engage in the task of learning. Active participation strengthens learning, since it requires more intellectual effort and higher-order, or critical thinking.[21] Chi, 2009 states that active learning empowers students, fosters student-centered learning and subsequently enables students to take primary responsibility for their education .[22] Active activities are important, but additional steps can be taken to encourage greater learning outcomes – interactive activities. As described by Chickering & Gamson, 1987, students must practice and engage with activities to truly understand them.[23] Educational technology is replete with examples of active-interactive tasks. Simulations, animations, and games are interactive environments where learners can practice a skill or apply their *past experiences* to the topic they are learning.[24] Other active-interactive tools in educational technology include tests and quizzes supported by immediate feedback, games and simulations for problem solving, and discussion boards like virtual chat and forums.[25]

The pveducation.org website has begun to embed tools that fill the active-interactive niche. The first of these methods includes the use of metacognitive prompts. Metacognitive prompts are self-regulatory learning strategies,[26, 27] that when used lead to enhanced academic performance.[28] These questions are specifically designed to trigger students' monitoring of their own understanding of the material, and provide students with an opportunity to consider different strategies to improve their learning.[29]

In the summer of 2011, researchers began to embed these prompts into the pveducation.com website, primarily Chapter Three: PN Junction. This section covers material pertaining to the semiconductor principles of a photovoltaic diode, and as such, is replete with complicated material and concepts. Ideally, it was the hope that these prompts would engage users as they use self-regulatory learning mechanisms to learn PV content. An example of the prompt can be seen in figure 1. At the bottom of each webpage is a button to 'check your understanding.' Once clicked, the metacognitive prompt pops up with a question pertaining to the content covered on the webpage. After submitting an answer, the user's response and the detailed correct answer are displayed. This provides the users with the opportunity to compare their answer with the correct one and then ultimately choose to go back through the content if they feel they aren't comfortable with it, or move on to the next section. Therefore, by embedding these prompts, we hypothesize that users will engage in self-regulatory behaviors for the learning of the content. Since their infusion in July, nearly 500 users have participated in the prompts.

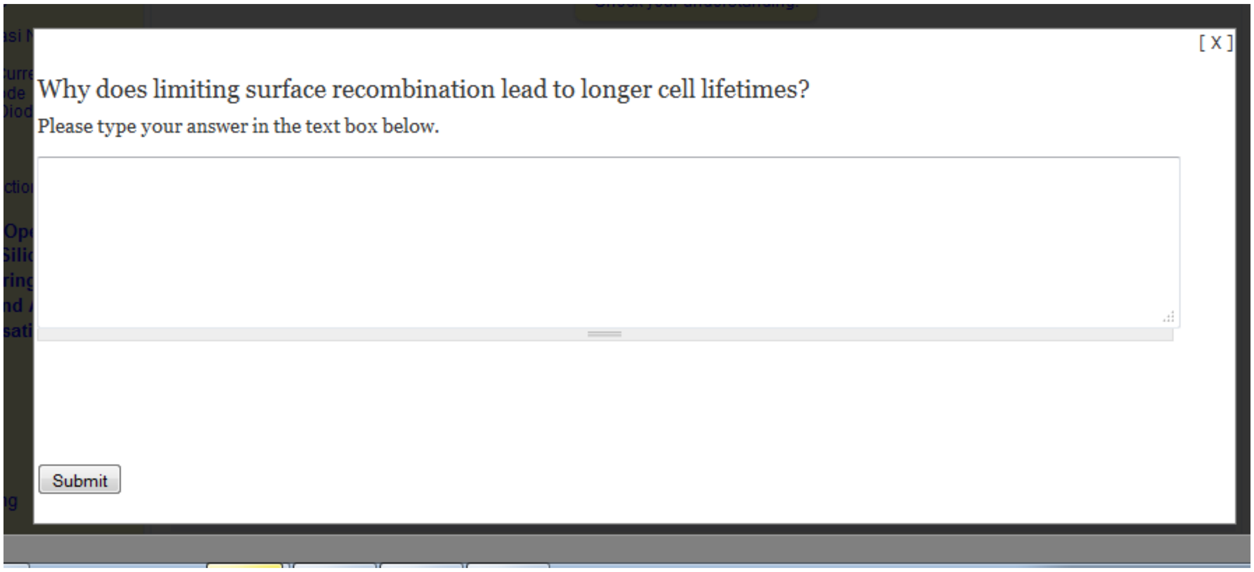

Figure One: Example of a Metacognitive Prompt

Additionally, animations or simulations have been built for each of the chapters in order to increase the learner's involvement in their learning and potentially provide an opportunity to enhance their learning gains from an active-interactive perspective. As we defined earlier in this paper, pveducation.org has eight chapters. Chapter Two: Properties of Sunlight, contains numerous subsections. One such section is the "*Motion of the Sun,*" and covers material about the relationship between the motion of the sun and photovoltaic device angles, and the impact on potential power generated. Quite simply, when the sun's rays are perpendicular to the PV module (at noon), the potential power generation is at its highest. Whereas when then sun's rays are parallel to the module (when the sun is setting) the power generation is very minimal. This information is conveyed to the user through an animation simulating the angles of the sun incident on the module as a function of time of day, and the associated power output. Rather than providing paragraphs of text, content is provided in a more accessible manner (through a visual animation). These types of simulations can reduce the amount of time and effort needed for learning.[13] Further, simulations and animations, emphasize higher-order learning, such as critical thinking, and aid students in the development of individual learning tools because these technologies are active-interactive. Learners can see, hear and interact with the system at the same time, which increases students' learning gains.[22]

Scaffolding

Scaffolding provides support for learners throughout the learning process. Research has found that scaffolding is an effective teaching strategy. According to McKenzie, 2000, providing clear direction can reduce students' confusion, facilitates students' setting of learning goals, and helps students understand what and why they are learning certain topics.[7] In educational settings, scaffolds may include models, cues, prompts, hints, partial solutions, think-aloud modeling, and direct instruction.[30] In educational technology, scaffolding can be provided by several different sources and include such things as decreasing cognitive load through properly displaying content.[31]

Scaffolding tools have been embedded into pveducation.org. Three scaffolding tools being utilized by pveducation.org are to limit cognitive load in the learning of content, infuse utility statements into the content, and structure content such that it builds from a foundational level. Cognitive load is the amount of information people can process in their short term memory. When the amount of information being processed exceeds the capacity of short-term or working memory, learning can be dampened.[31] Instructional web-based tool design needs to take this into account in order to maximize learning. Within the context of pveducation.org, some of the webpages had exhaustive equation derivations that were confusing and lacked an explanation of the progression of the derivation. Therefore, it was likely that the users were focusing more of their attention on how to solve the derivation instead of understanding what the derivation meant. We have begun to clean-up these pages with more succinct and step-by-step derivations that display the detailed descriptions of the derivation process, as shown in figure 2. As a result, users can focus on the content and not the derivation process.[31]

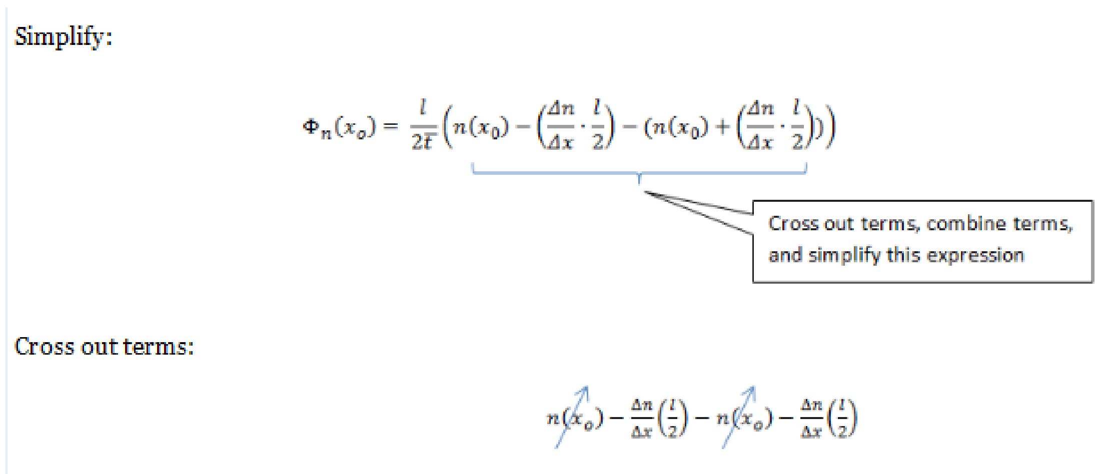

Figure Two. Example of an Equation Derivation that Can Ease Cognitive Load

We are also beginning to build utility statements into each of the pages in chapter three: PN-junction. These statements are important in that they provide a context for why the specific content covered on the webpage is important for the learning of PV. As shown in figure 3, these statements are located at the bottom of every overview section. The insertion of these statements is driven by expectancy-value theory, which states that individuals are more likely to persist in a task if they have utility for that task.[32] We anticipate that by building these statements directly into the website, users will develop a greater appreciation for the content. These results would be in line with those observed by Hulleman et al. 2009, whereby student's perceived utility for a task increased their persistence at it.[33]

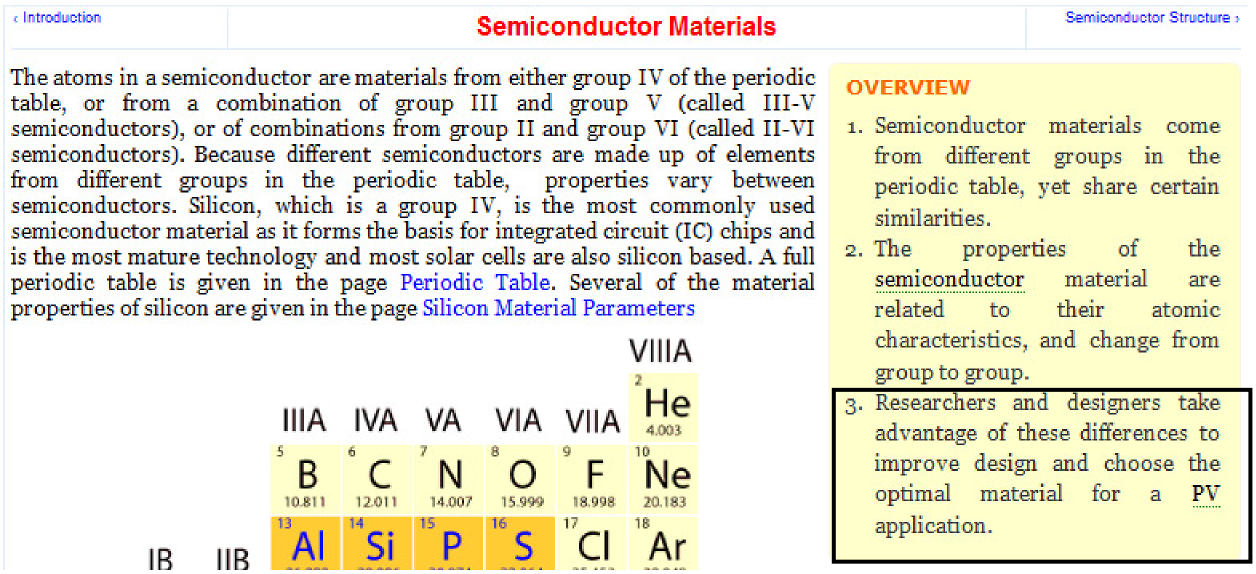

Figure Three. Example of a Utility Statement

Lastly, the website is encouraging learning for experts and novices, and everyone in between. Pveducation.org is designed to cover basic content then build in complexity. Therefore, users who have a limited understanding of semiconductors can focus on this material, and then advance to the more complex material after they have developed the necessary foundational knowledge to be successful. The website advances from basic to complex, as do each of the chapters. In addition, the structure of the content enhances the user learning capability of the website and provides a platform that encourages those from different disciplines to access the content more and understand it.

Future Directions/Conclusions

This paper is the first step towards describing the pveducation.org eLearning test-bed for interdisciplinary education – a domain that lacks additional education resources. Pveducation.org has been changed dramatically in the past six months. The website which currently acts as an educational resource for both those interested in learning PV on their own, and as a resource for student taking courses in PV, has changed from an online textbook to an interactive website. The website has numerous methods to potentially enhance the users learning of PV content through scaffolding and active-interactive tools. All of these are summarized in table 1. With a more succinct foundational knowledge of understanding education tools used in educational technology, proper steps can be taken in the future by pvedution.org to maximize their benefit.

Table 1: Blueprint for Implementation

Practice		Implications	Key Literature
Active-Interactive	Metacognitive Prompts	Increase students' monitoring of their learning, consider using different learning strategies	Atkinson, 2005 & Winne, 1997
	Simulations	Emphasizes higher order learning, decrease time and	Chi, 2009 & Deliktas, 2011

		effort needed for learning of the content	
Scaffolding	Limit Cognitive Load	Increases student's capability to focus and attend to key content which can lead to learning gains	Clark, Nguyen, & Sweller, 2006
	Utility Statements	Can add context to the content, increasing the utility students see with the content. This has been linked to persistence.	Wigfield & Eccles, 2000

However, using educational technology is only useful if it actually promotes learning gains. The pressure to adopt new and rapidly changing technology has unfortunately placed the emphasis on the use of technology, rather than on the best ways to serve student's learning needs through technology.[34] As such, additional steps are needed to assess the effectiveness of this PV test-bed, and to further delineate potential learning gains as a result of use of these tools in an online setting. Therefore, future steps being taken by the website should continue to embed the content with the aforementioned educational technology tools in addition to correctly measuring the educational benefits of these specific tools; tracking both their use and effectiveness in promoting learning of interdisciplinary content. We intend to assess how well users are learning the material through quiz modules and through a more thorough analysis of the responses from the metacognitive prompts. Additionally, we intend to assess the usefulness in including the utility statements as a means to lead to user's persistence in engaging in the content. Lastly, we plan to assess the efficacy of designing more articulated derivation processes in limiting cognitive load issues.

Through future research on assessing the effectiveness of pveducation.org as enhancing students' learning of PV, and continual efforts to infuse the website with additional educational technology tools, we hope to benefit the engineering education community. The educational tools embedded in pveducation.org can be used to facilitate the development of additional engineering education websites (using the summarized implementation practices shown in table 1). Further, because of the steps taken in the website to scaffold the learning of interdisciplinary content, it can also potentially be used as a model for the structuring of online content for interdisciplinary fields.

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This material is based upon work primarily supported by the Engineering Research Center Program of the National Science Foundation and the Office of Energy Efficiency and Renewable Energy of the Department of Energy under NSF Cooperative Agreement No. EEC-1041895. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect those of the National Science Foundation or Department of Energy.