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Higher Wattage - Improving Energy Literacy through Experiential Learning at Multiple Levels

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Abstract

As we proceed through the 21st century, our ability to responsibly manage our energy resources will determine our future. This will require that every human is literate about energy conversion and how our energy use is affecting the earth's energy balance. However, studies show that few people can describe how our natural resources are converted into electrical and thermal energy. Our work will report on teaching methods in higher education, from a first-year seminar course through a graduate-level engineering course, that aim to enhance student literacy and engage students in challenging problems encountered in mainstream energy conversion practices.

The first example is in a first year seminar class: "Know Watts Cooking, The Physics of Energy Efficient Cooking," where students are exposed to a discussion about the physics regarding the energy of our food system. This course includes student-designed cooking laboratories to test energy consumption of various cooking methods.

The second example is a physics general education course: "The Physical Principles of Energy and Sustainability," intended to teach students in a wide range of academic majors about the basic science of energy conversion and climate science. Students become engaged in understanding the physics of various energy conversions through individual energy research projects.

The third example is a graduate curriculum in Renewable Energy Engineering in which students are engaged in real engineering projects with real industry clients and real consequences related to the success of their work. These projects include not just technical challenges, but also economic analysis and policy research.

Our work shows that through project-based experiential learning in courses over the span of the entire university career, students are motivated to become involved in the transformation of our energy systems. These graduates are in-turn critical as we move forward to a more sustainable energy future. This is a teaching model that can be repeated in many other college courses at various levels, thereby greatly multiplying the effect.

1. Introduction

In order to transform our energy infrastructure to be more responsible to the fragile earth energy balance, there must be a conscience effort to lay a solid foundation across the entire higher education experience. While many visionaries have charted a future energy system that is not reliant on the damaging emissions of burning fossil fuels [1], a revolution in our energy conversion strategies will not occur if there is not sufficient public will to promote these technologies on a large scale. This concern will be fueled by clear education, including a dedication to ensure all college graduates have a firm understanding of the basic thermodynamics of climate science and energy conversion [2].

While the energy conversion system involves a highly complex set of scientific principles, the basic conceptual understanding of these technologies can be understood by the greater public if delivered in clear, uncomplicated vocabulary and conceptual explanations. This should occur at all levels of education, beginning in the K-12 classroom [3, 4], presented in more detail through higher education experience for all majors [5, 6] and continued through public education opportunities [7, 8]. Additionally, studies show that the inclusion of student projects enhances the learning experience, especially when these projects are collaborative [9, 10]. Without this basic energy literacy, decisions regarding future energy conversions, which need to be motivated by the public, can be easily swayed by false technical propaganda.

Rather than viewing this educational responsibility as a need for new, focused classes dedicated to these topics only, an alternate successful strategy is to infiltrate many courses with this energy content and implement project-based learning to further enhance the retention. This ensures that more students over

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a wide range of disciplines are presented with this material and that students have the opportunity to have repeated, continual exposure to these concepts that will maximize their long-term retention and true understanding. The following is a case study presenting the experiences of two faculty members and three classes which include a basic understanding of both energy conversion technologies and climate science with project components. These educational opportunities can help to develop the literacy necessary to transition to alternative, responsible energy futures.

2. University Course Case Studies

The following examples represent the breath of courses included in this case study. As the students' class level and chosen major becomes more focused on renewable energy, the content also becomes more detailed. Without this comprehensive strategy that builds knowledge from the beginning of the student's education, more advanced classes would not be as effective since students would lack the conceptual basis upon which to build more complex knowledge.

2.1 First Year Seminar Course, Know Watts Cooking

Appalachian State University requires that first year and transfer students enroll in a seminar course to help their transition into the university and allow them to apply critical thinking to examine a single issue from multiple perspectives. One of these courses is "Know Watts Cooking, The Physics of Energy Efficient Cooking." This course provides the ideal environment to present conceptual thermodynamics of cooking, which can then be applied to the thermodynamics of the earth's energy system and energy conversions that electrify many cooking appliances. The author has observed that since this is a first year course, the students' understanding of and attitude about climate change and the need to transition to renewable energy strategies at the beginning of this course are greatly impacted by their parents' and home community's opinions rather than sound scientific understanding.

To engage students actively in this learning process, project-based experiments are included to test various cooking techniques. As noted in C. Ramsdell's previous case study [11], students are more engaged in this work and the results when they are able to choose the experimental content and develop the experimental methods.

By integrating the study of food and cooking with climate change and energy conversion technologies in a project-based curriculum early in the educational experience, students are able to navigate the rest of their college career with a clearer understanding of these important topics. Some students emerge from this early experience with new passions, helping to shape their future major and career choices.

2.2 General Education Course, The Physical Principles of Energy and Sustainability

The second course in this case study is a general education course, PHY1830, The Physical Principles of Energy and Sustainability. This course is not part of the students' required science credits but rather contribute to their general education requirements thus allowing for a broad range of students to be enrolled, many of whom have very little knowledge of physics, climate change or renewable energy at the start of the class. Based on students' responses to basic questions about energy conversions and climate science on the first day of class as compared to the final exam day, there is a notable shift in literacy about these basic concepts. When energy conversion technologies are presented using conceptual science strategies and basic schematics, students come to realize that many methods used to convert various forms of energy to electricity are similar and not beyond their comprehension. This begins with a simple presentation of electro-magnetics and the way to induce the flow of electrons with mechanical energy. The next step is an explanation of how to provide that mechanical energy with a wide array of turbomachinery driven by either renewable sources such as hydro and wind or steam generated by the combustion of fossil fuels or concentrated solar energy. A brief discussion of non-generator based conversion strategies including photovoltaic introduce students to technologies they will likely learn more about in their future. Students then apply this knowledge in an individual research project and presentation, which helps them to synthesize information and apply it to real solutions. This coupled with a conceptual understanding of the climate energy system and our current shift in energy flows helps students to become passionate about the implementation of renewable energy technologies.

2.3 Graduate Curriculum Course, Theory and Practice of Engineering Thermodynamics

Note that this is the only class in the case study offered to students pursuing a degree in renewable energy. This graduate level course; TEC5210, Theory and Practice for Engineering Thermodynamics; is a core curriculum course in the Renewable Energy Engineering concentration in the Master of Science in

Technology program. Most students in this concentration have a bachelor's degree in engineering but want to focus more in the practical application of the fundamental knowledge they have obtained. This specific course covers the fundamentals of thermodynamics relevant to renewable energy and building energy systems, including the analysis of thermodynamic systems, reversible and irreversible processes, gas cycles, and vapor cycles. Thermodynamic principles are applied to renewable energy and building energy situations through experiential methods, including industry based projects in the regional community. As an example, a recent class worked as engineering consultants to a regional snow ski resort to perform an energy audit of the operation, as well as a design of an energy efficiency upgrade and a renewable energy system installation. This project did not only provide the students with a real client, real application experience, it also provided a uniquely effective learning opportunity through the study of the thermodynamics of the snow making process and the energy intensive nature of the ski resort industry. The practical knowledge gained by students through experience learning projects such as these, allows students to see the connection between the fundamentals of their engineering curriculum and the application of that knowledge in industry. Many students in the concentration, including some that have worked in industry between the bachelor's and graduate degree, have commented on their lack of understanding of how to apply their knowledge until participating in these projects.

3. Conclusion

Through a series of classes with increasingly complex content related to renewable energy science and climate change, our higher education system can promote a deeper understanding of these critical topics among all of our graduates. It has been shown that as the public becomes better educated, they are more likely to view risks of energy conversion strategies consistent with scientific knowledge [12]. The integration of these topics is natural since the same thermodynamic principles that explain energy conversions also explain the thermal energy balance of our climate system. This deeper understanding is increasing our students' ability to become agents of change in their communities and industry.

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