Teaching Energy Issues at a University

CCTC 2013 Paper Number 1569695499

J.M.K.C. Donev[1] and Y. Carpenter[1]
[1] University of Calgary, Alberta, Canada

Abstract

The University of Calgary has launched several energy literacy initiatives. In addition to having an energy concentration available for both engineers and natural science majors, the University of Calgary has started an innovative course on energy for non-technical students. This large lecture course uses blended learning and student response systems to promote a wide understanding of the entire energy sector among students from business, arts and humanities backgrounds. This award-winning course allows students entering the energy industry in non-technical roles to understand the importance of the sector to Canada's future. This paper will discuss this course, and future plans to grow this into an on-line course available to people outside of the University of Calgary. Eventually, this course will hopefully be available to interested parties across Canada.

Keywords: Energy Literacy, University Education, Modern Teaching Methods

Résumé

L'Université de Calgary a lancé plusieurs initiatives d'amélioration des connaissances sur l'énergie. En plus d'une concentration dans cette discipline offerte aux ingénieurs et aux personnes spécialisées en sciences naturelles, elle a mis sur pied un cours innovateur à l'intention des étudiants dans un domaine non technique. Cours magistral destiné à de grands groupes, il repose sur des méthodes d'apprentissage hybride et des systèmes axés sur les réponses des étudiants. Ainsi, les étudiants ayant une formation en affaires, en arts ou en sciences humaines peuvent mieux comprendre le secteur de l'énergie dans son ensemble. Ce cours primé permet à l'étudiant qui sera appelé à jouer un rôle non technique dans l'industrie de l'énergie de saisir l'importance du secteur pour l'avenir du Canada. Cette présentation traite du cours en question et des plans futurs visant à le rendre accessible en ligne à des personnes en dehors de l'Université de Calgary. Il est à souhaiter qu'ilsoitun jour offert aux parties intéressées dans l'ensemble du Canada.

Mots-clés : amélioration des connaissances sur l'énergie, études universitaires, méthodes modernes d'enseignement

1. Introduction

The Canadian energy sector has been rapidly growing and is employing emerging energy technologies. The technical issues related to this sector are important for the public to understand, but incomprehensible without expert guidance. This dichotomy is one of many difficult challenges that the Canadian energy sector faces in moving towards the development of a comprehensive energy strategy. As energy is a necessarily multidisciplinary field [1], energy policies are informed by diverse and sometimes opposing stakeholders from industry, non-governmental agencies, and federal or provincial political arenas, each with distinct motivations and varying degrees of technical expertise. Additionally, energy issues directly impact every citizen, leading to the prominent placement of energy debates in news media [2]. However, despite the importance of energy systems in our lives, genuine public understanding of energy issues remains limited. A comprehensive strategy for energy education at the post-secondary level is a crucial step towards igniting a critical and well-reasoned conversation about energy policy.

2. The need for energy education

Public perception of energy is shaped largely by media sources and conversations with friends and family [3], who do not necessarily have the encyclopedic technical knowledge. Even if a particular issue is explored in depth, most of this multi-faceted issue remains unexplored. The public responds positively to products, policies, and power sources carrying the label of ‘green’ or ‘sustainable’, without necessarily breaking down what defines these terms in context. Yet energy issues are complex; whether one energy source is better than another cannot be broken down into a simple binary ‘yes’ or ‘no’ proposition. This difficulty is further exacerbated by a natural tendency to take our energy supply for granted, since our electricity, heating, and transportation needs are met with such efficiency in Canada. The ‘out of sight, out of mind’ attitude is an almost inevitable consequence, even for people who are passionate about many of these issues. For instance, electric vehicles are touted as ‘pollution-free’ or zero-emission design – but a systems-level understanding, which includes electricity generation, allows individuals to understand the vehicle’s net impact.

Additionally, energy policy is a polarizing issue. Strong advocacy from stakeholders has helped lead to a view that technologies are strictly good or bad with few shades of grey. The issues are hotly debated on economic or environmental grounds, yet little attention is paid to the overlap between these needs. Advice to Canadians interested in energy issues is simplified – reduce your carbon footprint, or conserve energy. While these are valid ideas, it is important that we do not over-generalize the issues. As David MacKay says, “We’re all encouraged to ‘make a difference,’ but many of the things that allegedly make a difference don’t add up” [4]. The public needs sufficient education to allow deep thinking about our choices in order to make real decisions about our energy sector.

Ease of access to reliable and believable information is critical to creating informed participation to the discussion on energy policy. Many corporations and government agencies provide excellent information on energy, but people become quite suspicious of spin. Universities are still relatively trusted institutions that can filter out information, keeping both a perception and reality of a balanced view among stakeholders. Interested individuals have a herculean task to become informed enough to be appropriately engaged in energy issues when faced with the frustrating challenge of searching out reliable and objective information on energy and climate change. While advocacy and opinionated debate are important components of the democratic process, it is likewise critical that people have a safe and non-partisan educational space in which to begin their exploration of these issues. In particular, this trait is a critical distinction between traditional “environmental education” and newer “energy education” initiatives. Energy education emphasizes a balanced understanding of energy concepts, including environmental, social, and economic drivers, without presupposing the prioritization of any of these situational factors.

Universities can provide a neutral environment to learn about energy, whether the course participants merely have a passing interest or are planning a career (technical or otherwise) in the energy sector. Universities can teach campus-based students in a traditional lecture setting, but can also provide lecture series for the community, on-line courses and forums for discussion. Multi-week or term-long courses retain students as a receptive audience for extended time periods, allowing complex ideas and larger system-level perspectives to be developed gradually [1]. This type of in depth exploration is not possible with just a website, television show, newspaper or magazine article, or other passive methods of communicating ideas. People can also be engaged to scrutinize their preconceptions about energy and the environment.

Energy literacy, comprising both understanding of the nature of energy and application of this knowledge to real-world problems, has been recognized as a key priority in the U.S. education system, from “K-to-Gray” (comprising both K-12 and adult education) [1]. Significant recent research efforts [3,5-7] have focused on assessing and improving energy literacy in the middle and secondary school system. However, the problem of energy illiteracy remains persistent after high school. When the NEETF Energy and Environment Attitudes and Knowledge Survey was conducted in 2001, American adults self-reported either a “fair” or substantial amount of knowledge about energy issues, but only 12% obtained a passing grade when surveyed about basic energy production, consumption, and conservation [8]. Even college-educated adults scored, on average, less than 50% on this energy quiz, although some degree of post-secondary education did correspond to a significant score improvement [8]. Although similar data do not exist for the Canadian adult population, these disheartening results nonetheless re-emphasize the immediate and critical need for energy education not only at the K-12 level, but also for the college or university audience. On a more positive note, many of the responses in that survey [8] acknowledged ignorance, which may speak to a willingness to be educated and get more information.

Energy courses at the university level are currently most commonly found in environmental science or engineering programs, and energy is treated, in general, as a single aspect of another more specific field [9]. However, the most effective strategy for improved energy literacy necessarily involves “explicit instructional support that stresses connections across different topics, disciplines, and learning experiences” [1]. Rather than students only exposure to energy concepts being discipline specific (e.g. environmental science, economics, commerce, engineering, health and safety, etc.), a broader energy curriculum is targeted at bridging disparate glimpses into the energy sector, thereby helping each person or profession understand the need to balance competing interests and invest in an entire portfolio of primary energy sources.

With these factors in mind, the approach described in this paper focuses on the development of an introductory, interdisciplinary post-secondary course in energy fundamentals and resources.

3. Designing an introductory energy course at the University of Calgary

At the University of Calgary, the first endeavour into energy education directed at a general audience was affectionately dubbed “Energy for Everyone” (although, officially, the course is titled “Introduction to Energy”). “Energy for Everyone” fulfills the science requirement for students from non-technical degree programs, but interest has been high enough that even science students are taking the class to learn about the issues. In order to keep the course as accessible as possible, the course uses as little mathematics as possible (nothing beyond grade 10) and uses many lecture demonstrations. With each iteration of the course, additional teaching technologies are being incorporated into this class, including on-line videos vignettes of the problem-solving process to help students with calculation-based homework.

This course rapidly grew to almost 200 students a year. In the second iteration of the course, it won a teaching award for one of the authors. While the text [4] used in the initial iteration of the course was free, it was found that the lack of classical-textbook structure and homework made the book entertaining, but difficult to learn deeply from. It remains an optional supplemental book. The course seems to progress far more smoothly with a classical textbook [10], and an on-line homework system.

“Energy for Everyone” begins by showing students that quality of life depends intimately on energy distribution and, more specifically, electricity generation. The website *Gapminder.org* [11] is used to demonstrate how most reasonable measurements of quality of life track quite nicely with per capita energy use and per capita electricity use. These data include information on quality of life in countries all over the world, and energy use. Students have a chance to explore the data to draw their own conclusions, based on their own interests. While most of the students agree coming into the class that energy issues are important, a certain amount of time and effort has to be spent to show students exactly why energy issues are important, and specifically, what the energy issues affect. This has generated some wonderful conversations about the need to balance conservation of fuels with the preservation of a requisite standard of living.

The class then moves on to discuss the fundamental concepts of forces, work and energy. Substantial physics education literature [12] is devoted to students’ preconceptions about forces, demonstrating that fully addressing these preconceptions would require a substantial investment of time. However, since this is not the primary focus of the course, nor the primary interest of the students, this basic material is restricted to as small of a part of the course as can be reasonably allowed in order to understand the material that follows. Work transfers energy between systems, so students are shown a series of simple machines to demonstrate how force times distance is effectively identical no matter the mechanical advantage of a given simple machine. Pulleys work particularly well for this concept, although gears and levers are also mentioned. The idea of energy is developed from the idea of work and soon expanded to energy conservation and comparisons of useful energy versus thermal energy. Existing studies [13-14] have shown that a constructivist approach such as this is effective in building strong student definitions of energy. In the context of energy in society, this step-wise development of energy concepts has the additional advantage that it appears to aid students in forming a natural connection between energy and its necessity for real-life processes in commercial, industrial and residential sectors. Many students from the University of Calgary later work in some capacity in the energy industry; student feedback has indicated that this fundamental exploration of energy gives them a solid conception of what it is that the energy industry sells.

Students then move on to common, personal uses of energy, transportation and home use, with a view to enhancing their learning by developing a strong connection between class material and their own experiences [1]. A significant amount of time is spent developing practical, real-world ideas that are often glossed over in physics classes, like air drag and rolling resistance in transportation. Relatively simple models developed in the original course textbook [4] allow students with high school mathematics to figure out the relative efficiencies of various types of transportation. Heat engines and heat pumps are introduced early in the course, so that students recognize that significant electricity generation originates from differences in thermal energy. Home heating and cooling is discussed, with some focus on insulation and efficiency. Some discussion includes fundamental limits of efficiency for heat engines, but also some practical limits for personal energy use conservation. Students then use this background to critically evaluate common claims online or in the media that energy problems can be fixed by merely improving the efficiency of heat engines, or that energy usage can be reduced 90% without any need for lifestyle changes. These conversations lead to some very practical suggestions about how to cut energy use, reduce ones carbon footprint and simply save money. Students were particularly surprised as to how easy it was to reduce their heating bills. Students appreciate the practical money saving advice, and the insights to conservation that they wanted to employ, but simply did not have the needed information. Students are challenged to actively think about where and how their own household electricity was generated, beginning with simple online sources showing where electricity is coming from in any given hour in Ontario [15], or Alberta [16]. Again, the connection between class content and students' own experiences serves to pique student interest, strengthen learning gains, and challenge otherwise hidden preconceptions [1, 17].

By actively engaging students in conversation about these everyday processes, their awareness of the larger picture behind their energy usage can be increased beyond thinking that electricity comes "out of a socket in the wall." The course builds up these ideas slowly, and there has been much enthusiasm and curiosity in the course. Student anecdotes from this course suggest that the classroom is not only an excellent learning environment, but also, more importantly, an environment that gives rise to evidence-based changes in student opinions about issues related to energy sources. For example, one student commented that he was surprised to learn that cooling towers (for example, from a nuclear plant) emit only water vapour, as opposed to CO_2 or other more harmful gases. His comment suggests that every time he had seen a picture of a cooling tower for a nuclear power plant he believed that nuclear power contributed directly to global warming. This is consistent with a survey [18] that found 56% of those polled believe that nuclear power contributes to global warming.

Notably, each year, students have entered the course with different and, at times, unanticipated preconceptions, making regular discussion and feedback even more critical to their learning success. For example, students often do not naturally distinguish between energy, power and electricity and use them interchangeably in conversation. Students are prompted to challenge their own understanding of these and other concepts via student response systems (often known as clickers), which have been shown to increase student retention and comprehension [19]. Multiple choice and simple numeric clicker questions ensure the students are attending and participating in class. Students seem to enjoy an almost quiz-show like competition to show that they understand what we are presenting, or what they read for the homework. Physics education research has shown that when people passively read material from books, articles or websites the information has relatively little effect on their preconceptions [19].

One of the touchstone concepts of the course is that even plausible-sounding energy solutions need to be critically evaluated. Many statements about energy issues are made with vague words, but as MacKay [4] states, when discussing energy options it's important to use numbers, not adjectives. For example, 'Natural gas gives off a lot less CO_2 than coal, so we can switch and save the climate!' or 'The Earth's climate has always been changing, so current climate change isn't a bad thing.' A specific difficulty comes in vague terms such as of 'lots' or 'limited'. For example, society has 'lots' of solar power available, while there is a 'limited' amount of uranium on the planet, but these adjectives, while true, can give a very distorted view of the viability of practical implementation. Quantifying the available energy options, while keeping the mathematics at an appropriate level, is a key challenge to teaching a course like this.

These challenges are kept in mind as the course moves on to discuss specific energy resources, including fossil and nuclear fuels, solar power, wind power and hydroelectricity. Although sustainability is a factor in selecting energy sources, students must be presented with a full picture of all existing and available technologies to form realistic opinions based on real-world data [4]. Students are encouraged to consider the importance a diverse electricity generation portfolio, based on the demands of the situation. The students discuss energy sources and the related advantages and disadvantages throughout the course, with an emphasis on quantifying their claims where possible. This active discussion among peers creates a neutral forum for student questions to be answered. Summative (graded) assessments reinforce the importance of this form of critical thinking, as students are required to explain their answers to these discussion questions on exams and explain the advantages and disadvantages of different energy sources.

Energy literacy, however, consists of more than merely the content knowledge and energy-related decision-making evaluated in written examinations. Energy literacy also implies having thought about the material long enough to become comfortable with the trade-offs inherent in energy decisions [18]. In addition, conversations with students suggest that the course has also been successful at promoting broad energy literacy goals, including communication about energy topics with students' friends and family, as well as encouraging students to continue learning about energy topics, such as heating, transportation and electrical power, following the conclusion of the lectures.

4. Future Work

With its reasonably large class size and a diverse cross-section of disciplines, "Energy for Everyone" provides a valuable and interesting sample set of students for further study on the effectiveness of the course and its methods for improving energy literacy at the undergraduate level. At present, although the course gains have been promising, the results are still preliminary at this stage and are largely anecdotal in nature.

To adequately assess and quantify students' energy literacy gains as a result of this course, a new measurement instrument must first be developed. Existing energy concept inventories and assessments [20] at the undergraduate level focus solely on the physical science background knowledge required for this field, with no content related to critical ideas about energy resources, the electrical grid, or the broader social, environmental, or economic features thereof. Existing public energy surveys [8, 21-22], in contrast, provide substantial data about general energy knowledge and attitudes, but do not delve deeply into the fundamental concepts upon which these opinions are based.

A number of assessments exist that were targeted specifically towards energy literacy, including both conceptual knowledge and effective or behavioural traits. However, the majority of these are too outdated to be of value [23-25], given the vastly different technologies, environmental data, and economic landscapes of the present day. The few energy education assessments developed in the past decade focus on evaluating literacy gains in middle or secondary school students [6-7, 26-27], and, as such, adaptation and testing would be required to make these measures relevant at the post-secondary level. Additionally, the existing assessment measures focus almost exclusively on the U.S. energy context, so substantial modification would be required to ensure the reliability of results with Canadian students [24].

In parallel with scholarly research on the effectiveness of this course at improving energy literacy, efforts will also be made to increase the wider accessibility of energy education material, including the development of public workshops and online course materials. These new venues are intended to broaden audience for energy education and reduce the silo learning which often occurs in this field [8], particularly in the existing energy industry.

5. Conclusion

With the increasing popular media attention on energy and related issues, as well as a rapidly growing energy sector, universities must stop sitting on the sidelines and step-in with well-developed courses grounded in fundamental energy science, offering students real tools and knowledge to have informed conversations about issues like climate change. One relatively simple solution is to offer an introductory, interdisciplinary course on energy, from the science departments, but intended for everyone. Notably, the University of Calgary is not the only post-secondary institution to invest in this model for energy education. In the United States, the recently launched Energy 101 Project [2] aims to develop a similarly interdisciplinary framework for college-level energy education across the country. Starting with a pilot course launched at the University of Maryland, Energy 101 is developing open-source content modules that may be adopted by other post-secondary institutions to promote the sharing of energy-oriented content across disciplines and schools. In the same spirit of wide accessibility to energy education, the authors would be pleased to share all of their developed course materials with any person interested in teaching an introductory energy course at their own institution, with the hope that this will lead the way to a new wave of critical and informed discussions on energy.

6. References

[1] U.S. Department of Energy, "Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education", Version 1.1, July 2012, Online, <http://www1.eere.energy.gov/education/energy_literacy.html>, Accessed 2013-04-08.

[2] U.S. Department of Energy, "Energy 101: A Model Interdisciplinary Higher Education Course for Teaching the Fundamentals of Energy", Online, <http://www1.eere.energy.gov/education/energy_101.html>, Accessed 2013-04-08.

[3] Zografakis, N., Menegaki, A.N., Tsagarakis K.P., "Effective education for energy efficiency", *Energy Policy*, 2008, Vol. 36, pp. 3226–3232.

[4] MacKay D., *Sustainable Energy: Without the Hot Air*, 2009, UIT, Cambridge. Online. <http://www.withouthotair.com/>, Accessed 2013-04-08.

[5] Nordine, J.,Krajcik, J.,Fortus, D., "Transforming Energy Instruction in Middle School to Support Integrated Understanding and Future Learning", *Science Education*, 2011, Vol. 95, Iss. 4, pp. 670-699.

[6] DeWaters, J.E., Powers, S.E. "Energy Literacy among Middle and High School Youth", *38th ASEE/IEEE Frontiers in Education Conference*, 2008, pp. T2F-6–T2F-11.

[7] DeWaters, J.E., Powers, S.E. "Energy literacy of secondary students in New York State (USA): A measure of knowledge, affect, and behavior", *Energy Policy*, 2011, Vol. 39, pp. 1699–1710.

[8] National Environmental Education & Training Foundation. “Americans’ low ‘Energy IQ’: A Risk to Our Energy Future.” 2002, Washington, DC.

[9] Kirshenbaum, S.E., Webber, M.E., “Energy should form its own discipline”, *Nature*, 2011, Vol. 478, p. 37.

[10] Wolfson R., *Energy, Environment and Climate*, 2nd ed., 2011, W.W. Norton: New York.

[11] *Gapminder*, Online, <http://www.gapminder.org>, Accessed 2013-04-07.

[12] For example, Hestenes D., Wells M., Swackhamer G., “Force Concept Inventory”, *The Physics Teacher*, 1992, Vol. 30, pp. 141-158.

[13] Trumper, R. “Energy and a constructivist way of teaching”, 1990, Physics Education, Vol. 25, pp. 208-212.

[14] Lancor, R.A., “The Many Metaphors of Energy: Using Analogies as a Formative Assessment Tool”, *Journal of College Science Teaching*, 2013, Vol. 42, Iss. 3, pp. 38-45.

[15] Canadian Nuclear Society, “Where is my Electricity Coming From at this Hour? (if I live in Ontario,” Online, <http://media.cns-snc.ca/ontarioelectricity/ontarioelectricity.html>, Accessed 2013-02-27.

[16] Canadian Nuclear Society, “Electricity Generated in Alberta,” Online, < http://media.cns-snc.ca/albertaelectricty/albertaelectricity.html>, Accessed 2013-02-27.

[17] Ambrose, S.A., Bridges, M.W., DiPietro, M., Lovett, M.C., Norman, M.K., “How Does Students' Prior Knowledge Affect Their Learning?”, *How Learning Works: Seven Research-Based Principles for Smart Teaching*, 2010, Jossey-Bass: San Franciso, pp. 10-39.

[18] Bittle, S., Rochkind, J., Ott, A., “The Energy Learning Curve: Coming from different starting points, the public sees similar solutions”, 2009, Public Agenda: New York, Online, <http://www.c2es.org/docUploads/Energy-Learning-Curve.pdf>, Accessed 2013-04-08.

[19] Martyn M., “Clickers in the Classroom: An Active Learning Approach”, *Educause Quarterly*, 2007, Vol. 30, Iss. 2, pp. 71-74.

[20] Swackhamer, G., Dukerich, L., “An Energy Concept Inventory”, 127th AAPT National Meeting, 2003.

[21] “The University of Texas at Austin Energy Poll”, Online, <http://www.utenergypoll.com/>, Accessed 2013-04-08.

[22] Farhar, B.C., “Energy and the environment: the public view”, *Renewable Energy Report Issue Brief No. 3*, pp. 1–11.

[23] Holden, C.C., Barrow, L.H., "Validation of the Test of Energy Concepts and Values for High School", *Journal of Research in Science Teaching*, 1984, Vol. 21, Iss. 2, pp. 187-196.

[24] Barrow, L.H., Morrisey, J.T., "Energy literacy of ninth-grade students: a comparison between Maine and New Brunswick", *Journal of Environmental Education*, 1989, Vol. 20, pp. 22–25.

[25] Barrow, L.H., Morrisey, J.T., "Ninth-grade students' attitudes toward energy: a comparison between Maine and New Brunswick", *Journal of Environmental Education*, 1987, Vol. 18, pp. 15–21.

[26] NEED (National Energy Education Development Project). "Secondary Energy Poll", *Blueprint for Success*, pp.39–41, 2006, The NEED Project: Manassas, VA, Online, <http://www.need.org/needpdf/SecondaryPoll.pdf>, Accessed 2013-04-08.

[27] DeWaters, J.E., Powers, S.E. "Establishing Measurement Criteria for an Energy Literacy Questionnaire", *Journal of Environmental Education*, 2013, Vol. 44, Iss. 1, pp. 38–55.

7. Acknowledgements

The authors would like to acknowledge the Strategic Enhancement of Engagement through Design grant that allowed this course to be developed at the University of Calgary.

8. Biography

Dr. Jason Donev got his PhD from the University of Washington and is now an instructor at the University of Calgary who teaches about energy issues, especially nuclear power. He researches how people learn science and how science fiction has influenced science, technology and perceptions of science and technology.

Dr. Yuen-ying Carpenter received a PhD in Chemistry from Dalhousie University and now researches inquiry-driven teaching and learning tools for energy and chemistry.