84. A professional training program to help engineers thrive with the complexity of energy issues

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Abstract

The Masters of Engineer in Clean Energy (CEEN) at the University of British Columbia is a professional degree for engineers wishing to enhance their skills in the application of energy technology and policy. The program aims to reinforce fundamentals related to energy (for example, thermodynamics), then guides students towards a practical appreciation of the complexity of energy issues. Two examples of the curriculum are highlighted.

The first example is the use of debates in the course CEEN501 Thermal Energy Systems. In CEEN501, students spend the first half of the course reviewing the fundamentals of thermodynamics and their application to power plants, gasification and carbon capture. Later, students choose from a variety of debate resolutions with strong linkage to thermal energy issues. At the end of the term, teams (2-3 per side) debate the issues over 55 minutes. Following the debate, opposing sides come together to find common ground and/or ideas that would have strengthened their arguments.

The second example is drawn from the CEEN 550 Energy Efficiency and Conservation (EE&C). This course includes a Learning-Through-Service (LTS) project that involves conducting energy audits for community partners such as school districts, building and property manager associations, hospitals, and multi-unit residential buildings. Student deliverables include a team-produced screening audit, an individual detailed analysis, and an oral presentation to the community partner. Technical-economic analyses, including integration of utility incentives, form the core of the studies. However students are required to address commonly-overlooked issues such as the quality of energy services delivered, and behavioral interventions that apply concepts from social psychology.

Both the debates and the LTS project are highly valued by students as indicated in surveys and instructor observations of student enthusiasm.

1 Introduction: Student Composition, Program Design, and Employment Outcomes

The Masters of Engineer in Clean Energy (CEEN) at the University of British Columbia (UBC) is a professional degree for engineers wishing to enhance their skills in the application of energy technology and policy. The program does not aim to prepare students for research, and focuses on practical applications to prepare for professional employment. The program requires 12 to 20 months to complete, depending on the students' chosen pace of completing courses and the length of cooperative, or work-study, employment engagements (co-op).

A new cohort of 22-28 students has been admitted each September beginning in 2009. Approximately 2/3 of the students come from mechanical or chemical engineering degrees. The balance come from electrical engineering, other branches of engineering, and pure sciences. For the 2009-2011 cohorts, approximately 20% of the students were international (not permanent residents or citizens of Canada). For 2012, this portion is almost 50%. Most of the international students come from China, India, Mexico, U.S., and the Middle East.

In early 2013, program alumni were asked why they had chosen UBC's CEEN program. Two-thirds of respondents viewed the program as an opportunity to advance or change their career path toward clean energy engineering, while the balance cited "general interest" or "a means of obtaining advanced education".

The program is designed to ensure graduates achieve these key objectives:

- demonstrate an understanding of basic engineering knowledge expected of professional engineers employed in energy engineering jobs
- be able to perform technical analyses of anthropogenic energy systems, from supply-side to demand-side (end use) systems; this includes common fossil-fuelled systems as well as renewable energy sources and alternative conversion systems
- gain an appreciation for the complexity of non-technical issues involved in society energy use, specifically the role of policy and human behaviour
- be able to write professional reports and deliver effective oral presentations

The curriculum comprises coursework, a program-ending project, and an optional (but popular) co-op. Overall, the curriculum and learning activities include multi-disciplinary training and professional skills which are increasingly recognized as important for engineers by academic institutions (Redish, E.F., Smith 2008) and professional associations (ASME 2012). The mandatory courses are:

- CEEN 501 Thermal Systems: thermodynamics, power plants, gasification systems, carbon capture and storage, power generation issues.
- CEEN 502 Alternative Energy Systems: wind, solar, and hydro-electric systems; alternative energy carriers and conversions such as hydrogen and fuel cells
- CEEN 523 Energy and Environment: environmental impacts of energy resource extraction, conversion, and end-use consumption; life cycle analysis
- CEEN 550 Demand-side EE&C: engineering analysis methods for residential, commercial, and industrial facilities; demand-side management (DSM) program design; behavioural intervention, social marketing.
- CEEN 590 Energy Policy: taught from a political science perspective to introduce social and political processes involved in development of energy policy; introduction to basic policy instruments and policy analysis techniques.

Students also select 3 elective courses in areas such as green buildings, energy conversion systems (e.g. fuel cells, internal combustion engines), transportation, business and entrepreneurship, urban planning, and policy.

All students complete a project during their final, 4-month term of the program. Projects span a wide range of energy-related topics and functional activities, ranging from laboratory analyses to engineering design to policy studies. Projects are executed on an individual basis and it is required that students are supported by one or more Project Mentors. Project Mentors are defined as any working professional engaged in energy-related issues. Mentors include individuals from consulting firms, BC's energy utilities, UBC faculty, technology companies, and local government institutions. Student deliverables always include a written report and oral presentation, and in some cases supplemented by additional deliverables such as engineering design drawings or computer models.

Co-op is an optional, but popular part of the program. Typically about two-thirds of students are engaged in co-op employment. The opportunity for co-op employment is commonly cited as a strong draw to the program, distinguishing UBC's program from other energy systems-focused professional master degrees. The co-op program is enhanced through the creation of subsidies that provide matching funds for up to half of student salaries to qualified employers. These subsidies are administered through UBC's Engineering Co-op office, with funding provided by BC's two major utilities: BC Hydro and FortisBc.

To date, the program has 68 alumni and a good track record of success in terms of post-graduation employment. Social media, an annual alumni event, and other activities are used to retain connections with the alumni for a variety of reasons, including tracking employment statistics. As of early 2013, only 6% indicated difficulty finding employment. The balance found jobs ranging from strongly technical jobs to management positions, and cutting across a variety of economic sectors. Most (58%) of the jobs are related to energy efficiency. This outcome is attributed to the strong and positive influence BC Hydro Power Smart and FortisBC Conservation, through a variety of mechanisms such as the aforementioned co-op subsidies.

2 Description of Learning Activities

2.1 Classroom Debates

The modern use of classroom debates has been reviewed recently by Kennedy (2007). The format has been used in only a handful of engineering courses at UBC, and publications on its use worldwide are sparse. A few describe the use of classroom debates to introduce issues in computer languages or other technology classes (Scott 2008) (Alford & Surdu 2002). The advantages of debating in design education have been reviewed recently (Martin et al. 2008). They noted that some of the best outcomes occurred when students argued for positions counter to their personal opinions; this situation required students to approach issues from a fresh perspective and gather evidence from new sources. This is consistent with our experience in CEEN501.

In CEEN 501, about 50% of the course is on thermodynamic analysis of thermal power systems. The balance of the course covers broader energy issues (pollution, greenhouse gas emissions, power grid efficiencies, regulation and policy). The debates count for 25% of the course mark. The final exam involves calculations and an essay in which students must argue the merits of a selected energy system. The essential features of the debate component are as follows:

<u>Lecture introducing basics of argumentation</u> (1 hour) Construction of arguments and vocabulary useful in critique of arguments (premise, conclusions, evidence, fallacies…).

<u>Preliminary debates over proposed resolutions (1-2 hours small group work)</u> This sensitizes students to the details of the debate wording, and students are invited to propose new wording or topics.

<u>Student selection of topics (30 minutes homework)</u> Each student ranks the 9-12 proposed resolutions, and based on the rankings, the instructor forms teams of 2-3 students (ie, 4-6 students per debate). The least popular topics are removed from the list, and students are assigned to the remaining topics (nearly all get their 3rd or better choice). Sample resolutions used in the 2012 class:

- *Whereas energy conservation can produce major GHG reductions and other environmental benefits at low cost, energy conservation research should be funded much more than "clean energy" supply research.*

- *The widespread availability of shale and tight gas should be promoted as a method to reach global greenhouse gas reduction targets.*

<u>Team-instructor meetings (15 min./team)</u> After 1-2 weeks researching their topic, students outline their argument and plan for further research.

<u>Debates (55 minutes/debate)</u> Debates take place about 4 weeks after assigning teams. The 55 minute time allocation includes presentations (using visual slides), rebuttals and audience questions.

<u>Post-debate discussions (1-2 hours homework)</u> Opposing teams come together to seek common ground and discuss how each side could have made stronger arguments.

2.2 Learning Through Service (LTS)

CEEN 550 includes 1) an overview of anthropogenic energy systems to understand common technical and policy issues unique to demand-side management, 2) engineering and economic calculations for electric and thermal powered systems, 3) a module on behaviour and community-based social marketing (McKenzie Mohr, 2012), and 4) an introduction to EE&C programs and policies.

The overall aim of the energy audit project is to train students in common energy management skills (Capehart, et al. 2012), as well as the ability to recognize and solve problems for which engineers are commonly criticized as lacking, such as quality of energy services and behavioural responses (Auffhammer & Sanstad 2011).

The opportunity to apply all course content is provided in a LTS energy audit project performed for community partners. LTS is a recognized pedagogical tool to both improve learning outcomes (Lemons et al. 2011) and increase student satisfaction (Bischel & Sundstrom 2011). With support from UBC Engineering`s Community Based Experiential Learning Office, CEEN 550 has utilized LTS since the inception of the CEEN program.

Partners for the energy audits have included local school districts, health authorities, and associations of building owners and managers. Specific facility types have included schools, hospitals and privately owned commercial and residential buildings. The range of facilities allows for real-world learning experience with ubiquitous types of systems (lighting, heating and ventilation, plug loads, etc) as well as a variety of organizational arrangements. In particular, the practice of EE&C routinely encounters a variety of challenges which fall outside the realm of conventional technical-economic analysis; this includes market barriers and failures such as lack of information, inadequate financing options, performance uncertainty, and principal-agency problems (IEA 2007). In the LTS audits, students are encouraged to identify problems and suggest solutions beyond the conventional technical-economic paradigm. For example, they may propose ways to maintain or improve the quality (not just quantity) of energy services.

Required deliverables include:

- A screening-level energy audit analysis and report performed in teams of 2, in accordance with ASHRAE Level 1-2 guidelines(ASHRAE 2011).
- A detailed, technical-economic analysis of one energy-saving measure (physical retrofit or behavioural intervention) performed on an individual basis.
- Oral presentation to community partner staff.

Organizing the LTS audits demands more effort than conventional teaching modes. Increased time demands arise from networking with community partners in advance of the course, negotiating facility assignments and logistics, answering a multitude of student questions that understandably arise from the process, and marking of a large number of unique reports (1.5 times the number of students).

3 Evaluation of Learning Activities

The CEEN 501 and CEEN 550 courses and instructors are subject to standard end-of-term evaluations. Although the debates and LTS audits are frequently cited as valuable aspects of the courses, these standard evaluations lack detail on specific course components. As such, a 16-question survey was created to elicit an understanding of the value of these learning tools relative to other learning activities, and to understand which skills have been considered useful in post-graduation employment. The survey was created using Survey Monkey (www.surveymonkey.com), and responses were solicited through a Google Group (www.groups.google.com) for which only CEEN current students and alumni are members.

To date, 69 CEEN students have completed CEEN 501 and, 67 students have completed CEEN 550 (CEEN 550 was optional for the 2009 cohort, and 2 students opted out). There were 44 responses completed, which is 64% to 66% of the total possible for CEEN 501 and CEEN 550, respectively. The number of respondents for years 2009, 2010, 2011 and 2012 were 9, 9, 9 and 17, respectively. Approximately 28% of respondents had entered CEEN directly after their Bachelor`s degree (this group is denoted “inexperienced” below). About 75% of respondents listed English as the language of instruction for their previous degree.

3.1 CEEN 501 Debates

Results from the survey indicate that the debates are a positive experience for nearly all students. We thought that the response might differ depending on the amount of experience that a student had prior to CEEN, but this appears not to be the case (Table 1). Fewer students from the “inexperienced” category placed the debates in the “extremely important” category (Table 2), but even here the difference is marginally significant.

3.2 CEEN 550 LTS Audits

Students were surveyed to rate the importance of LTS audits relative to other course activities in CEEN 550, as shown in Table 3. Over 80% of students rated the audits as *extremely important*, more than three times the percentage than any of the other components. The majority rated assignments, exams, and lectures as still important; nonetheless, these results are aligned with the standard course evaluation comments reflecting positively on the LTS audits.

Table 1: CEEN 501 debate survey results (% of **all** students ,“inexperienced” subgroup).

Question	**Response (%)**		
Prior to taking CEEN501, had you taken courses with a debate as a required component?	No Yes	**86** **14**	92 8
Overall, was the CEEN 501 debate a useful experience for you?	Not at all A little Very much	**2.3** **28** **70**	0 33 67
Reflecting on your experiences in the CEEN501 debates, what was the most NEGATIVE aspect? (38/45)	Typical: large amount of time required; unclear connection between this effort and grades; procedural details e.g. lack of time for rebuttals		
Reflecting on your experiences in the CEEN501 debates, what was the most POSITIVE aspect? (42/45)	Most students appreciated the chance to think critically about an interesting issue and have perspectives challenged by others.		
Since completing CEEN501, have you found opportunities to use skills developed in the debates?	Never Rarely Sometimes Often	**0** **18.6** **58.1** **23.3**	0 33 58 8
Would you recommend that other professional programs involving engineering and society include a debate as a project in at least one course?	No Possibly Yes, definitely	**0** **25.6** **74.4**	0 25 75

Table 2: Student rating learning activities in CEEN 501 (**% all students**, inexperienced students).

	Not important at all		Somewhat important		Important		Extremely important	
Lectures on thermodynamics	**0**	0	**10**	17	**29**	33	**62**	50
Assignments involving calculations	**0**	0	**26**	25	**40**	50	**35**	25
Field trips	**0**	0	28	33	**47**	42	**26**	25
The debates	**0**	0	**16**	25	**53**	58	**32**	17

Table 3: Student rating of LTS audits in CEEN 550 (% of respondents).

	Not important at all	Somewhat important	Important	Extremely important
LTS energy audits	0.0	4.5	11.4	84.1
Assignments	6.8	13.6	65.9	13.6
Exams	15.9	27.3	50.0	6.8
Lectures	2.3	9.1	61.4	27.3

Additional questions were asked to elicit a better understanding of various aspects of the LTS audits, with the results summarized in Table 4. The responses demonstrate that LTS was a new experience for 84% of students. Students found the real-world aspects of the LTS audits most valuable (e.g. real clients, real systems, and real data sets), while at the same time some of these same aspects were frustrating in that data sets were often incomplete or poorly defined, time requirements were reported to be excessive, and in some cases clients were slow to respond or were perceived to be not engaged in the project. Nonetheless over half the students considered the audits helpful in their co-op or post-graduation employment, and 91% believe the project should be retained in the course.

Table 4: Survey questions assessing students' perceived value of LTS audit project elements

Question	Response (%)	
Have you previously completed engineering courses that incorporated LTS?	Yes No	15.9 84.1
In CEEN 550, was having the experience of completing a real-world energy audit useful and of good value during a co-op or post-graduation job interview?	No Yes Not Sure	75.0 6.8 18.2
Have the skills you learned completing energy audits in CEEN 550 been directly useful in the performance of your post-graduation job?	Not applicable Never Rarely Sometimes Often	29.5 2.3 9.1 22.7 36.4
Do you think that energy audits for community partners should be retained as part of CEEN 550?	Definitely yes Does not make a big difference Audits should be eliminated Not sure	90.9 4.5 4.5 0.0
What was the most POSITIVE aspect of the LTS audit project?	Themes described in multiple responses: people in real-world circumstances; real data (e.g. missing or unclear data); actual equipment (not laboratory)	
What was the most NEGATIVE aspect of the LTS audit project?	Themes described in multiple responses: feeling inadequately prepared; not enough time; clients not engaged; finding reliable cost information	
In performing the audit, how much time did you spend organizing and collecting data as compared to performing the actual analysis and reporting?	< 25% of time 26% -50% of time 51% - 75% of time >75% of time	25.0 38.6 31.8 4.5

4 Conclusions

The CEEN program aims to prepare students for the complexity of professional work through co-op experience, projects, classroom debates and LTS. Debates in CEEN 501 have been well received by students, consistent with the (very sparse) literature on debates in engineering. Debates are especially well-suited for learning about complex issues, where it is necessary to construct arguments from diverse sources of information and appreciate that multiple valid viewpoints exist.

The LTS audits were considered to be a valuable learning experience by the students and instructor alike. The real-world aspects of the project were, simultaneously, seen as the most beneficial and at times the most frustrating. Data sets were often incomplete, sometimes delayed, and typically required substantial effort to organize and scrutinize for validity. Conventional learning modes in engineering usually involve provision of clearly specified and consistent data, clear assumptions, and complete system descriptions such that students can begin technical and economic analyses with relative ease. It is the authors' experience that the positive and negative attributes of the LTS audits replicate real, professional practice of engineering in many ways, and thus should continue to be utilized as a pedagogical tool in the program.

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