Engineering Service Learning with Green Information Technology and Systems Projects

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Abstract

It is well established that university engineering students are capable of concrete contributions to sustainable development while improving their academic skills by undertaking service learning (SL) projects tailored for the content of the course. These SL projects can normally be classified as: 1) collaborations with a community group or non-profit organization to provide specific engineering design or construction around a community need, or 2) an internship-like experience with industry in which students provide solicited work for a client. The limitation of both of these approaches is that they do not prepare students to implement projects that are not prescribed. This paper presents the findings for a novel pedagogical exercise in which students were assigned SL projects in which they were to act as change agents for industry by implementing unsolicited energy conservation measures (ECMs) to improve the environmental performance of an organization. These ECMs focused on green information technology and systems (IT/S) SL projects, which were integrated into a 4th year mechanical engineering elective in engineering for sustainable development. The projects were broken into two components – a virtual and a real SL project. For the virtual component, the students used Appropedia.org, an appropriate technology wiki, to coordinate the five member teams and to develop and publish ECMs utilizing green IT/S. The ECMs created by students were constructed from templates, which had been developed by a multi-disciplinary team made up of representatives from economics, engineering, environmental studies, and management information systems. The ECMs were then open sourced and made available for any organization to use to economically and environmentally justify improvements in IT/S. For the second component, the student teams self-selected industry clients and obtained permission to perform IT/S energy audits of the organizations. After performing the audits, the teams selected among the ECMs developed by the class to make recommendations to the organizations. Preliminary results are presented and discussed and conclusions are drawn on the effectiveness of such hybridization projects to SL in engineering.

1 Introduction

Service learning (SL) is a teaching methodology that entails experiential education through combining academic instruction with community service, focusing on civic responsibility and critical, reflective thinking [1]. Because the community service and academic work are linked, they strengthen each other [2]. Thus, "experience-based education creates a powerful learning environment, which results in new educational outcomes" [3] and such education can be facilitated by SL in engineering courses. There is a vast amount of literature that supports SL outcomes being positive for students, faculty, educational institutions, and community partners [4][5][6]. Service learning has a positive impact on students' academic learning, course objective development, moral development and ability to apply academic knowledge to "real world" applications [7][8]. Students are therefore the largest benefactors as they gain increased motivation, better academic outcomes and real world experience [6][7][8][9][10][11][12][13]. The last decade of engineering pedagogy has demonstrated rising interest in SL in engineering, culminating with the establishment of a journal dedicated to the subject area in 2006: *The International Journal for Service Learning in Engineering (IJSLE): Humanitarian Engineering and Social Entrepreneurship* (ijsle.org).

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limitation of both of these approaches is that they do not prepare students to implement projects in industry that are not prescribed. In contrast, this paper presents the findings for a novel pedagogical experiment in which students were assigned SL projects in which they were to act as change agents for industry by implementing unsolicited energy conservation measures (ECMs) to improve the environmental performance of an organization. These ECMs focused on green information technology and systems (IT/S) SL projects, which were integrated into a 4th year mechanical engineering elective in engineering for sustainable development. The projects contained a hybridization of virtual and real engineering service learning. Preliminary results are presented and discussed and conclusions are drawn on how effective such hybridization projects are to service learning in engineering.

2 Background

Organizations are beginning to go beyond short-term economic indicators and focus on the so-called triple-bottom line of financial, social, and environmental outcomes. All of these indicators are important not only for the well-being of organizations, but for civilization as a whole. It is becoming increasingly apparent that ensuring environmental responsibility often benefits long-term financial goals, particularly for energy consuming businesses [14]. Thus, businesses are under increasing pressure to meet goals of global sustainability and environmental responsibility in particular [15]. However, spending on IT/S is growing two times faster than the Gross World Product [16], with important implications for the environment. Despite the fact that IT/S can have a substantial influence on the ecological impact of an organization, environmental issues underlying IT/S often have no clearly defined ownership in organizations [16] and the IT/S function is often not considered by organizations in their assessment of their environmental footprint [17]. Nevertheless, smarter IT/S use could reduce global emissions by 15% [18].

3 Engineering Service Learning Projects Studied

For the course, the green IT/S project utilized service learning in studying and using IT/S more effectively in organizations. The green IT/S projects were designed to be accomplished by engineering students using both service learning and commissioned assignment approaches [12][19]. This type of project compliments established engineering design programs because of the focus on students performing interdisciplinary research to find solutions to environmental problems. It has proven extremely motivational for students and is associated with positive learning outcomes [4][13][20].

In the SL projects, students were to act as change agents for industry by implementing unsolicited energy conservation measures (ECMs) to improve the environmental performance of the organization. These initiatives ranged from incremental techniques (e.g., replacing laptops with more energy-efficient models) to more innovative (e.g., using solar photovoltaic electricity to power data centres). For the projects, students were organized into groups of five, allowing audits to be performed for eight companies. Prior to student involvement, templates for the green IT/S projects were designed by a multi-disciplinary team made up of representatives from economics, engineering, environmental studies, and management information systems [21]. For the virtual learning component, student teams chose and researched a green IT/S topic and developed an ECM spreadsheet calculator/model that would evaluate the economic and environmental impact of the ECM. These ECMs were then corrected and open sourced on Appropedia.org. For the traditional learning component, the student teams performed basic IT/S audits of participating organizations, highlighting areas that would benefit most from recommended ECMs. The Green IT/S Project was broken down into five parts as summarized in Table 1.

As can be seen in Table 1, Parts 1-4 were student tasks and Part 5 was completed by a representative of the client company. Parts 1 and 2 represent virtual service learning objectives, whereas, Parts 3-5 represent traditional service learning objectives.

3.1 Virtual Service Learning in Green IT/S Project

Parts 1 and 2 of the project entailed service learning objectives using Appropedia.org as a repository and collaboration tool. Appropedia is a free wiki based tool for collaborative solutions in such areas as sustainability, poverty reduction and international development. It can be used for service learning especially geared towards applied sustainability [22]. As a group collaboration tool, multiple users can contribute (as with a team) on different sections and the wiki file manager interface allows for a spreadsheet model to be uploaded with a record of changes made and work to be done for the next person. Electronic time stamps and signatures are used, providing a valuable history record to see how students contributed to the work for grading purposes.

Lastly, a discussion page, attached to the main page allows for peers to review the work and make comments and suggestions to improve their work. Collaborators globally could comment as well. Thus, instead of the traditional classroom where assignments and projects are generally for marks and likely unused thereafter, Appropedia enables the work to be part of a useful knowledge database to enable any organization to improve the energy efficiency of their IT/S.

To prepare for the projects, Appropedia template pages and ECM excel spreadsheet templates were available on the main project website (www.appropedia.org/Mech425_GreenIT_Project). On the main website, updates were made and questions fielded as needed and students choose their project topic by "time stamping" their names. Projects were categorized and monitored by course teaching assistants. Resources were also made available to help with background information on engineering economics and green IT/S.

After choosing a specific green IT/S technology, system, or methodology, students created a topic page where they conducted a literature review of the topic, explaining the economic and environmental benefits and how they would incorporate them into an ECM excel spreadsheet model. Conducting the background research allowed the students to grasp the topic and provided references for assumptions and key data used in the ECM models. The ECMs were viewed as financial investments, such that the costs, savings and environmental benefits had to be evaluated and quantified. Thus, in the ECM spreadsheet models, students were able to utilize simple payback, internal rate of return and net present value as economic measures to evaluate the proposed green IT/S projects. Quantifiable environmental benefits were mainly due to reduced emissions (from electricity reduction) and conserved trees (by reducing paper). Students were graded on the communication, presentation and accuracy of their submissions. Further, students were asked to peer review another group's work. The discussion page on the project website enabled this feedback, and signed time stamps assisted in tracking the submissions. Students were graded on the usefulness of their peer reviews and were given the opportunity to incorporate feedback from the reviews into their ECMs before grading. The ECMs created were to be used by various groups for Parts 3 and 4, which meant that the work had to be correct and understandable for all other students. Since the ECMs were to be made available worldwide in the public domain, students were held to a higher standard than traditional course assignments. It appears that this encouraged a sense of responsibility and commitment to their work that motivated most teams to exceed expectations.

Table 1. Summary of service learning components of green IT/S project

SL type	Agent	Pt	Description
Virtual SL	Student	1	*ECMs and topic page*: Open source investigation of a chosen Green IT/S technology with literature review and quantification of economic and environmental benefits in through an ECM spreadsheet model uploaded to Appropedia.org
		2	*Peer review and correction of ECMs*: This was enhanced by using the open source capability of Appropedia.org where multiple students could view the project work, pages, attached documents and leave feedback on the discussion board.
Traditional SL	Student	3	Selection and completion of a *Green IT/S audit* of a business
		4	Final *recommendation reports* to the business and *work reports* to the course instructor
	Client	5	Client survey and feedback

3.2 Traditional Service Learning in Green IT/S Project

Parts 3 and 4 entailed traditional (real) service learning objectives where student teams undertook green IT/S audits at participating companies (field work). As a precursor to this, students had to identify a company that would be interested in this work and obtain the appropriate consents from company representatives. Students performed green IT/S audits at the participating company facilities, focusing on the IT/S resources, but also considering other ECMs applicable to the company. Students were required to use at least

two of the 13 available ECM models created by the class or the research team.

Once at the organizational site, students used surveys, conducted interviews, collated appliance specifications, and used electricity and solar flux measuring equipment to obtain the data required for inputs in potential ECMs and to improve assumptions and default values. They also collected important information regarding the company's current and proposed sustainability goals, current initiatives and past implementations and sustainability or green program information. All data were collected with signed consent from company representatives.

The final stage for the students included the preparation of two reports: a recommendation report for the company and a work report for the instructor. The recommendation report detailed the recommended ECMs with economic and environmental justifications for each ECM. Students also indicated implementation considerations and potential behavioural changes required for certain initiatives. All assumptions and limitations were addressed and summarized calculations were present. The work report provided a brief overview of the company and its green initiatives, all measurements made and data collected by the students (including surveys), why the specific ECMs were chosen, and whether the team thought the company was a good candidate for future work. A reflection on learning objectives met and project experience was also included.

Following completion of the students' work, a client survey was distributed by the course teaching assistant to each participating company. Clients were asked to comment on the professionalism of the students, general evaluation of the recommendations made (including limitations and improvements), and their desire to continue participation in the green IT/S work.

4 Outcomes of the Green IT/S Project

Overall reflections on the project suggest that the service learning method motivated students to demonstrate high commitment and go beyond course expectations in some cases. Seven of eight groups used more than the minimum two ECMs required. Many groups did additional calculations to recommend initiatives tailored to the organization, beyond the ECM models available. Students felt that their project work was like a real industry job and that they were actually contributing to being change agents (detailed in the Discussion).

All participating companies agreed that the project was a good initiative and valued the recommendation of an outside academic source. With the exception of one financially constrained client, all companies offered to participate in future studies. With most companies based in a city with a community sustainability plan, there was heightened interest to meet sustainability goals. Companies with regional and international operations (4 of the 8 companies) indicated that they would consider piloting the recommendations locally before expanding to their entire chain as proper evaluations and protocol must be followed. The major limitations of the study were time and resources. Since there were only 13 ECMS developed, the range of available initiatives was limited. Further, since the focus was on green IT/S, most applications were in service industries and within specific departments in these organizations. Finally, the client organizations would prefer a longer period of time spent on conducting the audit and then following up with a future study. In this case, the academic semester structure of the course was a constraint.

5 Discussion

5.1 ECM Development

In general, developing realistic ECM calculators is a non-trivial task [21]. However, the open source platform of Appropedia enabled rapid notification of edits and corrections that needed to be made. Although general templates were created, there was still considerable freedom for student innovation in developing ECMs. Some technical difficulties were encountered during the course, such as the use of different versions of the spreadsheet software that tended to corrupt some of the files. In the future, it is recommended that a standard open source data processor be used. As this was an initial attempt at constructing ECMs, significant learning occurred and the resulting ECMs provided a ledger of improvements that can be applied to provide better templates and ECMs in the future.

This project enabled a useful application of the basics of engineering economics, not just from a business point of view in project evaluation, but also as a tool in sustainability. Although basic engineering economics is covered in another fourth year engineering course, many students lacked an understanding of fundamental concepts and calculations and were unsure of how to apply it in real world projects. This was a stumbling block in developing the ECMs. It forced the students out of their comfort zone in engineering to thinking about what motivates businesses and what sort of presentation and discussion would be needed to

market their chosen ECM. Another difficulty from an engineering perspective was determining realistic assumptions for business inputs, such as utility pricing which differs by commercial size, labour costs, inflation estimates, risk free rate of return, capital cost allowance, leveraging considerations and others. Students were encouraged to improve ECMs used in the audits through interviews with the clients to ensure assumptions were more appropriate.

5.2 Field Work

Students developed several useful skills and learned important procedural protocols through their participation in the field work. This project was designed to provide students with the opportunity to add a vital skill set and knowledge base to their present degrees. The audits strengthened their basic understanding of energy, electricity, and applied sustainability. As well, students learned to work with rate equations, basic life-cycle analysis, cost benefit analysis, and managerial economics. The lessons can be broadly classified into ethics, business interactions, and technical and safety issues, three areas generally not taught in the classroom.

Apart from ensuring proper citations for references in their work, ethical lessons included navigating social science based research practices such as acquiring permission from the clients for conducting the work and collecting data, ensuring client confidentiality, and preparing value-added reports to clients in a professional manner.

Securing an appropriate client proved to be a challenge for some student teams and highlighted the importance of industry experience, networking and communication. This was different from other SL projects on campus that find clients for the students. In addition, in dealing with the companies, students gained an understanding of company protocol in terms of internal turnaround time needed for acquiring permissions, sustainability programs, visitor procedures and business organizational structure. Interviews taught students what considerations are important to a business for choosing viable projects, including the concept of using debt financing to improve the return on an investment. In general students gained an understanding of how they would need to communicate and market their green initiatives to make a change from technological, environmental and financial viewpoints.

The technical learning objectives achieved during the Green IT/S project included using equipment to do basic energy audits, using engineering economics for a real project and applying conventional measurement skills with proper data acquisition methodology. The importance of safety was emphasized for the field work, and students were required to complete Workplace Hazardous Materials Information System training as mandated by the Occupation Safety and Health Act. Furthermore, off-campus risk assessment forms were completed that demonstrate student willingness to participate and knowledge of the risks of doing the audit. This is applicable to true field work in industry.

Finally, field work indicated the limitations in the ECMs and assumptions made in the virtual service learning component. Future work will address these limitations in detail.

6 Conclusion

This paper presents the findings for a novel pedagogical exercise in which students conducted service learning projects that required them to act as change agents for industry by implementing green information technology and systems energy conservation measures. Unlike traditional service learning, both virtual and field components were included. The preliminary results of this study indicate that the use of an open source tool like Appropedia.org for virtual service learning combined with a field-work-based service learning project can be an effective means of achieving the dual goals of education and organizational change directed towards environmental sustainability. Future work is needed to quantify the impact on learning and the effectiveness of such an approach at catalyzing environmentally-beneficial change in organizations.

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