Paper 85. Accelerating Interdisciplinary Learning Outcomes in Sustainable Building Sciences

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Abstract

The building construction industry, valued at $4.7 trillion annually, accounts for approximately 10% of world GDP (McGraw Hill Construction, 2008). An increasing proportion of building design is moving towards sustainable building practices which include diverse challenges anchored in energy efficiency, high quality indoor environment, durability and livability. The rapid urbanization of developed and developing countries requires an increasing number of trained researchers, teachers, architects, and engineers with skills to solve complex socio-environmental design of sustainable buildings.

While there are specialists with specific disciplinary skills in building science and design, few have the ability to connect knowledge that is fragmented between varying fields of expertise. One of the goals of the Sustainable Building Science Program (SBSP) at The University of British Columbia was to address the need to educate graduate students and build their diverse knowledge base to prepare them for this growing field of research. SBSP was specifically created to be an interdisciplinary program to allow for multiple viewpoints to rethink how their fields interrelate. The program focuses on ‘applied sustainability’ solutions by creating a problem-driven project environment of real world challenges by working with industry experts, practitioners, academic experts, and policy makers.

The program was successfully funded with a CDN $1.65m strategic grant in 2010 and has already enrolled over 12 multidisciplinary graduate students and postdoctoral fellows with backgrounds in the engineering, physical and social sciences (UBC, 2011). In order to maintain interdisciplinarity throughout the program its innovative structure provides three dimensions: 1) a topics course that is taught by over 21 practitioners and research experts, 2) a projects course which collaborates with key external partners, such as the City of Vancouver (CoV), to tackle real world problems and 3) an interactive seminar series that invites participation from professionals outside the program to share their insights with participating students.

The aim of this paper is to review the progress of the program with a focus on student experience and the challenges of attaining the program’s goals. The analysis outlines the successes and challenges with respect to mapping learning objectives to outcomes. While the student experience is largely positive, learning experience is challenged by difficulty in collaborating, including a lack of interaction at the faculty level, the difficulty of working between disparate disciplines in terms of language and epistemologies, and the challenge creating a learning community between students.

1 Introduction

The building construction industry, valued at $4.7 trillion annually, accounts for approximately 10% of world GDP (McGraw Hill Construction, 2008). This industry is also becoming increasingly focused on green projects. From a survey completed representing 62 countries, the percentage of firms where 60% or more of their portfolio represents green projects is expected to increase from 13% in 2009 to 51% in 2015 (McGraw Hill Construction, 2013). This is further supported in the U.S. market with data from the U.S. Green Building Council website indicating a 77% increase in Leadership in Energy and Environmental Design (LEED) certificates (USGBC, 2013). Although there are an increasing number of architectural, engineering and construction (AEC) professionals entering this area to meet this increasing growth, there is still an expected 17% global shortfall predicted for 2015 (McGraw Hill Construction, 2013). This may be partly attributed to some unique challenges to filling this gap which include the requirement of multiple disciplines to solve problems, the emergence of new technologies, the interdisciplinary challenge of understanding relationships between human and technological systems, and bridging the performance gap in a multi stakeholder decision-making environment. One mechanism of providing these skills is to utilize post-secondary education to fill this gap, but there is currently a lack of programs that meet these criteria. The goal of the newly developed Sustainable Building Science Program (SBSP) at The University of British Columbia (UBC) is to help fill this gap by providing the Canadian building industry with highly qualified personnel. In order to aid other potential universities in developing similar programs, this paper illustrates a student perspective of the program with a focus on learning objectives, challenges, and outcomes.

2 Applied Sustainability

The Sustainable Building Science Program was created to bridge the expertise gap by creating a unique learning environment that will enable students to acquire the relevant skills for the green-collar economy. The program focussed on supporting a learning environment within the context of applied sustainability. This involved:

- Creating interdisciplinary challenges for project work
- Team building and real-world problem solving
- Learning through seminars, workshops and lectures with industry experts, practitioners, academic experts, and policy makers

The program is situated in the Centre for Interactive Research in Sustainability (CIRS), which already has multiple partners that conduct research in sustainability and building design. This includes industrial researchers from Haworth, BC Hydro, Honeywell and Perkins + Will. CIRS is both a test-bed and demonstration platform for new building technologies such as Solar PV, wastewater treatment, green roofing, solar thermal, advanced HRV and geo-exchange systems. While the program has been constructed with the intent of an interdisciplinary learning environment, upon which many of the learning objectives are founded, judging the success of its learning outcomes is challenging. Indeed, the "criteria for judgment constitute the least understood aspect of interdisciplinarity" (Klein, 1996). While there are well-structured evaluations criteria available, such as those developed by the Engineering Graduate Attribute Development Project (EGAD, 2012) and the Canadian Engineering Accreditation Board (CEAB), unfortunately they are of limited value due to the varied background of SBSP students. Drawing from established evaluation programs is difficult in an interdisciplinary environment. While many SBSP students have applied science backgrounds, approximately 30% of students have backgrounds in other areas such as commerce and social science.

3 Educational Programming – A Student Experience

A key program innovation is that students retain their home department while they are encouraged to work together in SBSP courses, hence reducing the institutional administration burden of a dedicated degree granting body. The students progress through the program, while enrolled in the home department, over either a two-year or four-year track depending on their status as a Masters or Doctoral student. However, maintaining a home department also causes integration and identity challenges due to the distributed nature of the resulting fragmentation of community and learning experience.

Figure 1 shows how students are admitted and progress through the program. SBSP students are brought together in the Topics course (third row, Figure 1), where they work in teams to solve multi and interdisciplinary assignments. The solutions for course work require the students to understand how building systems interact and the required integration of multiple disciplines to facilitate sustainable building design and construction.

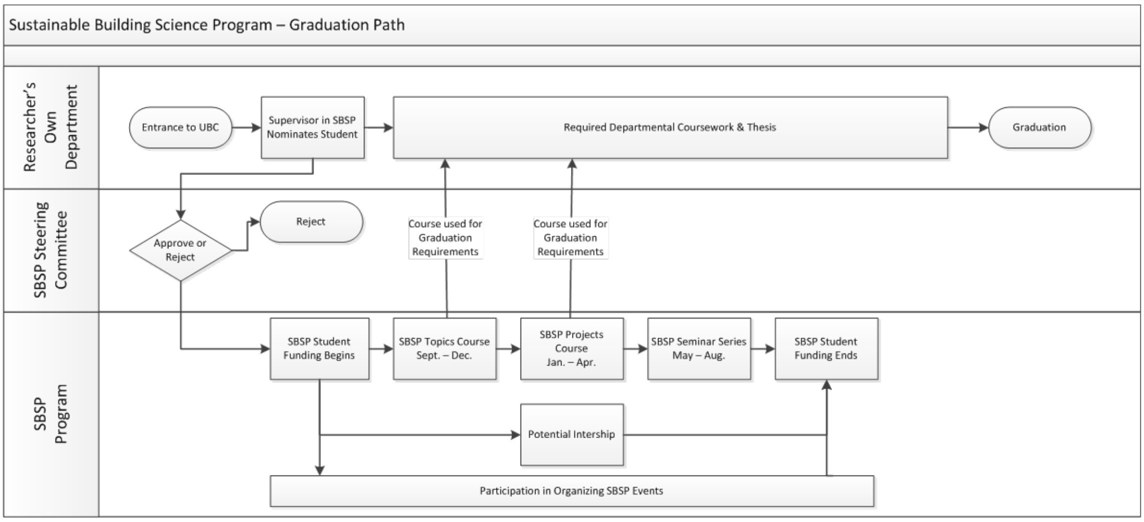

Figure 1: SBSP Graduation Path. Funding is 2-4 years depending on degree type.

4 Learning Environment

The program learning environment, and the attainment of learning objectives, is founded on the input of multiple stakeholders, many of which are situated in affiliated institutions, local faculties and industrial partners. This helps to provide a balance of industrial, municipal and external expertise (outside the academy) with conventional academic expertise.

4.1 Learning Objectives

The overarching objective of the program is to "[create] an environment for professional training and innovative research that is applied to the design, creation, operation and monitoring of buildings that promote health, occupant satisfaction, have a low ecological footprint, and that must exist in the larger context of the community" (Sustainable Building Science Program, 2011). The program attempts to achieve this goal by three main courses:

1) A Topics course that is taught by over 21 practitioners and research experts. Expertise is sourced from the AEC professional community:

2) A projects course which collaborates with partners, such as the City of Vancouver, the University Sustainability Initiative (USI), academic experts and other SBSP partners to solve real world problems; and

3) An interactive seminar series that invites participation from AEC professionals outside the program to share their insights with participating students. Seminars are open to the public to encourage broad debate and participation.

Some students are also given the option to co-habit an office space in CIRS which is a building designed for building science and technology development and demonstration. This option has considerable potential since it connects SBSP to unique resources, such as building systems data, while providing access to 'Campus as a Living Lab' projects.

4.2 A Student Review of Learning Objectives and Outcomes

From the student perspective, learning objectives of the program are populated not only by the overall program goal, but also specific objectives integrated into individual thesis work required by the faculty supervisors. We define the objectives from the student perspective and indicate corresponding learning outcomes. These are based on the original SBSP program objectives as drawn from the original grant goals. We also show a path to attainment for each objective and indicate example outcomes from student led project work (data from Natural Sciences and Engineering Research Council of Canada (NSERC) grant review, program output and recent work by authors). The list is not meant to be exhaustive, but rather indicative of progress.

The main learning objective and their outcomes are to:

1. Learn to work within a team comprising a broad base of disciplinary knowledge to explore solution spaces that are based on multiple, or between, two or more disciplines and implement them in an industrial/commercial environment.
Desired outcome: *To develop interdisciplinary professional expertise and hard skill sets for immediate deployment in the work force.*
Program path to attainment: *Topics course projects, project course.*
Examples of actual outcomes: *Khosravi & Scott, Electric vehicle charging station project; Storey and Montgomery, Wi-Fi Occupancy Project; Montgomery and Storey, Indoor particulate modelling and exposure simulation and experimental calibration.*

2. Learn and develop leadership skills to lead industrial and research innovation projects from ideation through development and implementation.
Desired outcome: *To lead, support, and fast track the propagation of sustainable buildings across the Canadian built landscape.*
Program path to attainment: *Topics course projects, Project course.*
Examples of actual outcomes: *Montgomery, YVR airport air filtration project; Storey et al, founding Life cycle analysis Alliance, Emerging Green Builders-UBC; Storey and Save, new business "Structured Reports Corp"; Fedoruk and Save, CIRS Integrated Design review.*

3. Learn how to approach problems in a collaborative manner for application in real world environments. Students can explore challenges to sustainability both on campus and further afield in a domestic and international context.
Desired outcome: *To understand how to generate a solution space and to pinpoint sustainable and viable designs, interventions and innovations in our current and new building stock.*
Program path to attainment: *Topics course projects, Project course, student projects, internships.*
Examples of actual outcomes: *Save, USI project work; Storey GSSS Summer school; Save, BCSEA leadership role; Garnier, CoV sponsored research work.*

4. Learn how to leverage existing knowledge to accelerate sustainability by building on both existing and emerging industrial and research capacity.

Desired outcome: *To utilize the extensive research capacity that currently exists in Canadian universities and by training and learning in sister institutions. To work with innovative industrial partners via internships.*
Program path to attainment: *Internships, Topics course partners.*
Examples of actual outcomes (Internships): *Montgomery + Modern Green (Beijing) internship; Incoming 5 x French intern students and 3 x Student Without Borders Brazilian students.*

5. Learn new methods knowledge co-production and sharing by working with partners to move beyond conventional systems of knowledge transfer.
Desired outcome: *To promote and participate with active knowledge sharing and co-production between industrial partners by working with common datasets, experimental systems, co-presentation and inter-institutional presentations.*
Program path to attainment: *Seminars, inter-institutional presentations.*
Examples of actual outcomes: *Save @ Florianopolis, Montgomery @ YVR airport authority (presentation), Storey @ CBE, UC Berkeley, Storey @ Stantec @ Perkins and Will.*

Many of the outcomes have been attained by either thesis, individually or SBSP initiated. Some of these attainments have been significant and have included grant proposals, novel research collaboration and new businesses. However, while many learning outcomes emerge from ideas shared and generated from within the SBSP community, many have originated simply from individual initiative and have been accelerated by co-location of student seats. Based on a qualitative review of the data by SBSP trainees, Figure 2(a) shows how effective the learning objectives have been mapped into outcomes. The objectives that involve collective endeavour are the weakest and those that involve individual endeavour are strongest. It is not clear that the paths to attainment for collaboration are sufficient; the course work and internships alone may not be providing strong paths without further development and support. Figure 2(b) shows the location of each student's activities in domain of academia versus outside academia and disciplinary versus interdisciplinary (based on data from a major program review provided to NSERC, the program funding agency). Most student activity remains focussed on disciplinary and academic work, which is expected for their thesis work, but is far from the SBSP optimal balance of industrial and socially based outputs in an interdisciplinary context. Getting to the desired focus area requires stronger community, collaboration and communication.

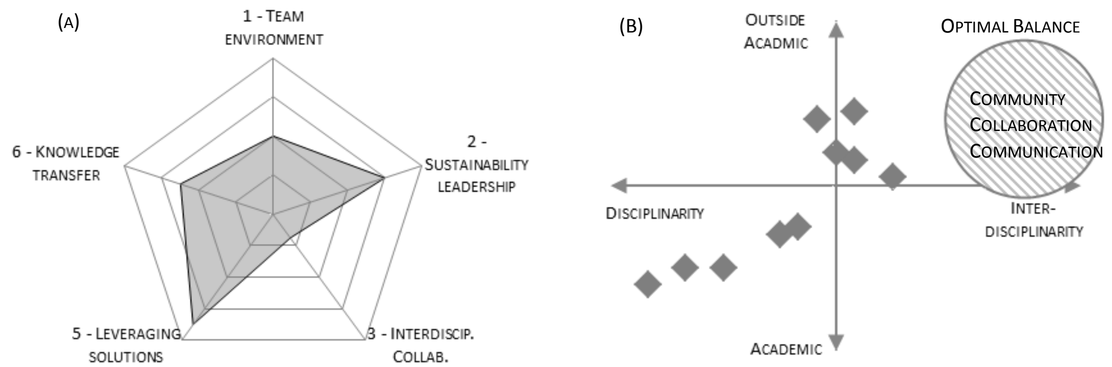

Figure 2: (A) Shows the effectiveness of reaching learning objectives and (B) shows the loci of student activity for individual work and the shaded area shows the ideal program goal and activity zone.

5 Challenges

While the diversity and plurality in educational background of SBSP students brings a large toolbox to a complex design problem, the barriers to collaboration between disciplines remain an integration challenge. Overcoming these barriers and opening a solution space necessitates extra steps to structure design problems at outset; students must (a) develop common ground before structuring problems and (b) learn each other's disciplinary 'language'. Additionally, the learning commons in the program is at times fragmented due to a lack of co-habitation and co-supervision. Finally, finding methods to confirm 'success' for each learning objective, in terms of outcomes, is currently underdeveloped. The conventional criteria used to judge disciplinary work cannot be easily applied to interdisciplinary work (Boix, 2004). Based on feedback from students enrolled in the program, including Postdoctoral fellows, the main barriers are identified as follows:

Problem A: Distributive location of students leads to fragmentation of the academic community. Currently, around 60% of students co-habit an area in the CIRS building with the remaining students seated within their home departments across campus. There is a marked difference in the level of collaboration between students located in distal locations, and those seated in close proximity.

Solution 1: Encourage co-location by providing requirements to occupy the main program area for a minimal period of time. While prescriptive rules may be at times difficult to implement, some flexibility can be given to students with regards to exact timing of seating in CIRS. This could be achieved by having a 'hot desk' in CIRS that can be rotated between visiting students.

Solution 2: Encourage regular and informal laboratory meetings with a focus on brainstorming and developing new ideas. The discussions could be problem focused with students examining issues rooted in building science and human health. The environment should be conducive to students connecting evidence, new data, and emerging ideas and for collective examination and critique.

Problem B: Difficulty in connecting supervisors for joint research projects. Professors already have ongoing disciplinary projects and most multidisciplinary projects are led by student initiative. This is sufficient if the students are adequately supported and rewarded for taking a leadership role, however there are few mechanisms currently within the program structure to provide incentive. The additional hazard to overly relying on students to take a leadership role is that the creation of projects is dependent on the particular value set of each cohort of student. If an intake of students for a particular year is dominated by students with an exclusively disciplinary focus, and who do not want to take risk within a collaborative project, then the program's interdisciplinary objective will be hard to attain.

Solution 1: Encourage joint funding of students instead of single point funding. For example, two supervising professors, from different disciplines, could each contribute 50% of funding which would ensure that they must work together on guiding the student's thesis project. This will ensure students newly enrolled to the program automatically have two supervisors and a focus on interdisciplinary research.

Solution 2: Provide (a) project management and leadership training to prepare new students for expected collaborative work; (b) an incentive structure that is mixed non-pecuniary, honour based, and purpose centred rewards.

Problem C: Disciplinary linguistic barriers exist between students of different backgrounds. The approach to program enrolment is 70% natural science and engineering (NSE) and 30%

non-NSE which means participation is from a wide variety of backgrounds including social science, architecture, engineering and physics. The challenge of communicating knowledge across the disciplinary spectrum means that the student often struggles to find a common ground.

Solution 1: Encourage students to develop an interdisciplinary vernacular by exchanging stories in plain language, facilitated by social interaction via journal clubs and 'brown bag' lunch talks.

Problem D: Professional development, innovation development and integrative skill building, which are within the intent of the SBSP program, require more than conventional academic training. Interdisciplinary problems in a real-world setting are messy, complex and require a high degree of structuring, management and leadership.

Solution 1: Students participating in the program would benefit from a greater degree of extra-curricular activity and service work. Students could be further encouraged to participate in institutionally provided professional development programs that exist in associated departments.

Solution 2: Students could be incentivised and rewarded to join existing or new organizations to support fellow students, participating in municipal organization dedicated to the advancement of an improved built environment, and volunteerism in both academic and non-academic settings.

Problem E: While individual students are pursuing interdisciplinary work, fewer projects involving interdisciplinary research are evident between SBSP students outside the project class. This is exacerbated by the lack of academic collaboration between professors. In part, this is due to many faculty members having only a peripheral interest in building science.

Solution 1: A requirement of the program could be for students to produce at least one conference or journal papers to be co-authored with one or two students from another department. These activities could be upheld and supported by faculty.

Solution 2: Professors could collaborate with students from another department, or other institutions, and their corresponding professors to publish a conference or journal paper.

SBSP is entering the third year of its six years of funding. With the funding window rapidly closing, creating a self-sustaining financial model after 2016 is an imperative. The lack of collaborative research among the co-investigators could be solved with the development of a larger-scale collaborative, interdisciplinary research project, involving both faculty and students. Having a central project could enable a move toward an issue-driven interdisciplinary endeavour which, as Robinson (2007) points out, can facilitate collaboration and integration. A research associate could be appointed to supervise this project and pursue avenues to develop a self-sustaining model and leverage the solutions that are outlined above. Deepening industrial collaboration and exploring co-funding opportunities could be conducted synergistically to advance learning opportunities. However, the remaining question of collaboration, quality, and rigour remain a challenge within the program. Jacobs (2011) suggests that finding and developing general criteria for the evaluation of interdisciplinary research would be an important advance. While many criteria will emerge during program operation, we suggest that generating key criteria as a program is founded provides useful metrics to track program success. Finally, we suggest that developing community and communication will enable stronger and more productive collaboration. Oberg (2012) suggest that navigating a challenging collaborator environment, especially where stakeholder priorities come into conflict, can be best resolved by taking a dialogue-based approach to creation-based processes from a basis of common grounding.

6 Conclusions

We have discussed the intent, structure, objectives and challenges for an interdisciplinary graduate-level building science program from a student perspective. We found that while many of the learning objectives have been met, some remain underdeveloped. These underdeveloped objectives, particularly the difficulty in collaborating, are challenged by (1) a lack of community between student members, (2) a lack of interaction at the faculty level and (3) the difficulty of working between disparate disciplines in terms of language and epistemologies. Advancing learning involves bridging divides between stranded or fragmented knowledge domains. These same skills will enable students to build bridges across the design-construction performance gap by identifying synergies and co-benefits across multiple participatory stakeholders. Finally, we conclude that building strong community and methods of communication will lead to more active collaboration. For future sustainability and leadership programs, we recommend that the metrics of progress be clearly delineated at the outset of program development and coupled to milestones set for regular review. Developing collectively agreed benchmarks and metrics to define progress will enable progress to be tracked as the program is underway.

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