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Graham Scholars Program: sustainability education through an interdisciplinary international case study

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Abstract A course for upper division undergraduate students was developed in response to a request for a cross-disciplinary course in environmental sustainability with an emphasis on an international issue. The topic selected for the course focused on the energy needs for Chile and a proposal for five hydropower projects on the Baker and Pascua Rivers in the Patagonia area. Collaborations between the University of Michigan (USA) and the University of Concepción (Chile) to develop the course led to a plan to offer a parallel course at both universities, with the students of both courses participating in a site visit to Patagonia. The courses were structured to enhance learning through interdisciplinary team-based activities. The courses were taught in a seminar format, with invited lecturers to provide background information on technical, environmental, economic, social, and political issues surrounding hydropower development in general and the proposed projects in particular. The students combined this information with insights obtained during the site visit to prepare a variety of course products, notably an assessment of the concerns of the various affected stakeholder groups. Assessment of the course outcomes is discussed.

Keywords Sustainability education · Inter-university collaboration · International development

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Introduction

Sustainability has emerged as a major issue on university campuses in recent years. In addition to the implementation of sustainability practices on campus, educational programs have been developed to emphasize the concept of sustainability. Professional organizations such as the Association for the Advancement of Sustainability in Higher Education and the Higher Education Associations Sustainability Consortium, have been created to promote sustainability in higher education. A relevant question is what core principles should sustainability education focus on? A review of the literature suggests that many courses on sustainability are project-oriented, with the students organized into functional teams to address a specific application. However, most courses are organized along disciplinary lines (Staniskis and Stasikiene 2007) and the emphasis of the projects is often on the implementation of sound environmental practices on campus (Brunetti et al. 2003) or product design (McKay and Raffo 2007). Others, such as Sherman (2008), argue that this approach is too narrow and that the focus of sustainability education must expand beyond practices such as recycling, energy conservation, or the installation of renewable energy facilities and begin to address the broader issues that relate to environmental limits and human values that will determine our future. These concepts extend beyond national borders and political institutions.

It was in this context that the Graham Environmental Sustainability Institute at the University of Michigan requested proposals for the development of a winter semester 2008 course to inaugurate their Graham Scholars Program focusing on a cross-disciplinary approach to environmental sustainability in an international context. The Graham Environmental Sustainability Institute is a jointly funded effort by the University of Michigan and the Graham Foundation for encouraging multidisciplinary research and education in environmental sustainability. The stated mission of the Graham Institute is to: "Create opportunities and encourage collaboration among science, policy, engineering, and business faculty to extend the knowledge of, and offer solutions to, complex environmental sustainability issues—recognizing the need for balance between societal needs and social responsibilities." The Graham Scholars Program is intended to engage highly qualified students, from the perspectives of a broad range of disciplines, to apply their knowledge to complex global sustainability issues. Courses in the program will involve the detailed investigation of economic, engineering, scientific, political, and human health/social aspects of environmental sustainability, with a focus on a particular international application.

This manuscript describes the concept that was developed and implemented in companion courses taught on two university campuses in the US and Chile, the context of the selected application, and the course objectives and organizational structure. Course products are discussed, along with an assessment of the course outcomes.

Water occupies a somewhat unique position with respect to sustainability concerns. Worldwide, an impending 'water crisis' (Gleick 1998) is driven by increasing demands for water for a variety of economic, environmental, and social objectives. Predictions on the potential impacts of global climate change include increasing water scarcity or distribution pattern changes in regions already suffering from supply shortages (Gleick 1993; Jackson et al. 2001; Vitousek et al. 1997). These issues have received broad international attention over the last two decades and broad elements of sustainability, including environmental limits and human values, have been embedded in a number of statements regarding integrated water resource management. Gleick (1998) suggests a set of seven sustainability criteria to govern long-term water planning and management; these include the following concepts:

- A basic water requirement (in terms of quantity and quality) will be guaranteed to restore and maintain the health of ecosystems
- Human action will not impair the long term renewability of freshwater stocks and flows
- Water planning and decision making will be democratic ensuring representation of all affected parties and fostering direct participation of affected interests.

The broad elements of sustainability (environmental limits and human values) discussed above are embedded in these criteria. A course integrated around a topic that addresses the tensions involved in meeting conflicting demands on natural water systems thus provides an excellent framework to address the 'big picture' aspects of environmental sustainability.

The Graham Environmental Sustainability Institute committed resources for course development to the extent that a visit to the international site of the course focus would be provided for all participants. Proposing Chile as case study was a natural choice, as the two co-instructors from the University of Michigan (UM) had previous connections with the University of Concepción (UdeC). The first author's connections included a Fulbright grant to study issues related to the proposed hydropower development and the second author had obtained an MS degree at that university. Chile provides an excellent context to consider sustainability issues in that it is a developing country currently facing an 'energy crisis,' with proposed hydropower development solutions presenting conflicts between private economic considerations and local socio-economic factors, as well as the environment.

Developing the logistics for a successful collaboration between universities generated the idea to conduct a similar course at UdeC. The two courses would not be offered simultaneously due to differences in academic schedules, but the intent was to integrate the two groups of students during the site visit and through other activities to as great an extent as possible. The major course objectives would be consistent, while allowing for differences in their structure according to local logistics.

Background

There is a considerable pressure on Chile to develop new energy sources due to relatively strong economic growth over the last 20 years that has resulted in a growth in energy demand of about 7.5% per year, or 2% greater than the growth in GDP (Iglesias 2008). Chile has minimal petroleum resources and, in a large part, has dealt with increasing energy demands over the last decade by importing natural gas from Argentina to fuel thermo-electric power plants. There has been increasing unreliability of this natural gas supply in recent years due to the inability of Argentina to satisfy its own internal demands.

The specific topic addressed in the courses was a proposal to develop hydropower projects in the Patagonia area

of Chile. A number of hydropower projects with a total potential of 8,500 MW are being considered in the region. One proposal involves two dams on the Baker River and three on the Pascua River, with a total installed generating capacity of 2,750 MW, representing approximately 30% of the current electrical consumption in the central grid. Since the electricity produced will not be used locally, a 2,000-km transmission line (an initiative independent from the hydropower projects), resulting in considerable environmental disturbance, will be required to conduct the electricity to the central power grid serving the majority of the country. The developments have been proposed by HidroAysén Co., a consortium of two companies, Endesa (Spanish) and Colbún (Chilean).

These proposed projects have generated considerable controversy for a number of reasons. Endesa's development of the Pangue and Ralco hydroelectric projects on the Bío Bío River over the previous 12 years created considerable negative publicity for the company due to population displacement, most of them indigenous (Nesti 2002; Newbold 2004). Patagonia is a remote area and represents a relatively pristine environment with a low population density ($\sim$0.4 inhabitants per km^2), with a unique social structure; there is concern about the destruction of this 'way of life' by the proposed projects. There are also concerns about the direct impacts on the river and fjord ecosystems which have been poorly characterized; Chile is a region with significant biodiversity and many endemic species (Dyer 2000), due to its unique geographical situation. Finally, there are concerns about how the projects may influence other economic activities, such as tourism and salmon culture in the region.

The course plan involved an examination of the Patagonia projects with an explicit consideration of sustainability issues, understanding the technical aspects of the hydropower projects, the characteristics of Patagonian aquatic ecosystems, the political issues surrounding the project review processes, and other social and political issues that would influence the decision.

Chile is a particularly interesting country to examine sustainability issues in relationship to energy, economic growth, and the environment. The development of the country's 1980 constitution under the former military regime emphasized a strong free market economic structure that has persisted to the present day due to conditions imposed during the transition back to a democratic government in 1990. The constitution provides the framework for the economic system by defining broad private property rights and severely constraining regulation by the state. Water rights defined in the 1981 water code follow this general structure and are often hailed as an example of the success of implementing water markets (e.g., Rosegrant and Binswanger 1994). Bauer (2004) provides an extensive analysis of the consequences of the water code since its implementation, including issues of social equity and environmental protection. A significant issue is how long-term sustainability concepts can be implemented in a society with no general energy policy and minimal governmental intervention in water management and environmental protection.

Course objectives and content

In keeping with the broad objectives of the Graham Scholars Program, the overall objective of the course was to provide insight into the processes for making sustainable decisions as societies struggle with multi-faceted problems. The choice to focus on a specific case study in an international location was dictated by the desire to provide the students with the contextual richness that the nuances of a real application bring to the educational process and in a circumstance relatively free of preconceptions. A more personal objective for the course instructors included the desire to reinforce the concept that solutions visualized from the perspectives of one's own culture and experiences are not always appropriate in other settings.

Teaching courses with a broad, cross-disciplinary framework presents challenges in defining specific content and reasonable expectations. We developed a list of issues that were considered to be most relevant to the proposed projects, including technical details on hydropower plants, the political system framing the decision-making process, characteristics of fluvial ecosystems, renewable energy alternatives, and lessons to be learned from previous dam projects. These topics were introduced in classroom presentations to provide the context from which to address broad questions such as:

- What lessons can be learned from past experiences and can these be generalized to anticipate consequences to a variety of stakeholders if the proposed projects proceed?
- What are the consequences of economic policy frameworks that were not established to address social and environmental concerns or long-term sustainability considerations?
- How will the ultimate decisions be made, by whom, and are there better models?

Course participants

Anticipating a strong demand for enrollment in both courses, announcements describing the general content were broadly distributed and application processes were implemented. Although the Graham Scholars Program is

restricted to upper level (third and fourth year) undergraduates, several graduate students applied to enroll in the course and one was selected. Application to the UdeC course was open to both undergraduate and graduate students, with a final selection of five undergraduate and five graduates. Enrollment was set at 18 students for the UM course, while ten students participated in the UdeC course. In addition to overall qualifications and experiences relevant to the course content, a key consideration in the selection of the UM students was the goal to assemble a broadly cross-disciplinary cohort. A total of 64 applicants for the program allowed this objective to be easily attained, with a final class mix of students from engineering (civil and environmental, mechanical, chemical, naval architecture), natural sciences, economics, Latin-American studies, political science, mathematics, geology, music, and public policy. Functional ability in Spanish was not made mandatory for selection but was considered to be a positive attribute in applicant evaluation; two-thirds of the course participants had completed more than an introductory course in Spanish. The backgrounds of the students selected for the UdeC course was somewhat more narrowly focused, with all students being in the area of science and engineering (including civil, environmental, mechanical, and electrical engineering, as well as environmental science, oceanography, biology, and marine biology). A key selection criterion for the UdeC students was English proficiency.

Course format

The two courses were organized along similar lines, basically following a seminar format with presentations by invited experts on specific topics, with subsequent discussion sessions. The topics discussed in the two courses were similar (Table 1). Targeted readings (technical papers and reports) were distributed prior to each presentation. Field trips (in addition to the combined trip for both courses) to relevant facilities were a component of both courses. Course activities in the UM course prior to the site visit included a field trip to the Hardy Dam, located on the Muskegon River in the State of Michigan, to provide direct experience observing a hydropower installation. The Chilean students visited areas with alternative energy project developments (wind energy and waste gas production).

The primary course products were a series of oral and written presentations, discussed in more detail below. Teams integrated the diverse student backgrounds in order to ensure that multiple perspectives were considered during the development of course products. For the UM course, four different team-related tasks were performed and three different team combinations were established to meet these requirements. The team composition was initially controlled, with the stipulation that a team be composed of at least one engineer, someone with a biology background, and someone with an economics or policy-related background. This policy did not need to be enforced following the completion of the first team activity as the student-formed teams achieved the desired diversity.

The UdeC course was conducted over a 12-week period following the site visit. Due to academic year differences, the first lecture in the UdeC course was almost coincident with the final presentation in the UM course. Two types of teaching activities were conducted: weekly 2-h lectures and separate seminar activities related to the lecture topics. These teaching activities were performed by a cross-disciplinary team of lecturers, including a biologist, civil, industrial, and chemical engineers, a geographer, and an architect. Two Fulbright visiting professors participated with the Chilean faculty to present lectures and seminars dealing with hydropower development and sustainability, and they also participated throughout the semester, contributing to the interdisciplinary approach and discussions regarding evaluation tools. Their presence was very important and relevant for the Chilean students, who developed their final oral presentation in English.

Table 1 Course topic coverage in the University of Michigan and University of Concepción courses

University of Michigan course	University of Concepción course
Sustainability concepts	Energy development issues
Basic technical issues associated with hydropower projects	Basic technical issues associated with hydropower projects
Water law and policy in Western United States and Chile	Principles of river ecology
Riverine ecosystem function and disruptions by dam construction	Upstream and downstream effects on hydrology and geomorphology
Experiences in the Columbia River system, US Pacific Northwest	Flow variability and ecological links
Analysis of World Commission on Dams report	Effects on biogeochemical cycles in coastal waters
Hydropower impacts on indigenous populations	Societal impacts of hydropower development
Energy alternatives	Tourism considerations
Non-governmental organizations' positions on the Patagonia projects	Hydropower impacts on biodiversity
	Energy alternatives

Site visit

The site visit was scheduled around the UM spring break week towards the end of February 2008. The UM students were exposed to all background topics prior to the site visit. UdeC students were provided with relevant reading material in order to prepare for the field trip, as the academic year had not yet begun at that time. The Chilean students served a guide role for the UM students during the site visit, facilitating the cultural interchange and communication with the local people and diverse stakeholders.

Primary targets for the site visit were the locales of the proposed Patagonian hydropower projects. Visits were also made to the facilities of various stakeholder groups connected with the implementation of the hydropower projects. These included visits to the offices of:

- HidroAysén to see displays and hear presentations on the five proposed projects
- Centro de Investigación en Ecosistemas de la Patagonia (CIEP, Center for Investigation of Patagonian Ecosystems), a research institute involved in basic scientific studies in the region
- SalmonChile, an aquaculture (caged salmon farming) trade organization with facilities in Puerto Aysén; water quality changes associated with hydropower development could impact aquaculture activities in the region.

Following the Patagonia visit, travel proceeded north towards the University of Concepción Ecological Research Station on the San Pedro River. Activities included field sampling to expose the students to biodiversity and the ecological status of rivers in the region and discussions on proposed hydropower projects on the San Pedro River. A final trip to the Laja River was conducted to visit a system where several run-of-the-river hydropower stations and irrigation intake channels have been constructed. The Laja River is a major tributary to the Bío Bío River, where Endesa hydropower projects have displaced indigenous populations.

Final trip activities included classroom activities held at the University of Concepción, where UM students made a series of presentations summarizing the UM course content that had previously been covered and a wrap-up discussion of the site visit activities and synthesis of the trip experiences.

Course products

UM course activities with student products were the following:

- Team oral presentations during the Concepción portion of the site visit summarizing the UM course content to UdeC students and faculty.
- New project teams were formed, each to analyze the perspectives of a stakeholder group that would potentially be impacted by the hydropower project implementation. UdeC students contributed to this process by providing relevant information. The stakeholder list included power producers, the Chilean people, the scientific community, non-governmental organizations, business interests, and governmental agencies. Findings were presented orally and discussed for omissions and clarifications. Each project team also prepared a summary document that was included as an appendix to the final project report.
- Final teams were formed to prepare a single comprehensive oral presentation and report on the research developed. The presentation and report included sections containing an introduction, overview and background of issues related to the problem, summary of stakeholder positions, analysis of shortcomings of the current decision-making process, recommended approaches to improve the process, steps towards implementation of these recommendations, and conclusions. Both were implemented as a collaborative effort, and the UdeC students and faculty were able to participate in the presentation via a video link. Sections of the report were prepared by individual teams and the final document contained 138 pages. To date, this report has been provided to the US Ambassador to Chile as background information on energy development issues in Chile, as well as to groups forming to respond to the environmental impact assessment prepared for the hydropower projects.

Activities and student products for the UdeC course included the following:

- Final presentation including stakeholder group discussions similar to the UM format
- A summary analysis integrating the various stakeholder group positions
- A wrap-up discussion involving the audience (primarily course lecturers) and students.

Evaluation and assessment

A series of informal and formal course evaluations by students were administered during the courses.

UM course assessments

With the expectation that the course would be offered in subsequent years, multiple assessments of the student responses to course activities and teaching methodologies were administered. The assessment objectives were to

investigate the effectiveness of the implemented teaching strategies in captivating student interest, as well as developing an understanding of the issues surrounding the sustainable development of complex water resource projects. These assessments took the following forms:

- Following the site visit to Chile, discussion was devoted to analyze various aspects of the site visit, concentrating on what worked well and identifying areas for improvement
- Students were requested to write a few paragraphs on their perceptions of the site visit and the course in general
- A formal course evaluation at the end of the semester, as customary for UM courses
- A follow-up questionnaire was distributed a few weeks after the end of the semester, soliciting final student impressions on the effectiveness of particular aspects of the course structure, such as the value of the field trip, choice of class presentation topics, and structure of the final project.

By all measures, the course was well-received by the students. On the basis of end-of-term evaluations administered by the UM Center for Research in Learning and Teaching, the course was rated 4.65 (median of the evaluation responses) on a 5-point scale, placing it in the upper 20% of all courses evaluated that semester at the University of Michigan. This is significant, given that it was a first-time course offering, and it is common for evaluations to increase in subsequent offerings following the implementation of best practices learned from experience. Table 2 presents a comparison of the median responses on several questions that broadly related to the course objectives. The first three questions in Table 2 relate specifically to the student's perception of whether they learned the concepts addressed previously in the "Course objectives and content" section. Although detailed statistics are not available, it appears that these scores are in the upper 5% of the university courses for which the same questions were asked.

Given the demands of developing a cross-disciplinary course on a complex sustainability issue and integrating an international trip into the course activities, it was perhaps inevitable that certain organizational aspects suffered. Nevertheless, concerns about these were relatively few. One area that presented some challenges was defining the course project. Initially, it was planned that teams of 4–5 students with different backgrounds would work on a project that concentrated on a particular issue related to the case study. This concept evolved into the collective group report, since we felt it important to retain the focus on integrated, interdisciplinary analyses of sustainable hydropower development. Many students felt uncomfortable with changing expectations, but most favored the structure of the combined group report that was ultimately selected. Some concerns arose with the logistics to coordinate the compilation of the material into a collective product. Another challenging aspect was facilitating group interactions. Students pointed out the benefits of having mechanisms in place to promote informal group discussions before and during the site visit. Daily discussions during the site visit were planned, but logistics associated with traveling in a large group in the remote areas placed unanticipated constraints. Further, several students wished that more time had been spent on providing background on Chile prior to the site visit. The course content was intentionally developed so that the perspectives of the course instructors would not influence the student's own 'lens' on the multiple issues involved in sustainable hydropower development. The goal was to challenge the students to discuss, defend, and, where appropriate, modify their views to best engage others to develop effective interdisciplinary solutions to complex sustainability problems. Finding a balance between challenging the students to better appreciate the complexities of sustainable development and providing appropriate background remains to be tested in future offerings.

UdeC course assessments

In order to assess student opinions on this new teaching experience at the University of Concepción, two surveys were administered to the students, one at the midpoint of the course and the other following the final presentation. The format was similar to the approach used in the UM

Table 2 University of Michigan course evaluation responses to items relevant to the course objectives

Evaluation question	Course score	University-wide 75th percentile
I learned a great deal from this course	4.89	4.38
I developed a greater understanding of the impact of engineering on the environment	4.73	4.08
I have a greater understanding of how course concepts apply to contemporary problems	4.79	4.25
I developed a greater understanding of my responsibilities as a professional	4.75	4.59
This course increased my desire to learn more about this subject in the future	4.89	4.25
I gained valuable experience working in teams on this course	4.89	4.21

assessments, where both general impressions and comments on various components of the course were solicited.

Conclusions

At the onset of the two courses, we explained that there was a situation to be addressed and that a certain amount of background was required to comprehend the range of issues necessary to arrive at a conclusion. Much of the remainder of the courses was involved in providing that background and letting the students form their own perceptions of the issues involved. Teaching the course in a case study format with a site visit contributed significantly to the success of the course in our opinion, and this was reinforced by student comments. Although this approach requires a larger organizational effort, specific case studies have unique characteristics that require students to connect up a range of diverse concepts to the intricacies involved in the specific application. Following is a sampling of comments received from the University of Michigan students when asked for their impressions of the course:

- "Never before had I been involved in a group of this diversity of interests. It has been a great experience to absorb the myriad of different thoughts and ideas. Another unique aspect of this program was the problem that was presented to us. As we have progressed through the course, I think its easy to see that the complexity of the energy crisis in Chile has emerged more and more. The more information we uncover, the more questions and uncertainties arise."
- "Finally, for me personally, the trip really opened my mind to how complicated development questions are. I was more interested in technical aspects of the trip, but after hearing from all the stakeholders, I realize how important the discussion and policy-making that goes into power production can be."
- "This really opened my eyes to how complex environmental systems and issues are, that hardly any issue is merely good or bad, and that the array of people affected is unimaginable."
- "Working with students of different academic backgrounds has not only opened my eyes to new ways of thinking, but has made me sensitive to the problems of such diversity and has prepared me with strategies to overcome those problems as a group and draw on the unique strengths of each individual."

Comments (translated) from the UdeC students included the following:

- The interactions with the foreign professors and students was important to be exposed to different visions of the energy and environmental problems, in particular from a more global perspective that includes the experiences of a developing country (Chile)
- Personally, I think that the course has permitted me to develop a more critical vision and more tolerance of others while developing a thorough analysis of the issues
- The experience with the foreign students and professors as well as the class theoretical discussions and field trips has been a most relevant part of my comprehension.

These comments touch on what we consider to be key aspects of major sustainability problems that will need to be addressed in the coming years and that should be highlighted in courses on sustainability. Specifically, the problems are exceedingly complex, involving multiple stakeholders, require a careful analysis of various technical, environmental, social, and economic issues, and might extend across international boundaries. The successful resolution of identified problems will require the participation of individuals from multiple cultures and disciplines. The course structures were implemented to provide an experience that attempted to capture this complexity. Key aspects included the participation in interdisciplinary teams on an application of immediate relevance. It is noted that these interdisciplinary collaborations existed at the faculty instructor level, as well as at the student level. The particular experience involved an exposure to a different culture that course assessments indicated added significant value to the courses. The ultimate success of the course is beyond what we can measure today as the 28 students incorporate the lessons learned from the experience into their future careers.

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