Pitfalls and Successes of Developing an Interdisciplinary Watershed Field Science Course

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ABSTRACT

At the University of Vermont, an interdisciplinary faculty team developed an introductory watershed science field course. This course honed field skills and catalyzed communication across water-related disciplines without requiring specific prerequisites. Five faculty (geology, engineering, geography, natural resources) taught the four-credit course, highlighting interactions between the hydrosphere, biosphere, and solid Earth. The course, based in the Winooski River watershed, followed the river from its headwaters downstream to its outlet in Lake Champlain focusing on data collection and analysis methods, while exploring threats to this freshwater ecosystem. This course was offered as a summer field course in 2007. Student learning was assessed using weekly summative assignments and final presentations incorporating field data and acquired knowledge. Attitude and knowledge surveys, administered before and after this first year, documented increased self-assessed learning, affinity for the field learning environment, and that the course provided training relevant to various disciplines. The fiscally unsustainable summer model, and course evaluations guided major revisions to the course. The second offering, in 2009, met weekly during spring term to provide students with context before a two-week field component. This field component was held immediately after classes ended to avoid the need to pay faculty summer salaries.

INTRODUCTION

The field camp experience is considered to be one of the most important educational experiences for geoscientists (Plymate et al., 2005). Yet, the number of colleges and universities offering geoscience field camps has decreased 60% since 1985, with less than 15% of geoscience departments in the United States offering summer field camps (Baker, 2006). Reasons for the decline of traditional field camps include increasing cost to the student, lack of faculty available to teach in the summer, and interdisciplinary trends in the geosciences (Kirchner, 1997; Day-Lewis, 2003). The appeal and success of field education extends from successful introductory courses (Elkins and Elkins, 2007) to the calculated integration of fieldwork into a curriculum (Knapp et al., 2006) to the many capstone field courses. Engineering curricula, initially founded on a practical education, have become increasingly distanced from the hands-on learning activities that attract engineering students interested in real-world problems. This is due in part to an increasing university emphasis on faculty research as well as high costs associated with modern equipment maintenance and operation (Feisel and Rosa, 2005).

The job market for geoscientists is shifting toward environmentally focused positions. In 2001, over 35% of all geoscientists earning masters' degrees found employment in environmental consulting firms compared to approximately 12% in the oil and gas industry and approximately 17% who continue their education (AGI, 2001). More striking are figures for employment of geoscientists with bachelor's degrees; more than 20% found employment with environmental consulting firms in 2001, while the minerals and oil and gas industries combined employed only about 5%. This trend is reflected by a 17% enrollment increase in environmental geoscience courses between the 2003-2004 and 2004-2005 academic years (Martinez and Baker, 2006). Engineering education is also changing, with a 95% increase in accredited environmental engineering programs in the United States between 1996 and 2006 (ABET, 2006). There is a strong desire to restructure engineering education similar to other liberal arts disciplines to provide students with more flexibility and benefit from the broader educational opportunities (Grasso and Martinelli, 2007; Duderstadt, 2008).

A team of faculty at the University of Vermont (UVM) from engineering, geography, geology, and natural resources collaboratively developed and tested an interdisciplinary watershed field science course. Our primary goal in developing this course was to provide students from these and related majors interested in water resources the opportunity to participate in an intensive, field-based, learning experience with a watershed approach. Thus, we offered the course to students in any science or engineering major. Each came to the class with a different set of background courses, knowledge, skills and previous field experience. To accommodate the diverse student backgrounds, this course did not require prerequisite courses, but only a desire for cooperative interdisciplinary learning. Initial development of the course was supported by a grant from the National Science Foundation (Award #0611544).

In this paper, we report on the development of UVM's watershed field science course, including information

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about what worked well and where we had difficulties. Although the specifics of our course development took advantage of the existing physical and intellectual resources available in Vermont, the broad concept could be applied anywhere. Objectives for designing this course were: 1) developing a modular, reusable curriculum, 2) teaching and learning in an interdisciplinary setting to provide value-added benefits to faculty and students, and 3) engaging the group in meaningful, hands-on activities. Student assessments were developed along with the curriculum so we could evaluate effective student learning and attitudes about this new, interdisciplinary course. These assessments provided the information we used to improve the course and evaluate its success.

COURSE DEVELOPMENT

The faculty, graduate research assistant, and assessment specialist developed the overall framework for the course during the winter of 2007. Beginning with student learning goals, outlined in Table 1, and faculty interests, the group compiled a list of specific skills as a basis for developing course content. This skill list became the foundation for a detailed knowledge survey (one of the assessment tools listed in Table 2). In 2007, the four-week course followed the Winooski River watershed from the headwaters to its receiving body, Lake Champlain. The class spent one week in the headwaters, the second week in a major tributary, the third on the main stem of the Winooski River, and the final week on Lake Champlain (Figure 1). Each week provided a different

TABLE 1: SUMMARY OF THE 2007 AND 2009 WATERSHED FIELD SCIENCE COURSE SCHEDULES

A) 2007 COURSE SCHEDULE				
	Week 1	Week 2	Week 3	Week 4
Theme	What makes a mountain watershed unique?	What factors contribute to the ecological integrity of a stream?	How do channels change over time?	How does Lake Champlain reflect its watershed?
Field Site	Mt. Mansfield	Huntington River	Winooski River and its floodplain	Lake Champlain
Monday	Introduction to regional geology (overnight in Stowe)	Holiday	Landscape change & air photo analysis	Burlington Bay: Sewer outfall, sediment analysis
Tuesday	Infiltration, flow measurement (overnight in Stowe)	Relationship between biota and geochemistry	River float trip: Geomorphology, land use	Fish & zebra mussel sampling
Wednesday	Macroinverterbrates & geochemistry	Soils, River Management	Research flume exercise	Calculate loads to the lake
Thursday	Laboratory analysis	Riparian vegetation & stream habitat assessment	River bank failure model and GIS exercise	Presentation preparation
Friday	Statistics & report writing	Data Analysis	GIS exercise: Channel change from air photos	Final presentations
B) REVISED COURSE FORMAT FOR 2009 [1]				
Course phase	Weekly semester lecture and discussion	Field training	Transect measurement	Transect presentation
Duration	75 minutes, weekly	6 days	2 days	2 days
Content	Lectures on specific topics of watershed science	Daily field exercises and discussion each focused on a specific topic (e.g. hydraulic measurement, geochemistry, biota and habitat)	Conducting measurements in a mountain watershed, large lowland river and receiving lake	Poster preparation and presentation

1 - Lecture and field topics are available on the course website: http://www.uvm.edu/watercamp

setting and a new focus. Due to financial constraints, the course did not run in summer 2008. In fall 2008, we revised the course structure and curriculum based on assessments of the 2007 course. The course ran in 2009, meeting weekly throughout the spring semester and everyday for 2 weeks in late spring after classes had ended.

The large, diverse Winooski watershed provided a unique opportunity for students to observe and document the differences between steep, high-elevation streams and a large-scale, low-gradient river. While small, instrumented watersheds on or near college campuses provide many opportunities for field labs (Woltenmade and Blewett, 2000; Salvage et al., 2004), these watersheds cannot give students the opportunity to observe changes at a range of scales larger than typically represented in a teaching watershed.

Faculty established a plan for the division of workload and teaching based on specialties and interest. For each field day of the course, we selected one lead faculty member who was responsible for initial design of the field exercise and collection of the needed equipment. The schedule for 2007 and 2009, summarized in Tables 1A and 1B, included allocated time for assessments and presentation preparation.

In 2007, student performance was evaluated through weekly writing assignments asking students to use the data collected each week to discuss the thematic topic question presented each week in Table 1A. Reading materials and datasets collected in class were available to

TABLE 2: SCHEDULE OF 2007 ASSESSMENT TOOLS, INCLUDING SAMPLE QUESTIONS AND RESPONSE TYPES

Assessment Tool	When?	Sample Questions	Responses
Knowledge Survey	Pre and post class	What chemical parameters would you need to measure in the field to describe water chemistry accurately? What techniques could be used to determine dissolved ion concentrations in water? How do land use activities influence runoff pathways? What is the difference between concentration and load for solutes or particulates transported in streams?	1 = "I could not answer this question today" 2 = "I could answer this question partially with help" 3 = "I could answer this question completely"
Attitude Survey	Pre and post-class	I know I understand when I can explain the ideas to someone else. I learn well by doing hands on activities. I prefer problems that have one right answer to problems that are open-ended. It is important to me that a course provides time for discussing ideas.	Likert Scale 1 = strongly disagree to 5 = strongly agree
Demographic Survey	Pre-class	Reason for taking course? Where are you from? Anticipated grade?	Written responses
Weekly Self Reports	Every Friday	How are your course expectations being met or not met? Describe your small working-group experience this week. Describe your interdisciplinary learning this week. What new academic and personal skills have you gained this week? Are there any issues related to the course we should know about?	Open ended, written comments
Rated Questionnaire	Post-class	I believe this course will help me define my career path.	Likert Scale 1 = strongly disagree to 5 = strongly agree

the students through the course website, http://www.uvm.edu/watercamp. The first three days of the course were residential, but the remainder of the course was non-residential, with students traveling by van to the field locations. Scheduled immediately following spring graduation, students had the opportunity to seek summer jobs or take additional classes after the course.

In 2009, we began the course in January and met once a week for 75 minutes. There was one lead faculty (Bierman) who led 4 classes. Each of the other faculty led 2 classes and we had guest lecturers one week. In early May, after the semester had ended, the class spent 2 weeks in the field. The first 6 days were instructional with faculty, usually working in teams and with the graduate teaching assistant, leading exercises designed to teach relevant field skills – these exercises were modified directly from those used in 2007. Over the next 2 days, students with minimal faculty supervision, collected physical, chemical, and habitat data along a mountain to lake, downstream river transect. After working in groups for a day reducing data, they spent a morning on the lake, completing the transect sampling, then, presented their findings in the form of a poster to the group.

Grant funding provided $1,000 stipends for 8 students chosen to participate in this first year of the course. To recruit the best students, the course was advertised throughout the UVM and broader New England community using list-serves, fliers, the course website, in-class announcements, and word of mouth. Students applied by submitting online their contact information, a transcript, a letter of recommendation, and a short statement describing their interest in the course. The course was cross-listed through the programs of each of the participating faculty, Civil and Environmental Engineering, Geography, Geology and Natural Resources, where we sought to attract students from these disciplines with a specific interest in water resources.

STUDENT ASSESSMENT STRATEGY

Student assessment data were collected throughout the 2007 course with Institutional Review Board approval.

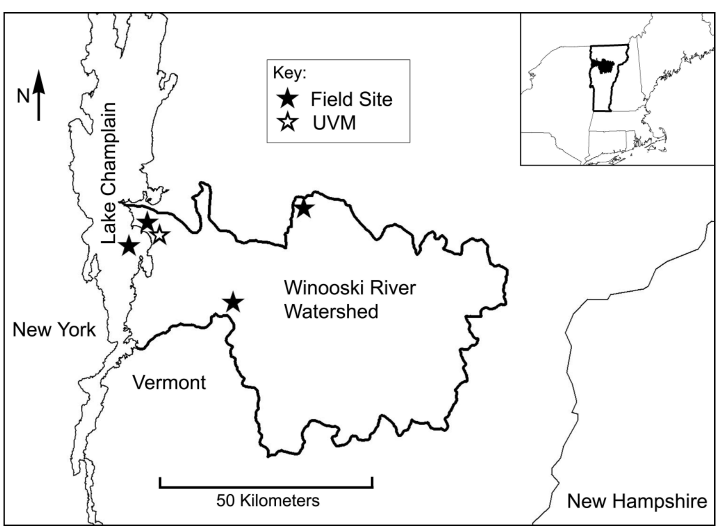

FIGURE 1. Location map of the Winooski watershed and field areas used in the watershed field science course.

Six different tools, summarized in Table 2, were used to evaluate and understand the student experience: a knowledge survey, an attitude survey, a demographic survey, weekly self reports, a rated questionnaire, and an individual taped exit interview. Students were informed about the intensity of the planned assessment of the course and all gave consent for their responses to be used for research purposes. The data from these metrics was used both formatively and summatively.

Students completed an 85-question self-assessed knowledge survey prior to the start of the course and again at the end of the course. Knowledge surveys ask students to rate their confidence in answering the question, rather than actually answering the questions (Nuhfer, 1996). Carleton College's Science Education Resource Center (SERC) website (http://serc.carleton.edu/NAGTWorkshops/assess/knowledgesurvey/) provides a good review of the principles and application of knowledge surveys. Knowledge surveys assess student learning in specific detail and have been suggested to be a better indication of student learning than a single overall rating of a course, which does not necessarily correlate with student learning because perception can be biased by their individual experience (Nuhfer and Knipp, 2003). Knowledge surveys also help faculty plan and organize course content prior to and during the course and also serve as a study guide for students (Nuhfer, 1996). Our knowledge survey was a major tool in the development of the curriculum for this watershed field science course.

We used a 37-question attitude survey (using a 5-point Likert scale, 1-strongly disagree to 5-strongly agree) to quantify student perceptions about their ability to learn, the speed of their learning, and the source of their knowledge and learning. The same basic epistemological concepts are included in survey instruments presented by Jehng et al. (1993) and Schommer (1993) designed to evaluate student attitudes about knowledge and learning (Duell and Schommer-Aikins, 2001). Our motivation in using this assessment was to identify attitudes typical of students interested in this course and to document any changes in perceptions about learning from the beginning to the end of the course.

To modify and improve the course, we sought frequent feedback from the students during 2007. Through weekly, open-ended, written, self-reports, students discussed and provided feedback about our teaching goals through the questions highlighted in Table 2. This type of regular feedback has been successfully used to monitor and modify student progress in geoscience courses (Trop et al., 2000; Harris, 2002). This weekly feedback was supplemented by a rated questionnaire and individual taped interviews during the final day of the course. The rated questionnaire was designed to provide some quantitative feedback about how fundamental structural elements of the course impacted the student learning experience while the taped interview gave students an opportunity to comment on their experiences in a discussion format allowing the interviewer to ask for clarification or elaboration on specific comments.

RESULTS OF STUDENT ASSESSMENT

All assessment results were compiled after the completion of the course in 2007. Results of the student demographic survey were representative of traditional science and engineering courses (e.g. not very diverse). Of the 5 men and 3 women in the course, 6 attended high school in the northeastern United States, one in California, and one, a non-traditional student, in South Africa. Three students were majoring in engineering, three in environmental sciences, one in environmental studies (conflict resolution), and one in geography and applied math. Seven of the students were undergraduates at UVM; one student attended a private four-year college elsewhere in New England. Several open-ended questions were included in the demographic survey including reason for taking the course and course expectations. Student expectations at the outset of the course were that it would be a lot of work and that they would receive good grades (5 reported A's and 3 reported B's). Students' reported motivation for taking the course included 1) interest in the topic, 2) relevance to their intended major, and 3) interest in gaining experience in the field. This course satisfied a science elective requirement for all represented programs.

All eight students completed the knowledge survey before and after the course. The overall average in responses increased one full point from 1.74 to 2.74 out of 3, with one student omitting questions 22-85 of the pre-test. Figure 2 shows on average, knowledge survey responses increased from the pre-test to the post-test for all 85 questions. Questions with the smallest increases between pre and post-test tended to be associated with one of two categories, 1) topics not covered in as much detail as had been originally planned due to last minute schedule and curriculum changes and 2) questions that elicited very high responses on the pre-test. The largest percent difference between pre and post-test responses were associated with the most discipline specific vocabulary or skills (e.g. bankfull elevation, laboratory test for e-coli) as opposed to conceptual questions (e.g. How does water reach streams? and How does land use influence runoff pathways?)

The fifty-eight-statement attitude survey was completed by all students, pre and post-course. One student did not complete a page of the survey, missing thirty-three statements in the assessment. Five of the statements elicited statistically significant differences between pre and post-course evaluations using a paired t-test or Wilcoxon signed rank test as shown in Table 3a. These statements reflected positively the type of teaching styles and learning environments presented in the course, summarized as, non-lecture based, complicated group field projects enhanced by the use of computers. Questions generating highest and lowest average responses in the pre and post-course evaluation are also reported in Table 3 sections b and c. While the assessment results reflect student attitudes, the unique educational setting of the course may self-select for specific learning preferences among students.

The open-ended writing in the weekly self-assessments was useful for observing changes in attitudes from week to week. Comments were, in part, specific to each week of the course; and this detailed information was considered while modifying the course design and implementation in 2009. Over the four weeks, several themes emerged in these assessments about group working dynamics, how specific material was presented in a larger context and specifically which exercises worked or didn't work for whatever reason. In most cases students and faculty had similar concerns and

TABLE 3: 2007 ATTITUDE SURVEY RESULTS

A) Significant Changes*

Question	p value	Significant
I learn well by using computer-based materials.	$p > t = 0.023$	Increase
I learn well by listening to lecture.	$p < t = 0.015$	Increase
I learn well by completing lab or field reports.	$p > t = 0.063$**	Decrease
I learn well by working in a group.	$p > t = 0.063$**	Increase
Science is a complicated subject.	$p > t = 0.099$	Increase

B) Questions drawing the highest average pre-course response (n=8)

Question	Pre-Class	Post-Class
I learn well by doing hands-on activities.	5	4.86
I learn well doing field-based work.	4.63	4.86
Being able to ask questions is important to me.	4.38	4.88

C) Questions drawing the lowest pre-course average response (n=8)

Question	Pre-Class	Post-Class
Science is not useful to the typical professional.	0.14	0.25
I will find it difficult to understand watershed science concepts.	0.88	0.38
Watershed science is irrelevant to my life.	0.5	0.43

* Paired t-test, n = 7
** Indicates Wilcoxon signed rank test

suggestions, allowing us to easily focus on specific ways to improve the course.

The rated questionnaire provided feedback on the course format, the quality of course content, and the perceived effectiveness of the course as a learning model. In general, students had positive responses about the content and format of the course, though they found the open-ended assignments difficult; we responded to this in the 2009 course by replacing the open-ended assignments with daily worksheets. The students indicated the course provided a good mix of faculty and a good working environment. The course helped conceptualize career options, but the students felt that the course could have presented a stronger connection between our exercises and real-world problems. In 2009, we responded to tailoring exercises and discussions to focus more specifically on directly relevant watershed science skills and techniques used in the workplace.

We did not do detailed assessment in 2009. Of the 17 students who participated in 2009, there were eleven women and six men, all enrolled at UVM. There were two graduate students in the course and one non-traditional undergraduate student. Nine different major courses of study were represented in 2009, including, middle level teacher education, environmental engineering, environmental studies, environmental science, geography, geology, natural resources, plant biology and public communication. Anecdotal responses from students indicate continued strong support for field-based teaching and learning. Students repeatedly self-reported to faculty that they felt they learned concepts better in the field than in the classroom and that the 2-week format, with daily reports and a final presentation, was much preferred the 4 week format.

DISCUSSION

As research and teaching become more subject specific, students are not exposed to the significance of interrelationships with and between other disciplines (Gregorian, 2004). Thus, throughout Earth science, environmental sciences, geography, and engineering there is a need to integrate teaching across disciplines, at all academic levels, while incorporating modern technology. This is particularly important in the teaching of water resources, where virtually all physical and social sciences are germane in some manner. Our faculty developed course exercises in teams, in order to bridge pedagogical and topical boundaries. Furthermore, courses such as ours, presented by an interdisciplinary team, illustrated for students firsthand how the contributing fields overlap in watershed science, while allowing them to see where their specific interests fit within traditional disciplinary boundaries.

Although several field courses in US colleges focus on water resources and hydrogeology (*e.g.* Lautz et al., 2007; Lehigh University, http://www.lehigh.edu/%7Efjp3/fieldcamp/index.html; Clemson University, http://www.ces.clemson.edu/hydro/FieldCamp/index.html;

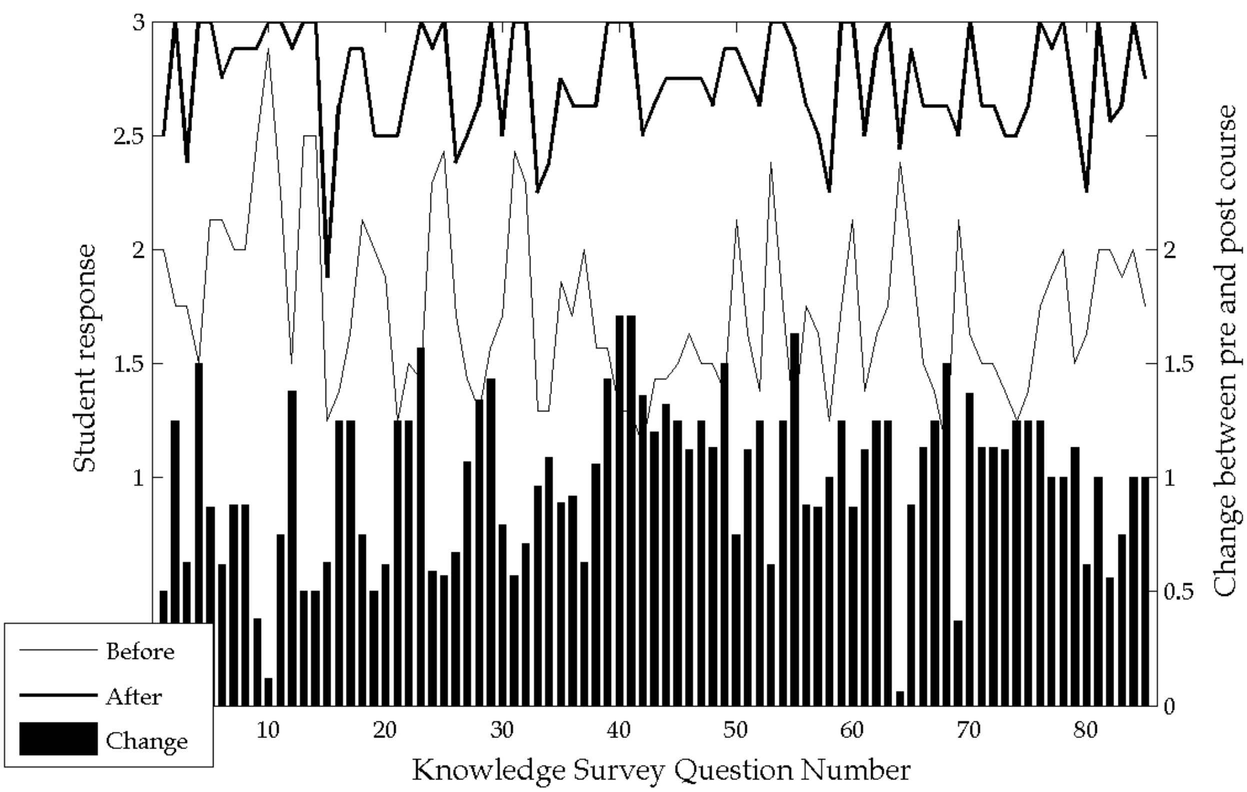

FIGURE 2. Knowledge survey plot shows lines for pre test and post-test responses for each question in the 85-item survey. The corresponding bars show the change between pre and post-test for each question. Pre and post-test averages have n=8, with 22 questions unanswered by student G in the pre-test, leaving n=7 for those questions.

Northern Indiana University, http://www.niu.edu/geology/courses/field_methods.shtml; University of Minnesota, http://www.geo.umn.edu/orgs/camp/hydrocamp/), ours is one of the few truly interdisciplinary courses by design. This approach reflects our belief as a team that it is no longer sufficient to consider water resource problems from within the isolation of a single discipline; rather, a systems-thinking approach is needed for teaching and studying watersheds. We are not alone in this belief; for example, Woltemade and Blewett (2002) emphasized a systems-type philosophy in successfully implementing a watershed research laboratory and associated courses at Shippensburg University including faculty and courses specializing in geology, geography, biology and ecology.

In addition to an interdisciplinary perspective, we wanted this course to illustrate the dynamic relationship between human land use and ecosystem health at a variety of spatial scales. Teaching the UVM watershed field science course in the diverse Winooski River watershed highlights human impacts over time and space from relatively recent development in the headwaters (alpine ski resort) to two centuries of agricultural use along major tributaries and the main stem Winooski River. We used simple exercises such as measuring increases in electrical conductivity in a headwater stream downstream of its first road crossing (road salt is used heavily on Vermont roads in the winter months) to illustrate small-scale, immediate impacts on water quality. Larger temporal and spatial scale impacts to the watershed were introduced and discussed throughout the course using multiple field examples and different perspectives. A series of discrete exercises and discussions were developed, focusing on modern stream bank erosion, historical land clearing and sediment deposition, geochemistry, and nutrient cycling in the water column of Lake Champlain and the resulting threats to habitat. For example, exercises emphasized links between terrestrial and in-stream conditions, both biological (riparian vegetation type, leaf litter, physical fish habitat indicators) and abiotic (bank stability, shading and water temperature). These exercises helped students identify the cumulative impacts and sediment loading which threaten Lake Champlain.

Possibly the single largest benefit to students in this course was the community created by bringing together faculty and students from disparate disciplines in a non-traditional physical setting. Student evaluations recognized and cited the benefit and uniqueness of the opportunity to communicate and interact with faculty outside of the more formal, classroom setting. Students were more at ease with faculty and felt comfortable engaging in a dialog about course topics. The watershed field science course was the first fieldwork experience for several of the students, which they reported as overwhelmingly positive. When compared to lecture courses, students believed they would:

1) retain more course content,

> "I feel like I'll retain a lot more of this knowledge… Because I'm actually learning it in the field and I saw something happening and I took that information out rather than the information just being given to me. So I don't know, when you're able to extract data from something yourself and extract connections, figure out things yourself, find reasons for certain things, it just sticks with you more"

2) understand what they were learning in a different way,

> "It's definitely valuable to understand, you know, why you're taking the data and understand how it's useful. So certainly crunching some numbers and writing about it I'd say helps to understand why you're collecting the data in the first place."

3) become more engaged,

> "I personally get a lot of motivation from other people, hearing what they've been doing and their ideas… It made me realize there's a lot more out there that I have potential to learn about.";

> "I had more of a relationship with my professors and my fellow students."

The benefits of the learning community extended to faculty as well. Not only did the interdisciplinary team strengthen relationships with faculty across departments, all faculty had the opportunity to work closely with students of diverse academic backgrounds. This experience resulted in at least two students, from both the 2007 and 2009 classes, engaging in further work-study and summer research work with course faculty.

The three initial residential days in 2007, with at least three instructors in residence at all times, helped students bond early and fostered an inclusive and cooperative spirit; in 2009, the spring semester weekly meetings served much the same purpose. Students (2007) ranked the residential experience highly in the rated questionnaire (average response of 4.4 pts on a 5 pt scale) and spoke favorably about it during the remainder of the course, even though survey results show that students were not particularly interested in a fully residential course (average response of 2.5 on a 5 pt. scale).

For some students, this course was their first introduction to many of the topics beyond an introductory level and influenced course selection for the following year.

> "I just think it was really cool that I got exposed to a lot of things that I would never have exposed myself to otherwise."

> "I originally wanted to get into architecture, which is why I got into civil engineering, because they have it here at UVM. But now that I'm in civil engineering, I'm not sure if that's what I want to do anymore. But I'm very interested in the impacts on the environment just because I've learned so much about that in this class."

The course highlights similarities and overlaps of the represented disciplines within water resources.

> "I think I am starting to understand the connections between the different fields and I even see the professors learning from other professors."

> "I don't know, the line [between engineers and environmental scientists] is getting a little bit smaller. Like I don't know, I always thought engineering was, oh, they're all the way over here and we're all the way over here. But now they're getting a little bit closer together."

Although students with interests in geography, natural resources and engineering have different attitudes about learning (Jehng et al., 1993), having students with different disciplinary backgrounds did not cause problems or slow the pace of the course. There was a pervasive cooperative attitude during fieldwork, lab work, and computer exercises.

Several students remarked on the difficulty of collecting high quality data,

> "The data that we collected often times had so much error in it that we couldn't actually use it, which was really frustrating."

and recognized that many of the skills acquired in this course are transferable to other disciplines and situation,

> "Just understanding that there is, you know, a science or skill or an art to collecting good data which, I mean, I can apply to any field."

This is a valuable insight in the education of any scientist or engineer who will either collect data for someone else or analyze data collected by someone else during their career.

Our primary tool for modifying course structure in 2009 was the feedback from the weekly self-reports and the exit interviews in 2007. Several themes for improving the course emerged from this feedback, including varying the nature and schedule of the assignments, creating more modular daily exercises, and presenting more background material for each topic.

Based on student feedback and faculty observations, a major improvement to the course structure was the spring semester classroom component which provided overall context and setting for the fieldwork that we did in early summer. In addition, in 2009, we added short, focused topical introductions each morning and at the end of each day, we added afternoon wrap-up discussions to bring closure to the day's work and emphasize interconnections between topics and disciplines. Unlike a traditional field camp, where students have a common knowledge base, this course recruits students with diverse backgrounds. Students with specific expertise were able to help one another with the details of day-to-day course activities, but we found that many students required more focused instruction to achieve a fundamental understanding of the material and the background knowledge necessary to complete the assignments well.

Surprisingly, the 2007 attitude survey results conflict with feedback in the weekly self-reports, exit interviews, and informal conversation. One of the few significant differences in the attitude survey about student learning, as reported in Table 3, is a decrease in the perceived usefulness of lecture as a learning tool. We suspect this discordance in the assessment results reflect students' attitude toward learning from lecture-based courses in general rather than specifically from lectures as part of the field course. In response to this student feedback, in 2009, we added both the semester presence and the short, topically focused introductions as the starter for each day. Both additions were well received.

To emphasize individual conceptual goals, while simultaneously making day-to-day content more modular, in 2009, we allowed daily time for data reduction, analysis, and wrap-up discussions led by faculty and TA's in small groups. This daily structure reflects suggestions made by the students in their assessments and interviews and comments from a discussion of the faculty. Students in a hydrologic processes laboratory class, reported by Trop et al. (2000), made a similar recommendation for a daily wrap-up discussion. There are many benefits to such a model. A daily informational digest keeps individual exercises modular within the framework of the course, allowing them to be reused while reinforcing learning goals established at the beginning of the development process. The wrap-up strategy gave students a better understanding as to why they are collecting specific data and the errors and difficulties in specific field data collection. Most importantly, analyzing their data and discussing the results daily helped students make interdisciplinary connections more immediately and made the final summative assignment, in 2009, the poster session, less daunting.

In 2007, students were evaluated on weekly writing assignments graded by alternating pairs of instructors. Assignments required students to respond to the overall question and theme for the week, as outlined in table 1, considering the specific data they collected as part of field exercises that week. Students did not submit any other work during the week for grading. We found that students had difficulty synthesizing a week's worth of data at one time to prepare a weekly report. They disliked the intentionally open-ended questions and indicated they would prefer shorter more specific questions as assignments. The intention of these assignments was to put the details of the week's field exercises into a larger context and stimulate thinking at a broader scale. In addition, the timing of the assignments, Friday morning with a midnight deadline, was not well received. Student's dislike of the summative assignments was likely the combination of a short submission deadline at the end of the week, and the more difficult synthetic nature of the homework assignments.

In the 2009 revision of the course, we created specific daily assignments due at the end of each field day. These daily assignments helped us to evaluate students at different levels of understanding, while focusing on basic facts and concepts. Students often spent an hour or two at the end of each field day completing the assignments individually, or in groups depending on the topic. The daily assignment deadlines appeared to be well received by the students.

Introducing a new interdisciplinary field course to an institution at which there was no precedent has presented several distinct challenges, both financial and logistical. In 2007, faculty participation in the course was not counted toward yearly teaching workloads creating difficulty for junior faculty. In 2009, only the lead faculty member got to count the course toward his workload. Finding the time for five research-active faculty to meet and plan during the academic year was very difficult. Until there is an accepted method for recognizing interdisciplinary teaching efforts, faculty involved in courses such as ours will be disadvantaged.

At the University of Vermont, we could not establish a sustainable financial model that allowed the course to be offered in the summer. To be competitive with traditional field camps, the course must be offered at a reasonable cost on the order of $500 to $600 per credit; however, summer tuition structure at UVM is designed for large-enrollment, single-faculty member lecture courses and could not cope with the costs and logistics associated with multi-faculty field courses. Furthermore, the mandatory application of in-state and out-of-state tuition rates resulted in a very low cost course for Vermont residents and an exceedingly high cost course for out of state residents – effectively making ours an in-state only course and slashing our hopes that we would be able to draw from a national audience. As a result, we were not able to attract enough students in 2008 to teach the course and the 6 students we did attract were all Vermont residents, not the diverse demographic we sought. While external funding allowed greater flexibility and educational materials development at the outset, a high-cost, low-enrollment course was not viable in the long run.

We worked with the UVM Provost to address this difficulty. Our solution was teaching the course in spring semester using a 75-minute block over the course of the semester and teaching the week before and the week after graduation. This schedule avoided issues with summer semester and meant that faculty were still teaching within the window of their union contract and thus were paid on academic year salary. To reduce the load on busy, research-active faculty, we had a graduate student teaching assistant do all of the daily grading. Pedagogically, the spring semester model appears to have worked well from both a faculty and student perspective; however, it restricts participation to UVM students and thus prevents us from offering the course to a wider, more diverse audience.

CONCLUSIONS

One of the major benefits of this class, and classes like it, is the opportunity for students to engage with other students and faculty outside of traditional settings and roles. Both students and faculty were pushed to the edge of their intellectual comfort zones by thinking across the boundaries of traditional disciplines to learn, teach, and work collaboratively. Many of the students relished this experience. To make the curriculum coherent, given the diversity of instructors, faculty must be able to think objectively about their teaching to ensure it compliments the rest of the curriculum. Results of the several assessments administered to students were integral in redesigning the course structure to reach our stated goals. The role of this course in the academic curriculum varies depending on the individual goals of the student. While it is most appropriate for students at the start of their careers and may well motivate and guide the remainder of their coursework, the course is also appropriate for more senior students in disciplines where hands-on experiences are rare – in the latter case complimenting concepts and ideas presented in classroom instruction.

We made every effort to take advantage of our location in designing the curriculum using field sites, instructors, and place-specific examples that are significant and appropriate to Vermont; yet, at the same time, we have tried to keep the curriculum design sufficiently modular that exercises could be modified and used elsewhere. Making this course available as a summer offering to students beyond the UVM community would require surmounting significant administrative, financial, and logistical changes. By far, the largest challenge to the success of this interdisciplinary course was finding a way to make it financially and administratively sustainable. Despite some typical difficulties, our foray into interdisciplinary watershed education at the University of Vermont motivated students and created a unique teaching and mentoring opportunity for faculty.

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