AC 2011-1838: DESCRIPTION OF THREE ALGAE-RELATED INTERDISCIPLINARY SENIOR DESIGN PROJECTS IN MECHANICAL ENGINEERING AND THEIR IMPACT ON STUDENTS

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Description of Three Algae-Related Interdisciplinary Senior Design Projects in Mechanical Engineering and Their Impact on Students

Abstract

Algae related research is an exciting field. The Annual Algae Biomass Summit, established only four years ago, now draws more than 700 participants, including those from industry, academia, research institutions, and entrepreneurs. The algae industry, although still in its infancy, has the potential to develop sustainable fuels, foods, and chemicals, that can replace many products made from crude oil. Algae related research, however, is problematic for undergraduate mechanical engineering students because it requires an understanding of plant biology and chemistry laboratory techniques. In 2006, the mechanical engineering department at Seattle University was approached by a local startup company and asked to design a photobioreactor to grow oleaginous algae. This project was established as a year-long capstone design project. It was manned by four mechanical engineering students and supervised by industry liaisons from the company, and faculty advisors from both mechanical engineering and biology. Although the advisors were initially concerned about the interdisciplinary component of the project, the students were enthusiastic and successfully completed the project. The successes of that project lead to three more algae related year-long capstone design projects. In 2009, a team of students designed and tested a mechanical algal oil extractor. That team collaborated with faculty and students from biology and chemistry. In 2010, a team designed and tested an electro-coagulation device to harvest algae. That project involved significant interactions with the electrical engineering department's staff and resulted in a provisional patent. In 2010, we began our fourth algae related capstone design project.

This paper describes the three completed project. The description includes a summary of the project requirements, design processes, and laboratory work. It also summarizes the interactions between faculty, staff, and students from the different departments. Special emphasis is placed on understanding how to make interdisciplinary projects successful. The paper also explores the student's motivation for undertaking an interdisciplinary project and looks at how they were able to remain motivated. Initial results show that student's motivation remained high as long as the project remained challenging. However, the interdisciplinary subject matter, laboratory techniques, and interactions between students, staff, and sponsors all played a role in the project success. Finally, the paper explores how participation on these interdisciplinary projects influenced students in their subsequent career choices.

Introduction

At Seattle University all engineering seniors participate in a three quarter capstone senior design project. Participation on these projects is a graduation requirement for each student in the BSME program. The projects, which satisfy ABET's design-related criteria for accrediting engineering programs[1], are sponsored by either government or industry. They commence at the beginning of fall quarter (commonly last week of September) and end at the end of spring quarter (commonly second week in June.) Students work in teams of three to five, are supervised by a faculty advisor, and are encouraged to work closely with the liaison engineer from the sponsoring company. This setting is an excellent platform for undertaking open-ended design problems.

Typically, when scoping the projects with local industry, the faculty advises the company to assign projects that are on the "back-burner". Our goal is to distance the students from the commercialization pressures and provide them with learning opportunities. However, the algae projects that are the focus of this paper are quite the opposite. Two of them were among the top priority projects for two different companies, one of which is out of state, and all involved development of new processes in a new field.

The field of algae has recently begun to expand. After the Aquatic Species Program[2] at the National Renewable Energy Laboratory (NREL) ceased in the late nineteen-nineties, government funding for algae as a source of fuel became sparse. A few companies continued to explore where the Aquatic Species Program left off and began developing new algal strains and processes. In the mid-2000s, the need to replace foreign oil with domestic sources that are sustainable and environmentally friendly began to influence the public. The heightened public awareness resulted in a significant numbers of attendees at the four Annual Biomass Summits organized by the Algal Biomass Organization, ABO[3]. The speakers at the second Annual Biomass Summit, held in Seattle in 2008, warned, however, that too much excitement is not good for the industry in its infancy that is facing tremendous technical and commercialization challenges. Algae biomass is still produced at a cost that is at least ten times too high. The algae cultivation and processing technologies, including harvesting, dewatering, and chemical separation, all have technical challenges to overcome. Also, all these processes are energy intensive and/or involve significant water loss.

If the industry is to succeed in developing sustainable technologies, as is the vision of the Algal Biomass Organization, the industry will need engineers that are environmentally conscious, work well on interdisciplinary teams, and perform interdisciplinary work. For example, a company at the Algae Biomass Summit in 2010 told us they had an immediate need for recent mechanical engineering graduates who can also do mass-spectrometry. These kinds of requests for inter-disciplinary skills are expected, and we as educators of engineers have to respond. National Academy of Engineering's publication "Educating the Engineer of 2020: Adapting Engineering Education to the New Century" suggests that engineering schools should "introduce interdisciplinary learning at the undergraduate environment, rather than having it as an exclusive feature of the graduate programs"[4]. Naturally, this involves significant organizational challenges[5, 6, 7], and this paper sheds just one view on the challenges involved.

This paper describes three senior design projects that are algae-related and were conducted as senior design projects at our university under the supervision of a mechanical engineering professor, who is also an ABO member. The paper also presents the results of a survey taken by students on these projects. The unique results in this paper are presented and discussed in terms of the student motivation for undertaking and remaining motivated on an interdisciplinary project, implications for conducting inter-disciplinary undergraduate projects, and influences projects had on students' future careers.

Project 1: Photobioreactor Design

This project was conducted by four mechanical engineering students during school year 2006-2007. In summer of 2006, our program was approached by a local entrepreneur and president of an algae start-up company, Bioalgene. He tasked our students with designing a photobioreactor to grow two microalgae, *Botriococcus braunii* and *Prymnesium parvum*. The photobioreactor was to be implemented at their pilot facility the following year. He also assigned an engineer and a biologist to work with the students. They met with the students once or twice per month, where they discussed progress and brainstormed problems and future tasks. A biology faculty at our university, who is also a phycologist, joined in advising students from the biology standpoint. The students learned how to: purchase algae, make growth medium, grow algae on a bench under controlled conditions (see Figures 1 and 2), monitor algal growth, and use a heamocytometer and a spectrophotometer. They also began searching the literature for information on existing photobioreactors and how they operate. This steep learning curve happened during the first quarter. The following quarter, they designed three different carbon-dioxide gas delivery methods that were integrated into three tubular reactors. These designs relied on applied basic fluid mechanics, materials, and strength of materials calculations. The students also designed experiments to test the algae growth rates using factorial experimental design. In the third quarter, they tested the reactors (see Figures 3 and 4). The growth rate established in these reactors was on-par with the best reported growth rate obtained on the lab bench scale. The team also won second place on regional ASME Old Guard competition. After graduation, one student attended graduate school, two worked for local engineering consulting firms, and one returned to his family's business. The sponsor was very pleased and continued to collaborate with Seattle U faculty in the following years.

Figure 1. Mechanical engineering student transferring algae from test tubes to flasks under the biological fume hood.

Figure 2. Manifold for CO_2 and air delivery to algae growing in flasks on a bench in a room with controlled temperature, pressure, and humidity.

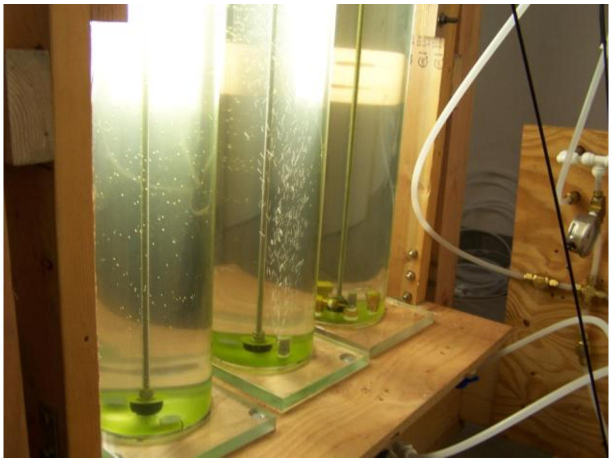

Figure 3. Three photobioreactors soon after inoculation. Gas bubbles are visible in the middle tube. Gas delivery manifold is partially visible on the right.

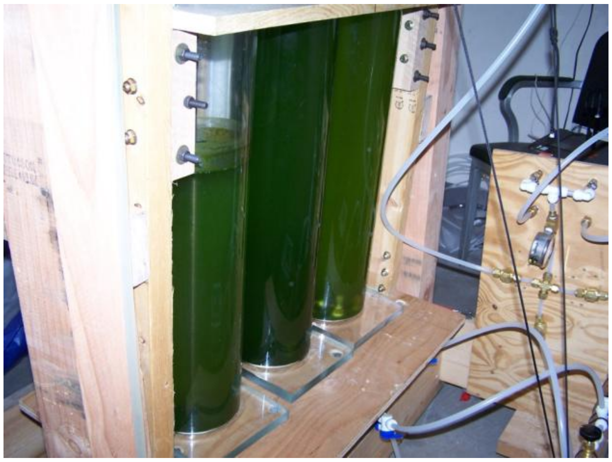

Figure 4. Three photobioreactors after a week. Deep green color is from algae that grew rapidly. Rapid growth was caused by effective mixing of CO2 into the liquid containing algae in aqueous growth medium. Photobioreactors were six feet tall each.

Project 2: Lipid Extraction

This project was conducted by three mechanical engineering students during school year 2008-2009. The project was sponsored by a grant from The Boeing Company, who tasked the team with developing a low-energy-consumption lipid extraction device for two algae, *Botryococcus braunii* and *Nannochloropsis oculata*. Two engineers from Boeing served as liaisons and met periodically with the student team. This team did not grow algae because they expressed disinterest in doing that in the beginning; they wanted to “work on mechanical engineering project”. Biology professor and phycologist generously maintained the algae stock for them. In the winter, the team was joined by a biology student, and a chemistry professor and her student. The students and the three professors met periodically as a group to discuss progress and make plans. The mechanical engineering team did an extensive archival literature search on existing methods for lipid extraction and their energy consumption, and brainstormed potential innovative ideas during fall quarter. They then proceeded to design and build two prototypes: a mechanical ball mill and an electroporation device, (see Figure 5). Both designs required an understanding of basic fluid mechanics, materials, and electromechanical systems. The ball mill was turned by an electric motor connected to the center-shaft of the ball mill. The electroporation device was powered by a DC power supply and a basic analog circuit. The biology student was tasked with growing the algae stock, and the chemistry student with chemical lipid extraction from algae. In the spring, the students worked together to test the two devices. They were able to prove that the ball mill is prohibitively inefficient, while the electroporation device is more energy effective in extracting lipids than chemical methods alone. Results are shown in Figure 6. The sponsor was very pleased with the results and recommended us for continued funding. However, due to changes in budgetary priorities at that company in summer 2009, the continued funding did not materialize. Two of the mechanical engineering students are now in graduate school, and one of them is pursuing algae-related research. The third one is not pursuing a mechanical engineering career.

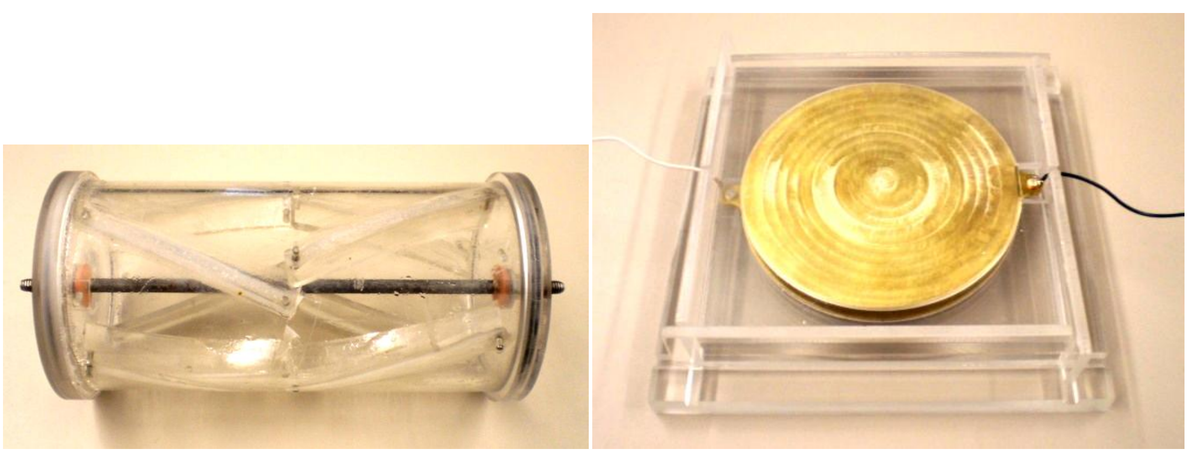

Figure 5. Ball mill and electroporation device designed by mechanical engineering students on second algae team.

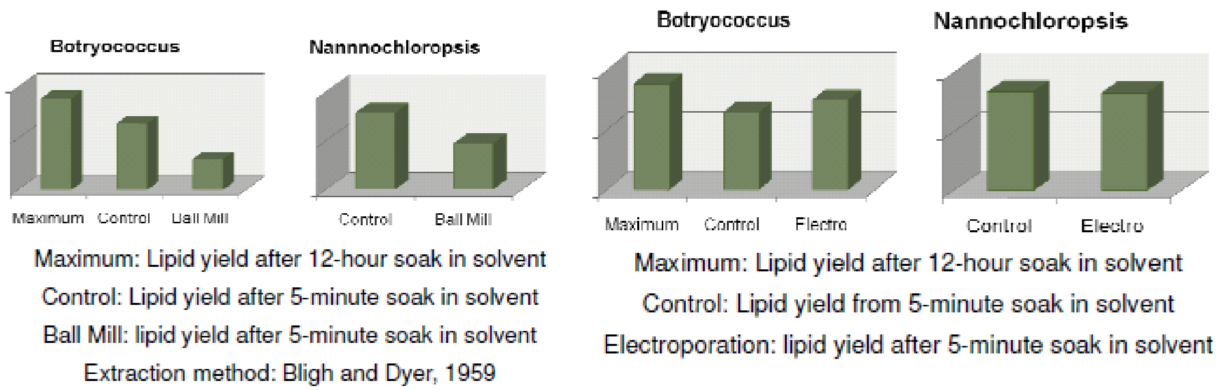

Figure 6. Depiction of one set of results obtained by the second mechanical engineering algae team, work done together with one biology and one chemistry student.

Project 3: Electroporation

This project was conducted by four mechanical engineering students during school year 2009-2010. This project commenced, September 2009, without a sponsor, due to shifting of budget priorities at Boeing. Another company, Solution Recovery Services, Dexter, MI, offered to sponsor the project after conversing with us at the Algae Biomass Summit in early October 2009. They began actively working with the students in December. By early February, students traveled to their headquarters to conduct tests on their novel batch electroporation device along with engineers at that company. They continued to meet periodically with the engineers over phone and via Skype until June. At the beginning of the school year, the team was joined by another mechanical engineering professor, who was an expert in electromechanical systems. The students were tasked with designing and testing a pulse electric circuit for the novel batch electroporation device designed and built over the summer 09 as an extension of Project 2. Once they had refined the batch device, the students were to design, build, and test a continuous flow device. Three months into the project, the team realized that the batch device was extremely useful for concentrating algae, while its use to separate lipids from the algae was not apparent. That shift in focus occurred in January 2010. The company, after joining as sponsor, agreed to pursue this new emphasis, and provided concrete design parameters that would benefit their plans for scaled implementation of the continuous device into their pilot plant. Before their role became finalized, the students spent considerable time in the biology labs growing algae and learning biology laboratory techniques from the biology professor-phycologist. However, those skills became unnecessary once the company decided to send us algae from their supplier. The circuit design and testing on the batch reactor, as well as the continuous flow reactor brainstorming and design occurred winter quarter, while most of the testing of the devices occurred in spring. All of the testing, including that using a fluorometer, a pico-fluorometer, a spectrophotometer, and a turbidity meter, was done by the four mechanical engineering students. The chemists did not join the team because the professor who worked on the project the previous year took an administrative position and could not devote time to this project any longer. The circuit design required analog and basic digital electrical circuit knowledge, so students worked extensively with the electrical engineering department's technician. Students also designed a data acquisition system using LabView, and applied basic fluids and materials calculations to design the continuous-flow system (see Figure 7.) They also designed experiments to test the batch reactor using factorial experimental design (see Figure 8.) The building and testing of the continuous-flow reactor involved interactions with our mechanical engineering technician. The project was successfully completed and the sponsor filed a provisional patent with students' names on it in June. That company continues to work with us, and is sponsoring an ongoing algae project in 2010-2011.

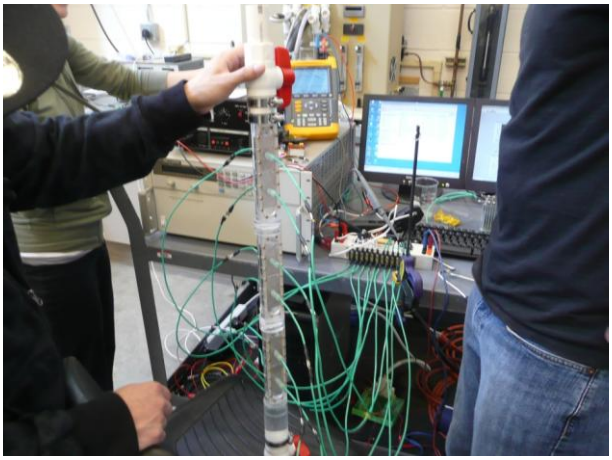

Figure 7. Students setting up continuous flow reactor test.

Figure 8. Students conducting parametric design testing.

Project analysis

The projects described in the previous sections were complex. They involved solving complicated and cutting edge problems, research and discovery, interdisciplinary work and interactions, management issues with respect to resources and other constituents. However, all projects were successful, and left strong influences on undergraduate students who participated. To help us better understand these influences, we surveyed the graduates who had participated in these projects. The survey questions were designed to help us understand the student's interest in the project, their motivation and challenges throughout the project. We received responses from two of four students on the first project, two of three students on the second, and from all four on the third (a 73% response rate). Results of the survey are presented in the following sections.

All students are referred to as males, although some respondents were female. Student quotes are presented verbatim, with names excluded for privacy.

Students' initial interest for their project

When assigning students to design projects, we attempt to match student interest with project content. This decision is based on a limited survey taken of students in their junior year. That survey however does not provide any insight into why student prefers certain types of projects. The survey discussed in this paper was taken after students had graduated and included questions that addressed the importance of interdisciplinary and environmental components of a project on a student's interest. Those results are summarized in Table 1.

The results suggest that students were interested in working on these projects in the very beginning, but that the interest did not necessarily stem from the fact that they were environmentally conscious. Although most students found it important to work on an environmentally conscious project, it is the "interesting challenges" lying ahead that motivated some of them.

Table 1: Survey responses on student initial interest

How would you rate your interest in your senior design project at the beginning – knowing it was an interdisciplinary project?															
Interest	*Uninterested*			*Somewhat*			*Average*			*Very*			*Exceptionally*		
Project	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Responses									1	1	2	3			1

How important was it to you to participate in an environmentally conscious project in the beginning?															
Importance	*Unimportant*			*Somewhat*			*Average*			*Very*			*Exceptionally*		
Project	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Responses		1[1]		1[2]	1[3]		1			1	1[4]	1		1	
Comments	[1] I don't doubt that the environment is important and that humans tend to mess it up, but it is not something I was seeking to work on in senior design. I simply wanted to work on a project that had some interesting challenges to it. [2] I wanted a project that was more interesting than designing a bathroom or condiment cart for …. The fact that the project had an environmental aspect made it more interesting. [3] I didn't really care about the environmental part of the project, as much as I wanted to work in vastly expanding field. [4] Participating in an environmentally conscious project felt like a very beneficial use of an engineering education, and one that could have a lasting positive impact.														

Students' interest and motivation throughout the project

Student interest and motivation in a project typically varies throughout the year. To help us understand the factors influencing student interest in the algae projects, the survey asked student to rate and comment on their interest and motivation throughout the project. Those survey results are presented in Tables 2, 3, and 4.

The results from Table 2 show that for most students, their interest increased or remained the same throughout the project. The two students who had lower interest at the end than in the beginning were among those who were *very interested* in the project in the beginning. They also belong into the 3rd project group and were generally disappointed with the amount of engineering challenges on their project. They felt that there was a change in project direction and were frustrated that there wasn't enough engineering in their work. Although the project requirements did not change, the perception of direction change may have been provoked by the delayed entrance of the sponsor, and the finding of unanticipated use for the device that became the focus towards the end and the essence of the filed provisional patent. Some of that perception may have been caused by the overall organizational challenges that plagued the 3rd project, as was explained by another member of the same team, whose motivation to work on the same project generally remained high (see Table 3 for that comment).

Student comments about motivation, in Table 3, generally point to two things: 1) the projects were challenging on many aspects, which made the motivation decrease at times; and 2) technical interest and weekly progress were causing morale to increase (or decrease when there was no progress). These conclusions are corroborated in the results shown in the Table 1 where most students found the projects technically challenging or somewhat challenging. Yet, students were split as to whether technical challenges improved their motivation to work on the project. Table 4 shows that only one student did not find his project to be technically challenging. Five said that technical challenges improved their motivation to work on the project and three that it did not influence their motivation. Table 4 also shows responses to how organizational challenges, sponsor, and interdisciplinary nature influenced students' motivation.

Table 2: Survey responses on student interest through the project

At the end of your project, was your interest higher or lower than in the beginning?															
Interest	*Much lower than in the beginning*			*Lower than in the beginning*			*Did not change*			*Higher than in the beginning*			*Much higher than in the beginning*		
Project	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Responses						2[1,2]	1[3]		1	1[4]	1[5]	1[6]		1[7]	
Comments	[1] Change in direction, lack of organization, and excessive amount of testing/data collection with poor execution- it was difficult to stay focused when the background knowledge to really understand the topic continued to be in another field of study (biology, chemistry, electrical engineering- practically no emphasis on mechanical engineering which is what we had spent 3+ years learning about). Since I had been really looking forward to Senior Design as a capstone of what I had learned in the program, this disconnect and lack of control was rather disappointing for me. [2] The lack of direction and concrete goals made me wary of algae by the end of the project. Plus at times it felt like we were not working on an engineering project which is what we wanted. [3] There was no change in my interest because this was a challenging project. There were so many things we needed to build before we could really even start the project, it kept things interesting. [4] I never felt like we got to really finish. It was a subject I was interested in, so I wanted to keep working on it. [5] The fact that I was working on very new technology definitely piqued my interest. Also after graduate school that biology could be inherently useful to a mechanical engineer in certain fields, opened up a whole new realm of knowledge to learn and deal with. [6] My interest increased in this project because I did not know that it involved a lot of other interdisciplinary interactions (Biology, Chemistry, Electrical Engineering, and Machinery). [7] The project showed me how close we were to finding a semi-final solution.															

Table 3. Survey responses on student motivation through the project.

During the project, did your motivation to work on the project:															
Motivation	*Generally decrease*			*Generally remain low*			*Not change*			*Generally remain high*			*Generally increase*		
Project	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Responses			1						1	2[1]	1[2]	2[3,4]		1[5]	
Comments	[1] The project was complex enough and the learning curve steep enough that at times it was discouraging. I believe it was the fact that we made progress that helped maintain our morale. [2] My motivation varied with various setbacks and challenges, but the work was interesting technically so it remained high. [3] Since our project was more research based than most other senior design projects, our group experienced many hardships and our efforts did not always yield promising results. In some cases, we would work for weeks to find out what we were doing was wrong or maybe even be waiting on the sponsor for samples. It did not help that all the other groups were able to move forward with their work when they were able to whereas we were unable to move forward at times due to the plethora of variables. What made this project most difficult was that our scope seemed to be continually changing. This made it difficult to put our efforts into the right areas since we never really stayed on the same goal for more than a few weeks all the way until the end of the project. This combination of variables made it difficult to present our work thoroughly and could be seen from an outside perspective as a poor senior project. [4] My interest would be high when we learned about new ideas that we can use (like using turbidity meter to measure settling rates, learning how to use it and using it). Designing and building of the continuous-flow device was also exciting. [5] All of the demands put on students throughout the entire year made it difficult to constantly stay upbeat about the project.															

Table 4. Additional responses to questions about students' motivation for their project

Questions	Responses per Project		
	1st	2nd	3rd
Rate the technical challenge of the project:			
Not challenging			1
Somewhat challenging	1	2	2
Challenging	1		1
Relate the technical challenges of the project to your motivation:			
The technical aspects of the project decreased my motivation to work on this project			
The technical aspects did not influence my motivation to work on this project		1	2
The technical aspects enhanced my motivation to work on this project	2	1	2
Relate the organizational challenges of the project to your motivation:			
The organizational aspects decreased my motivation to work on this project			1
The organizational aspects did not influence my motivation to work on this project	2	2	1
The organizational aspects enhanced my motivation to work on this project			1
Rate your sponsor's (liaison's) role in your motivation to work on this project:			
The sponsor reduced my motivation to work on this project			2
The sponsor did not influence my motivation to work on this project	2	2	2
The sponsor increased my motivation to work on this project			
The sponsor played the key role in my motivation for this project			
Relate the interdisciplinary nature of the project to your motivation (mark all that apply):			
The interdisciplinary work decreased my motivation to work on this project			1
The interdisciplinary work did not influence my motivation to work on this project			1
The interdisciplinary work enhanced my motivation to work on this project	1	1	1
The interdisciplinary interactions decreased my motivation to work on this project		1	
The interdisciplinary interactions did not influence my motivation to work on this project			1
The interdisciplinary interactions enhanced my motivation to work on this project	1		1

Project organization did not seem to play an important role in student motivation. Five students indicated that their motivation was not influenced by the organizational aspects, while one felt that those aspects enhanced, and one that they decreased his motivation. This was surprising since organizational aspects presented the primary challenge for faculty. It may be that the faculty organized the projects well enough that students did not perceive that organizational challenges influenced their motivation. The faculty provided project spaces, equipment, daily guidance and technical and organizational support, as well as training for the sponsor on how and when to interact with the students. The student who felt that organizational aspects enhanced his motivation to work on the project, who was on the 3rd project, also said:

> Hoped that if we could figure out how to better organize our group we could actually accomplish something- it felt like our stride came too late though, such is life…

What is also surprising is that the majority of students on the algae projects had a perception that the sponsor did not influence their motivation. This is opposite from the faculty's perspective, which is that our projects in general are significantly influenced by the sponsors and how they interact with the students. It may be that the sponsor's role on the first two projects was sufficient, which is indicated in this comment from a student on the 2nd project:

> The liaison's role was very hands-off which allowed us to function autonomously. This style worked well because of the open ended nature of the project, if the project had been more of a hard list of deliverables that lack of contact could have lead to some communication issues.

Two students, both from the 3rd project, said that sponsor's role reduced their motivation. Below are their comments:

> Huge disconnect between our group and our sponsor, especially since we didn't have a sponsor until 1/2 way into the year and there was a big difference in priorities/deadlines/etc.

> In the beginning the idea of working with (company name) increased my motivation however towards the end I lost interest. Working with (company name) was difficult, they could never give us straight answers. They did give us a lot of algae, but the information about the algae was sparse so the algae was basically useless.

Based on these data, we conclude that sponsor/student interactions were adequate in the first two projects, while in the 3rd there was too little communication with the sponsor. The sponsor did not provide strong motivation for the students, and was slow to respond to their questions. Although the sponsor filed a provisional patent at the project's end, it came too late to influence student motivation. From this we conclude that regular interactions with the sponsor, once or twice per month, are important, as long as during these meetings there is technical exchange, (for example, in meetings students report on their progress and brainstorm with the sponsoring company about upcoming work,) and sponsor gives students the "big picture" about the importance of their work. These regular interactions give meaning and importance to the project from the students' perspective.

Implications on how to make interdisciplinary projects successful

Based on the survey results from Table 4, it can be concluded that the interdisciplinary aspects received mixed reviews. Five answers point to interdisciplinary aspects enhancing their motivation, two that they decreased, and two were neutral. Here are student's comments:

> I felt like our group had the chance to study something that a lot of engineers wouldn't get to. Both in terms of it being a relatively novel concept and being a very interdisciplinary project. That made it something that I could get excited about. (Student from 1st project.)
>
> Want to believe that interdisciplinary work motivated me, even though it definitely led to a lot of frustration within our group. (Student from 3rd project.)
>
> Some interactions (like with electrical and mechanical engineering technicians) increased my motivation whereas my interactions with other people (chemistry) decreased my motivation. (Student from 3rd project.)
>
> …biology could be inherently useful to a mechanical engineer in certain fields, opened up a whole new realm of knowledge to learn and deal with. (Student from 2nd project.)
>
> My interest increased in this project because I did not know that it involved a lot of other interdisciplinary interactions (Biology, Chemistry, Electrical Engineering, and Machinery). (Student from 3rd project.)

While the first algae project team embraced the interdisciplinary aspects, the other two had mixed perceptions. There were several reasons why the 1st project worked successfully as interdisciplinary. First, the students that worked on this project were particularly motivated and positive throughout. That cannot be understated. Second, their interdisciplinary work and interactions only involved biology. The biology professor is particularly knowledgeable and pleasant person to work with. Also, their sponsor interactions included interactions with a biologist. During the second project, the students were disinterested in performing interdisciplinary work, yet they functioned on an interdisciplinary team of faculty and students, that included both biologists and chemists. Some of the interactions of that interdisciplinary team were strained however. The mechanical engineering students did not communicate well with the chemistry student. The communication was so bad that mechanical engineering students believed that they could have completed the same tasks better without that student and with the chemistry professor's guidance. Since the 1st team performed all biology tasks alone and with professor's guidance, we decided that the 3rd project could continue on without involving students from the other two departments. The problems for the 3rd team mounted when the chemistry professor could no longer devote her time to guiding the students, beginning fall quarter 2009. That team not only dealt with biological and chemical aspects, but also with electrical engineering and some environmental engineering aspects. While at least one student on the team was energized by interdisciplinary aspects, another was not. He, however, offered this suggestion:

> My opinion after attending graduate school for one quarter: I am currently attending a large university where research is huge. The project I am working on is interdisciplinary and multiple

> departments are working together. They however have the project that they were trained to work on. Plus this puts less pressure on faculty from other departments to provide their time to students that they have little to no investment in. I do like interdisciplinary projects. Most if not all engineering jobs require some interdisciplinary cooperation. Working in this kind of setting is good preparation for the real world.

To his comments, we add that when doing an interdisciplinary project, communication is the key. Our suggestion is to have meetings of the entire team at least once per week, and the role of the faculty and sponsors is to periodically remind students of the common goals to foster adhesiveness of the group. Naturally, this poses significant organizational challenges, not the least those on trying to find meeting times for several undergraduate students, whose schedules are, typically, riddled with many classes they are required to take.

Projects' influence on students' career choices

Student participation in these project had some influence on their career choices. After graduation, four students sought work in an algae related field and two stated that they were interested in algae related work, but received job offers from other companies. Only two students indicated that the project did not influence their career choice. Currently, four work as engineering professionals, none in algae related field, but two in jobs related to environmentally conscious practices. This is an interesting result considering the students initial interests. Two of the respondents attend graduate school, one in algae related field, and the other in field unrelated to algae or environmentally conscious practices. Two of the respondents do not currently work as engineers nor attend graduate school.

Conclusions

Students assigned to work on the interdisciplinary algae projects were generally very interested to work on them in the beginning, and at the beginning some found it important to be on an environmentally conscious project, but some were motivated by the challenges that lie ahead. Throughout the school year, most students' motivation to work on the project would vary, but would generally remain high. The project problems, including lack of progress, would decrease motivation at times, but technical interests and general progress would increase it. Most students found projects technically challenging or somewhat challenging, and technical challenges enhanced their motivation to work on the projects. Organizational challenges did not influence majority's motivation to work on the project nor did the interactions with the sponsor. However, they may be detrimental to student motivation if significant lapses occur. The faculty plays the key role in providing organization, guidance, and support to the students. Regular meaningful interactions with the sponsor are important. Interdisciplinary projects can be successful but require that all involved parties have regular meetings alone and with faculty and sponsors.

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