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An Evaluation of a Course that Introduces Undergraduate Students to Authentic Aerospace Engineering Research

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ABSTRACT

This paper describes the implementation and assessment of an aerospace engineering course in which undergraduate students worked on research projects with graduate research mentors. The course was created using the principles from cooperative learning and project-based learning, and consisted of students working in small groups on a complex, open-ended research project. The course provided undergraduate students the opportunity to learn about and be involved in authentic research within their field. Quantitative and qualitative methods were used to assess the effectiveness of this course by answering the following research questions: (1) What are the experiences of undergraduate students, graduate students, and faculty involved in this course?, (2) What skills are developed and/or improved in undergraduate and graduate students?, and (3) What recommendations can the course faculty provide to other faculty interested in implementing a similar course?

Key Words: undergraduate research, project-based learning

INTRODUCTION

The purpose of this paper is to describe a novel 400-level aerospace engineering course at a mid-Atlantic research University. The course involved undergraduate students in authentic aerospace engineering research projects. In this course, undergraduate students worked throughout the semester in small groups led by graduate research mentors. The course creation and implementation were guided by the principles of cooperative and project-based learning.

The course consisted of two main groups of participants: the undergraduate students and the graduate student research mentors. For the former, this course served as a unique undergraduate research experience, an opportunity for them to be exposed to and learn to conduct research. For the latter, this course was an opportunity to develop their leadership and mentoring skills, and to receive help on their theses and research projects, as will be explained below. Two course faculty were in charge of overseeing the projects and providing help and support when needed.

In the following sections, we will provide background literature on cooperative and project-based learning, describe the course in more detail, and assess the effectiveness of this course.

BACKGROUND LITERATURE: COOPERATIVE AND PROJECT-BASED LEARNING

The creation and implementation of the aerospace engineering course described in this paper was guided by the principles of cooperative and project-based learning. Cooperative learning can be defined as "a technique where students work in small groups to accomplish specific educational tasks jointly" (Boehm and Gallavan, 2000, p.419). There are different types of cooperative learning, depending on how it will be used and what goals need to be accomplished. For example, in informal cooperative learning, students work in temporary groups, typically no longer than one class period (Johnson, Johnson, and Smith, 1991). In formal cooperative learning, on the other hand, groups stay together longer and work on "complex tasks" (Smith, Sheppard, Johnson, and Johnson, 2005, p.94). The student groups in the course described in this paper were formal cooperative learning groups: they were together the entire semester, and were given a research problem (the "complex task") to work on.

Although sometimes perceived as a typical group work experience, cooperative learning involves much more than having students work together. A formal cooperative learning experience should have certain characteristics:

a) Positive interdependence: Students must believe that they depend on each other, that "one cannot succeed unless the other members of the group succeed and vice versa… students must perceive that they sink or swim together" (Smith, et al., 2005, p.94). When there is positive interdependence, students help each other learn, share their resources, and support each other (Johnson, Johnson, and Smith, 2007); all team members "cooperate to complete the task" (Smith, 1995, p.1).

b) Face-to-face promotive interaction: Team members in a cooperative learning group interact with each other and help each other be successful (Smith, et al., 2005). They accomplish this by "helping, sharing, assisting, explaining, and encouraging" each other (Smith, 1995, p.2).

c) Individual accountability: Team members are responsible and held accountable for their individual contributions to the group (Johnson, Johnson, and Smith, 2007).
d) Teamwork skills: Skills such as "leadership, decision making, trust building, communication, and conflict management" are taught to and used by team members to accomplish their goals (Smith, et al., 2005, p. 95).
e) Group processing: Team members reflect on their working relationship, helpful and unhelpful individual actions, and how well they are achieving their goals (Smith, et al., 2005).

Millis and Cottell (1998) provide several reasons why faculty should consider adopting cooperative learning methods into their courses. One reason is the changing workplace. Millis and Cottell write that there is now a "new emphasis on cooperation and teamwork," and "interdependence and cooperation" are now greatly valued (p.20). Cooperative learning prepares students for the professional and teamwork skills they will be using in the workplace. Another reason to adopt cooperative learning is the changing student population. They write that because of the increase in minority and nontraditional students, learning should not continue to take place using the traditional methods.

While there may be several barriers to making changes in instructional approaches (see Millis and Cottell, 1998 and Akili, 2012), implementing cooperative learning can have many benefits. Benefits for students include that it can "maximize student learning…and long-term retention" (Johnson, Johnson, and Smith, 2007, p.27), students exhibit greater self-motivation regarding their learning (Boehm and Gallavan, 2000), and students in these classes can also have higher grades (Mourtos and Allen, 2001). Benefits for faculty can include more interaction with their students and getting to know their students better (Johnson, Johnson, and Smith, 1991), as well as "greater satisfaction from their teaching" (Mourtos and Allen, 2001, p.672).

The principles of project-based learning were also used in this course. In project-based learning, students work on "one or more open ended projects" and would usually have "technical reports, presentations, and physical artifacts" as deliverables (Malicky, Huang, and Lord, 2006, p.4). In addition, in project-based learning, students have some degree of freedom and responsibility for their learning (Morgan, 1983). Although very similar to problem-based learning, Malicky, Huang, and Lord (2006) write that project-based learning is "closer to professional practice," focused on application, and "accompanied by subject-based courses" (p. 4). Project-based learning provides students with a good approximation of the tasks professional engineers encounter (Mujika, Osinaga, Uria, and Manso, 2013), as the projects typically involve hands-on group work that "model 'real-world' work situations" (Pleiss, Perry, and Zastavker, 2012, p.1).

Research has shown that compared to lecture-style courses, students learn more in project-based courses and even prefer this type of course (Cappelleri and Vitoroulis, 2013). Research has also shown that project-based courses help students improve professional skills such as teamwork and communication (Fang, 2012).

For the aerospace engineering course described in this paper, students worked in small groups on a research project. As is the norm in cooperative learning, the groups were small (Boehm and-Gallavan, 2000; Ledlow, White-Taylor, and Evans, 2002) and consisted typically of three members. The students' "complex task" (Smith, et al., 2005, p.94) was working on a research project that was usually related to the graduate mentors' theses/graduate work, and involved hands-on work, as is typical in project-based learning (Pleiss, Perry, and Zastavker, 2012). As is the norm in project-based learning, the course instructors were facilitators who provided guidance and support (Morgan, 1983). Although the first few weeks of the course followed a traditional lecture format, for the rest of the semester, when students worked on their projects, the instructors' role was to make sure the students were making progress on their projects and to help them with any problems that arose. The course is described in more detail in the following section.

DESCRIPTION OF THE INNOVATION

The first few weeks of the course (roughly the first one-third of the course) followed a traditional lecture format led by the instructors. These lectures focused on introducing the students to certain aerospace engineering concepts and to computerized methods of importance in modern research experiments. While this is not a necessary component of project-based learning, it has worked well for this particular course setting. The students then spent the rest of the semester with their groups, working on their project. The course structure can be seen in Figure 1.

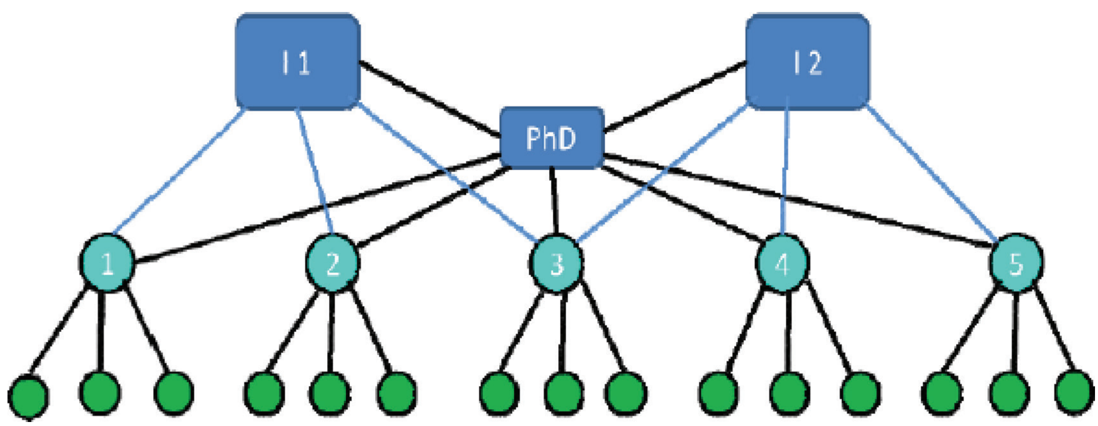

Figure 1. Organization of Instructors and Students in the Course.

The green circles at the very bottom represent the undergraduate students. They worked in groups of typically no more than three, and were led by a graduate research mentor, represented by the turquoise circles with the numbers. The graduate research mentors were students in the Masters or PhD programs. While a few graduate research mentors received course credit, most were involved with this course as volunteers, because the undergraduate students would be working on the research mentors' theses or research projects as their course project. As a result of this arrangement, undergraduate students were exposed to authentic, emerging aerospace engineering research, and graduate student mentors received help on their theses/research projects.

The undergraduate students and graduate research mentors were supervised by an experienced PhD student who was the course's official teaching assistant. This PhD student's responsibilities included grading progress reports, providing laboratory assistance and LabView tutorials, and leading lab sections. The two course instructors provided additional mentoring to all students in the course.

The graduate student mentors were normally advisees of faculty who had shown a genuine interest in the success of this course. The course instructors selected the projects from knowledge of "unfinished components" of the graduate students' research and an assessment of the scope of candidate projects matching the available time and technical backgrounds of the students. To assign groups and projects, the undergraduate students provided their top three project choices. Then the instructors apportioned the students onto the prearranged projects based on student interest and background ability. In these first three semesters of the course offering, approximately three-quarters of all students were assigned their first choice and the remaining quarter was assigned their second choice.

This course had the goal of helping undergraduate students develop many skills (see Results sections, and also McLaughlin, Schmitz, & Mena, 2013, and Mena & Schmitz, 2013). For example, by working on some aspect of the graduate students' theses or research projects, undergraduate students were typically involved in both indoor and outdoor work, such as coding or building/testing, respectively, so they got experience doing "hands-on" work characteristic of their field. Specifically, some of the projects were designed in support of an emerging wind-turbine field-testing facility at the University that involved CAD design of equipment, fabrication processes (for example, milling and working with composite materials), and also computational projects on source code development for advanced aerodynamic designs. In project-based learning, projects typically involve this kind of hands-on group work (Pleiss, Perry, and Zastavker, 2012, p.1) and are typically open ended (Malicky, Huang, and Lord, 2006).

As is characteristic of cooperative learning, the individuals in each group were depending on each other to succeed (Smith, et al., 2005, p.94) and were holding each other accountable (Johnson, Johnson, and Smith, 2007) such as through the use of Gantt charts that they had to periodically share with the course instructors. Specifically, the course instructors required that each week, a different group member would be responsible for writing and distributing meeting minutes and documenting the group's progress (or lack thereof) with respect to the Gantt chart. The group's progress with respect to the Gantt Chart was discussed at every meeting, and adjustments to the Gantt Chart as a working document were encouraged. These weekly progress reports, as well as the final reports and presentations, provided students the opportunity to reflect on their work, an important characteristic of cooperative learning (Smith, et al., 2005).

In addition, the focus on group work led to the enhancement of certain professional skills such as teamwork, leadership, and communication. At the end of the semester, the students shared their findings both by turning in a technical report and by presenting to the class; this is another characteristic of project-based learning (Malicky, Huang, and Lord, 2006), and served as an opportunity to further improve the students' communication skills.

This course also had the goal of being beneficial to graduate students. By being research mentors, graduate students had the opportunity to develop their mentoring, teaching, and leadership skills. Engineering graduate students do not always get experiences to develop these skills as part of their programs. Therefore, establishing an arrangement where graduate students can serve as mentors to groups of undergraduate students provided an opportunity for some supervision/management experience.

ASSESSMENT

To assess the effectiveness of this course, we used qualitative and quantitative methods to answer the following research questions:

- Research question #1: What are the experiences of undergraduate students, graduate students, and faculty involved in this course?
- Research question #2: What skills are developed and/or improved in undergraduate and graduate students?
- Research question #3: What recommendations can the course faculty provide to other faculty interested in implementing a similar course?

Data Gathering Methods

Data were collected the first three semesters of the course (Fall 2011, Spring 2012, and Fall 2012), and several sources of data were used to answer the research questions. At the beginning and end of each semester, surveys were administered to the undergraduate students. These pre and post surveys consisted of eleven items asking the students about their experiences with and their perceptions of the course teaching methods, research, their teams, and the graduate mentors. At the end of each semester, focus groups were conducted with the undergraduate students. In these one-hour semi-structured focus groups, students talked about their experiences with the course, and shared what they thought did and did not work well. At the end of each semester, the graduate student mentors were also interviewed. In these 20-30 minute individual, semi-structured interviews, the mentors described their roles and responsibilities, and shared what they learned as mentors. In addition, the two course instructors participated in semi-structured individual interviews after the initial three semesters of the course, to learn about their experiences with this course. The interview protocols for the focus groups and individual interviews are included in Appendix A. Finally, throughout the semesters, observations were conducted. Class/lab sessions and team meetings were observed with the purpose of learning about the team dynamics and relationships, the mentor-mentee relationships, and the overall learning environment.

Data Analysis

Interviews and focus groups were transcribed and coded using the NVivo software. To code this data, a process of open coding, as suggested by Creswell (2008), was followed: the data was first read as a whole, to get a general sense of the data, then codes were assigned, and finally, recurring themes were identified. No predetermined codes or themes were used in the analysis process; all codes and themes emerged from the data.

To analyze survey results, pre and post means were analyzed using a paired t-test to determine statistically significant changes using the SPSS software.

RESULTS

Before answering the research questions, the results from the surveys completed by the undergraduate students are provided in Table 1 below. Forty-five students completed the pre and post surveys during the first three semesters of the course. The surveys consisted of Likert-type items, with possible responses ranging from 1 (strongly disagree) to 5 (strongly agree).

Table 1 shows that there were increases in means in most items, with significant differences in the following items:

- "The way this course is taught helps me learn" ($t=-2.563$, $df=39$, $p=0.014$)
- "I am good at doing research in wind energy" ($t=-2.766$, $df=34$, $p=0.009$)
- "My team works well together" ($t=-2.040$, $df=39$, $p=0.048$)
- "Having a graduate mentor is helpful to my learning" ($t=-2.454$, $df=38$, $p=0.019$)

	Mean	Standard Deviation
1. The way this course is taught helps me learn.	Pre: 4.11 Post: 4.36	Pre: 0.71 Post: 0.71
2. I enjoy doing undergraduate research.	Pre: 4.67 Post: 4.51	Pre: 0.52 Post: 0.69
3. I am good at doing research in wind energy.	Pre: 3.33 Post: 3.81	Pre: 0.87 Post: 0.71
4. My team works well together.	Pre: 4.20 Post: 4.40	Pre: 0.76 Post: 0.69
5. My choice of research topic is interesting.	Pre: 4.62 Post: 4.52	Pre: 0.49 Post: 0.55
6. Having a graduate mentor is helpful to my learning.	Pre: 4.29 Post: 4.59	Pre: 0.87 Post: 0.62
7. Working with my team is helpful to my learning.	Pre: 4.16 Post: 4.42	Pre: 0.77 Post: 0.84
8. I would like to attend graduate school after I graduate.	Pre: 3.44 Post: 3.58	Pre: 1.22 Post: 1.29
9. I would like a career in wind energy.	Pre: 2.98 Post: 3.13	Pre: 1.21 Post: 1.14
10. I would like to take another course that uses similar teaching methods.	Pre: 4.13 Post: 4.36	Pre: 0.79 Post: 0.71
11. I would like to do some more research in wind energy.	Pre: 3.57 Post: 3.64	Pre: 1.09 Post: 1.10

*The highlighted items indicate a significant difference at the 0.05 level between pre and post surveys

Table 1. Differences in pre and post means.

Though not statistically significant, there were increases in means in “Working with my team is helpful to my learning,” and “I would like to take another course that uses similar teaching methods.” The increase in means in these and the other items suggests that the course had a positive impact on students in different ways.

Two item means decreased. Specifically, the means for “I enjoy doing undergraduate research” and “My choice of research topic is interesting” went down from pre to post. The decrease in means gives evidence that the undergraduate students did indeed experience the reality of conducting original and open-ended research, with its associated drawbacks in progress. It is likely that after experiencing authentic research and what comes with it, some students found that they did not enjoy it very much. Nevertheless, even after the decrease in means, the means were still over 4, indicating that although the means decreased slightly, the overall responses remained positive. Appendix B includes a table with results from the statistical analyses, including confidence intervals and p-values, for all survey items.

Data from the interviews, focus groups, surveys, and observations were used to answer the research questions. The results are presented below.

Research Question 1*: What are the experiences of undergraduate students, graduate students, and faculty involved in this course?*

Undergraduate students

During the first three semesters of the course, there was a total of 61 students (54 male, 7 female) taking the course. Forty-five of these completed the pre and post surveys, and nine participated in the focus groups.

The data revealed that undergraduate students seemed to be satisfied with the course and the course teaching methods, and provided three main reasons why this course was a positive experience. First, they believed that the way the course was structured (having groups work on projects) was similar to what they would be doing in the "real world," and they "[got] experience in [their] field." Therefore, they believed this course was good preparation for their future employment. Likely because of this, they believed having this course on their resumes would be beneficial for them, because it would show that they had project experience as well as "hands-on experience," and would provide them with good examples of projects they could discuss with potential employers.

Second, they liked that the course focused on hands-on work, research, and projects. They liked that they worked on "real project[s]," on things "people haven't done before, that's exciting." They also liked that this experience was a "nice change of pace from the classroom," and helped them learn better, since "it's hard to grasp a subject when you haven't actually seen it or done it . . . so this was nice." Third, they enjoyed working with the graduate research mentors. They found the mentors to be very helpful, knowledgeable, and willing to answer their questions.

The students' satisfaction with the course was also evident in the surveys. For example, there was a statistically significant difference from pre to post for the item "The way this course is taught helps me learn," as well as for the item "Having a graduate mentor is helpful to my learning," and an increase in the means from pre to post (though not statistically significant) of certain items such as "I would like to take another course that uses similar teaching methods."

McLaughlin, et al. (2013) provide more information on the experiences of the undergraduate students.

Graduate students

The first three semesters of the course, there were 18 graduate mentors. Fourteen of these (13 male, 1 female) were interviewed for this study.

Across all three semesters, the research mentors agreed that this course was a positive experience for them, and provided three main reasons why. First, working with the undergraduate students meant they were getting help on and making progress in their research theses and projects. One mentor described it as follows:

> This was all stuff I would be doing in my research eventually, but I think that having a lot of hands kind of helped because it got a lot of the stuff accelerated. There are some different viewpoints, and I think that it helped get a lot of work done at once, so I think that the output was pretty good overall – probably more than I could have done by myself.

Second, being a research mentor helped them get a better understanding of their technical field and the topics and tools associated with it. For example, one mentor said "I think . . . the [mentoring] experience in general…just gave me a better understanding of everything that I was working with and the fundamentals behind everything . . ." Another mentor said:

> I actually learned a lot about electrical systems and the lab view code, which is the primary system for data acquisition – definitely a lot about electric work… I hadn't really had too much hands-on with that . . . So I definitely…learned more than I even thought I would on that…I definitely learned a ton on the subject matter.

Third, the research mentors talked about how much they enjoyed interacting with the undergraduate students. The enjoyment they experienced when working with the undergraduates contributed to making the research mentor experience a positive one.

The mentors' experiences in this course, as well as the benefits of participating in this course, are further described in Mena and Schmitz (2013).

Faculty

In the interviews, the faculty described their roles as instructors for this course, as well as the challenges and benefits they believe are associated with this course.

As previously stated, the course followed a traditional lecture format for the first one third of the semester, and then students worked on their projects for the rest of the semester. The instructors taught the lectures for the first third of the semester, and later advised and supervised the teams. Their role consisted of three main tasks:

1. The instructors had to dedicate time to organization: "trying to organize everything and make sure . . . that we're offering a reasonably quality education." This included organizing the lectures, projects, teams, and team monitoring (see below), among other tasks.

2. The instructors had to continuously monitor the teams' progress. This included "follow[ing] them through with progress reports, and…class meetings where everyone [came] back together and we either [gave] another lecture or [had] progress project presentations . . ." This also included providing additional advice and support when necessary; for example, students working on more complex projects would sometimes need more advice ("if you don't give them advice, they'll get very frustrated, [because] the problems are tough").
3. The instructors had to guide and support the graduate student mentors. One way they did this was by meeting weekly with the mentors. In these meetings, the mentors would discuss their groups' progress. One instructor described these meetings as "it is mostly 'what are you doing, how are you encouraging your undergraduate students to do something, what are you planning, how do you help them, how do you go into meetings prepared, what are the problems that have occurred.'"

There were some challenges associated with the instructors' roles. The first is the need for organization ("if it's going to work reasonably well, it's a big demand on organization; it's a very big demand on organization"). The need for good organization often meant a greater time commitment from the instructors.

The second challenge is a result of working with the undergraduate students and research mentors. Regarding the research mentors, it is important to note that not all were adequately equipped for the task of mentoring a group. The instructors therefore had to learn to identify these research mentors as early in the semester as possible, and identify and address the challenges they were facing, so that the group could complete the project. One instructor described it as follows: "A challenge is of course . . . if you as an instructor allow an intermediate step in the advisor role through a graduate student mentor . . . the guidance that he or she needs varies greatly, and so a challenge is to understand that pretty quickly, how this works, and to step in without overruling your volunteer mentor . . ."

The most common weakness of the graduate student mentors was coming to student meetings with very weak preparation. This occurs because they typically lack experience in judging the time needed for a productive research group meeting. The course instructors addressed this by asking students at the end of a meeting if they knew what to do next, and by de-briefing with the graduate student mentors.

Regarding the undergraduate students, sometimes there were conflicts in the team dynamics. For example: "If you have a group dynamic that can be difficult, where you have two strong individuals that kind of want to do naturally the leading role, then that becomes difficult, and so that can be challenging." The instructors had to learn to address the team issues that arose, and this was sometimes a challenge.

As stated earlier, one of the instructors' responsibilities was monitoring the teams' progress. Depending on a team's progress and dynamics, the instructors would have to determine the appropriate course of action to follow, and how much of their direct interaction would be needed for the team. One instructor said:

> . . . depending on the project group and the role of the mentor and the difficulty of the project I had more or less direct interaction with them. In one group I was…there at every meeting with the graduate student mentor but I was staying in the background, but it was because of the difficulty of the project, [for] when questions came up . . . I had another group where I could be very hands off…because the graduate student mentor was handling it terrifically . . . so it really depends . . . it's difficult to generalize because it requires a lot of people skills… you need to interact with them, you need to figure out what dynamics [are] going on here very quickly . . .

One of the challenges of a course such as this one, therefore, is being able to quickly and accurately determine how each team is doing and what the appropriate course of action for the team, research mentor, and instructor should be. This included adjusting the project if it was proving to be too challenging for the undergraduate students.

In spite of these challenges, the instructors believe this course was beneficial to the undergraduate students: ". . . undergraduate students [get] an opportunity to get to feel a) what research is, and b) how graduate student research is." The instructors also believe this course was beneficial to the research mentors, because they get experience in teaching and mentoring, which the instructors believe will be useful to them in careers within both academia and industry. Finally, the instructors note that a course such as this one is beneficial to faculty as well, because it provides an opportunity to meet undergraduate students within a research setting, which means they can recruit some undergraduate students into their research groups. These students would already be partially trained by the time they joined the instructors' research groups. In the three semesters that this course was offered, each instructor recruited one undergraduate student into graduate school.

Research question 2: *What skills are developed and/or improved in undergraduate and graduate students?*

The undergraduate students and research mentors were both consistent in saying that the main skills they learned as part of this course were those related to teamwork, working with others, and managing groups. For example, one research mentor said: "I got some experience with dealing with a group and trying to manage everybody's time and experience levels and stuff like that, so that was helpful."

Undergraduate students also mentioned improving their communication skills and time management skills, while research mentors also mentioned improving their leadership, communication, and teaching/mentoring skills.

The skills developed and improved in the undergraduate and graduate students are further described in McLaughlin, et al. (2013) and Mena and Schmitz (2013), respectively.

Research question 3*: What recommendations can the course faculty provide to other faculty interested in implementing a similar course?*

Faculty who are interested in adopting the teaching method and organizational structure should first of all be aware that considerable coaching time is needed for a graduate student mentor beyond what is necessary to advise a typical teaching assistant for a course. It is important that, before the course, the instructor explains very carefully to the graduate student mentor the responsibilities and possible setbacks that may occur. These responsibilities include scheduling regular meeting times with undergraduate students and instructors, assisting with grading progress and final reports, and preparing before the meetings. A possible setback that should be communicated to the graduate student mentors is that more time investment may be needed for a given research return that, in some cases, could be obtained faster by the graduate student simply doing the task himself/herself. The faculty member needs to be alert for signs that the graduate student is too focused on his/her research so as not to welcome this type of work. It was our experience that graduate students who are, in general, interested in teaching show a higher motivation than those who are simply looking for a helper in their research. Hence identifying suitable graduate student mentors is important, and can have multiple benefits that involve professional development of the former and of the undergraduate students as well as the potential of future recruitment of undergraduate students into the instructor's research group.

Second, it is recommended that faculty select appropriate research projects for the course. Given the challenge of progress in research that is oftentimes slower than expected, it is recommended that the research project not be time critical to the instructor's and/or graduate research mentor's research activities. This greatly alleviates the pressure of immediate performance and progress and certainly improves the climate within the group.

Finally, faculty should remember that a large portion of the instructor's advising activity lies in explaining to the students how to analyze both technical problems and personal barriers and devising strategies to overcome them within a reasonable time. Faculty should also remember that the goal of this course is not "free labor"; instead, "the objective is an educational objective." As such, it is important that both the graduate student mentor and the undergraduate team members have a positive learning experience of conducting research, working in a team, and developing their professional skills.

CONCLUSION AND SUMMARY

This paper described an aerospace engineering course in which undergraduate students were mentored by graduate research mentors as they worked on research projects. The course was created using the principles of cooperative learning (students in each group worked together and depended on each other to succeed) and project-based learning (students worked on a complex, open-ended research project, and were expected to submit a report and present at the end of the semester).

The qualitative and quantitative data showed that this was a positive experience for the undergraduate students: they were exposed to research and gained experience that they believed was preparing them for their future employment. The data showed that this was a positive experience for the graduate research mentors as well: they received help on their projects and developed professional skills such as mentoring and leadership, among others. Although there were some challenges for the instructors, it was a positive experience for them as well, and they were able to recruit some undergraduate students into their research groups.

Future research can focus on the longitudinal effects of participating in this course. Specifically, in what ways was participating in this course helpful to the students' careers?

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APPENDIX A: INTERVIEW PROTOCOL – FOCUS GROUPS WITH UNDERGRADUATE STUDENTS

- Where are you in your program?
- Why did you decide to take this course?
- Did you know about the way this course would be taught beforehand?
- What did you like about the way this course was taught?
- What did you find helpful? What helped you learn?
- What would you have liked to be different about the way this course was taught?
- Is this your first experience with wind energy research?
- What did you learn about research in wind energy?
- What did you learn about research in general?
- Will you be doing any more research as an undergrad student? Why or why not?
- What are your plans for after graduation?
    - Will you be going to grad school? Industry?
    - Will you continue working in wind energy?
    - In what ways did taking this course affect your decision?

INTERVIEW PROTOCOL – GRADUATE MENTORS

- What is your engineering discipline and where are you in the program? What is your target graduation date?
- What are your career goals?
- Are you interested in an academic or non-academic position?
    - If student is close to graduation: Have you started looking for jobs? What types of jobs?
- Do you have any previous teaching experience?
- What are your responsibilities in this course?
- In what ways did you feel prepared to be a graduate mentor for this course?
- Have you participated in any training to prepare you to teach?
    - If yes: Describe training.
    - If no: Would you have liked some kind of training?
- In what ways did you feel unprepared to be a graduate mentor for this course?
- How closely did you work with faculty? With peers?
    - Would you have liked to have had more/less of either? Why?
    - What aspects of working with faculty/peers did you value the most/least? Why?

- Do you have any suggestions on how to better prepare students for their roles as graduate mentors for this course?
- What advice would you give new graduate mentors?
- What did you learn as a result of teaching this course?
- How do you think this experience will help you achieve your career goals?
- In what ways have your career aspirations changed as a result of this experience?

INTERVIEW PROTOCOL – INTERVIEWS WITH FACULTY

- What are the challenges of this course's teaching methods?
- What are the benefits of using these teaching methods?
- What was your role as the instructor?
- What are the graduate mentor-instructor relationships like?
- What are the undergraduate-instructor relationships like?
- Describe the characteristics of a successful graduate student mentor.
- What skills do you think were developed or improved in the mentors and in the students?
- In what ways can a sustainable model for this course be created?
- What recommendations do you have for faculty interested in implementing this type of course?

APPENDIX B

	Mean	Standard Deviation
1. The way this course is taught helps me learn.W	Pre: 4.11 Post: 4.36	Pre: 0.71 Post: 0.71
2. I enjoy doing undergraduate research.	Pre: 4.67 Post: 4.51	Pre: 0.52 Post: 0.69
3. I am good at doing research in wind energy.	Pre: 3.33 Post: 3.81	Pre: 0.87 Post: 0.71
4. My team works well together.	Pre: 4.20 Post: 4.40	Pre: 0.76 Post: 0.69
5. My choice of research topic is interesting.	Pre: 4.62 Post: 4.52	Pre: 0.49 Post: 0.55
6. Having a graduate mentor is helpful to my learning.	Pre: 4.29 Post: 4.59	Pre: 0.87 Post: 0.62
7. Working with my team is helpful to my learning.	Pre: 4.16 Post: 4.42	Pre: 0.77 Post: 0.84
8. I would like to attend graduate school after I graduate.	Pre: 3.44 Post: 3.58	Pre: 1.22 Post: 1.29
9. I would like a career in wind energy.	Pre: 2.98 Post: 3.13	Pre: 1.21 Post: 1.14
10. I would like to take another course that uses similar teaching methods.	Pre: 4.13 Post: 4.36	Pre: 0.79 Post: 0.71
11. I would like to do some more research in wind energy.	Pre: 3.57 Post: 3.64	Pre: 1.09 Post: 1.10

*The highlighted items showed a significant difference at the 0.05 level between pre and post surveys

Table B.1. Differences in pre and post means.

	Paired differences						
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	t	df	p-value
1. The way this course is taught helps me learn.	–0.35	0.86	0.14	(–0.63, –0.07)	–2.56	39	0.014
2. I enjoy doing undergraduate research.	0.10	0.71	0.11	(–0.13, 0.33)	0.89	39	0.378
3. I am good at doing research in wind energy.	–0.43	0.92	0.16	(–0.74, –0.11)	–2.77	34	0.009
4. My team works well together.	–0.23	0.70	0.11	(–0.45, –0.002)	–2.04	39	0.048
5. My choice of research topic is interesting.	0.05	0.60	0.10	(–0.14, 0.25)	0.53	38	0.599
6. Having a graduate mentor is helpful to my learning.	–0.41	1.04	0.17	(–0.75, –0.07)	–2.45	38	0.019
7. Working with my team is helpful to my learning.	–0.25	0.87	0.14	(–0.53, 0.03)	–1.82	39	0.077
8. I would like to attend graduate school after I graduate.	–0.23	1.02	0.16	(–0.55, 0.10)	–1.39	39	0.173
9. I would like a career in wind energy.	–0.10	0.64	0.10	(–0.31, 0.11)	–1.00	38	0.324
10. I would like to take another course that uses similar teaching methods.	–0.25	0.81	0.13	(–0.51, 0.009)	–1.96	39	0.058
11. I would like to do some more research in wind energy.	0.00	0.90	0.15	(–0.30, 0.30)	0.0	37	1.00

Table B.2. Paired t-test results.