2006-890: PROMOTING UNDERGRADUATE RESEARCH BY CREATING A RESEARCH OPTION IN A TECHNICAL COMMUNICATION COURSE

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Promoting Undergraduate Research by Creating a Research Option in a Technical Communication Course*

Abstract

Although many institutions have called for more undergraduate research, incorporating significant research experiences into undergraduate engineering curricula has proven to be challenging. This paper presents the results of an experiment in the College of Engineering at Virginia Tech to address this problem by means of a research option in the traditional technical communication course, which is a required course in many engineering curricula. In this research option, students had the opportunity to prepare for and to document a summer research experience. To that end, the research option of the course was divided into two segments: (1) a spring segment to prepare students for a summer research experience, and (2) a fall segment to teach students how to document that research experience. This research option culminated with the students participating in an undergraduate research symposium that showed other undergraduates the benefits of and the opportunities for research experiences.

For the Spring 2005 segment of the course, 20 of the 25 designated slots were filled, those 20 students had high academic achievements (an average GPA of 3.7/4.0), and 11 of the 20 students were from underrepresented groups in engineering. During that Spring 2005 segment, all 20 students secured offers for funded research positions over the summer, with more than half of those positions occurring at research institutions other than Virginia Tech: MIT, Georgia Tech, Penn State, the University of Illinois, Vanderbilt, the University of South Carolina, and Woods Hole Oceanographic Institute. For the Fall 2005 segment, 15 of the original 20 students enrolled, with 2 of the remaining 5 students opting to take a co-op and the other 3 choosing to continue their studies without taking the second segment. In this Fall 2005 course, the 15 students documented their summer research through a poster, a formal presentation, and a formal article.

Although more time is needed to assess the effect of this course's research experiences on the careers of these students, the course appears to be a success. The quality of the communication assignments produced by the students indicates that the students gained much from the course. Supporting that assessment is that several students in the course have had conference papers of their research accepted, several students have applied for graduate research fellowships, and all those who are graduating this year have applied to graduate school. This first offering of the research course sequence has provided several valuable lessons to the instructors that will make next year's offering of this course proceed much more smoothly. Given that, other engineering colleges in the country should consider such a research course sequence for at least one section of the technical communication courses that their engineering students take.

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Introduction

The Boyer Commission Report has urged universities to "make research-based learning the standard" for the education of undergraduates [1]. Also calling for more research by undergraduates in science, technology, engineering and mathematics are the National Science Foundation [2], the American Association for the Advancement of Science [3], and the National Research Council [4]. Participation in research not only deepens a student's understanding in science, mathematics, engineering, and technology, but also promotes communication and teamwork to solve complex problems [5]. As stated by the Reinvention Center at Stony Brook [6], "When undergraduates working alongside faculty participate in the generation of knowledge or artistic creation, they join the university's rich intellectual community and they derive unique, life-long benefits." For these reasons, engaging more engineering undergraduates in research is a goal of many engineering colleges. However, given the pressures to reduce the number of credit hours in engineering curricula, engineering departments are hard pressed to find courses to foster an appreciation for research.

One opportunity that exists is the three-credit technical communication course required by so many engineering curricula, including the University of Texas at Austin [7], the University of Wisconsin at Madison [8], and Virginia Tech [9]. Typically, these courses require students to perform library research that serves as the content for the assignments: proposal, formal document, and formal presentation. Given that this required course already provides the foundation for a significant research experience, the question arises whether a substitute to this course could be created that complemented the course's library research component with experimental, computational, or theoretical research in actual laboratories. The benefits would not only be that the students would gain valuable research experiences, but that the students' appreciation for the communication would deepen, because the students would be more likely to assume ownership of the content.

This document presents the results of a proof-of-concept test [10] for whether an undergraduate technical communication course could effectively be linked to larger research experiences, such as those offered by Summer Undergraduate Laboratory Initiative, Los Alamos National Laboratory, Virginia Tech, or other research institutions. Presented in this paper is a description of the technical course that was tested. Following that are the results of the five phases of the project: (1) recruiting of undergraduates in the College for the pilot offering of the course sequence, (2) the one-credit spring course to prepare students for the summer research experience, (3) the summer research experiences, (4) the two-credit fall course that taught students how to communicate those experiences, and (5) the recruitment of students for the next offering of the course sequence.

Description of Technical Communication Course That Was Tested

Spanning two semesters and framing a summer research experience, the technical communication course sequence that was tested has been designed both to enrich the summer research experiences of undergraduates and to attract other undergraduates to pursue such research experiences. As shown in Figure 1, the first part of the proposed course, which was taught in the spring before the summer research experience, was to prepare undergraduates for that research experience by having them apply and be selected for research positions, learn about

best research practices (including ethics in research), and perform a literature review on their intended research topic. The second part of the course, which was taught in the fall following the summer research experience, was to give students the time and instruction needed to properly communicate their summer research in papers, presentations, and posters. During the fall course, the students participated in an open symposium. One of the purposes of the symposium was to attract other undergraduates into pursuing research experiences, either on-campus in a research laboratory or off-campus at another institution. For that reason, freshmen, sophomores, and juniors in engineering were encouraged to attend the symposium.

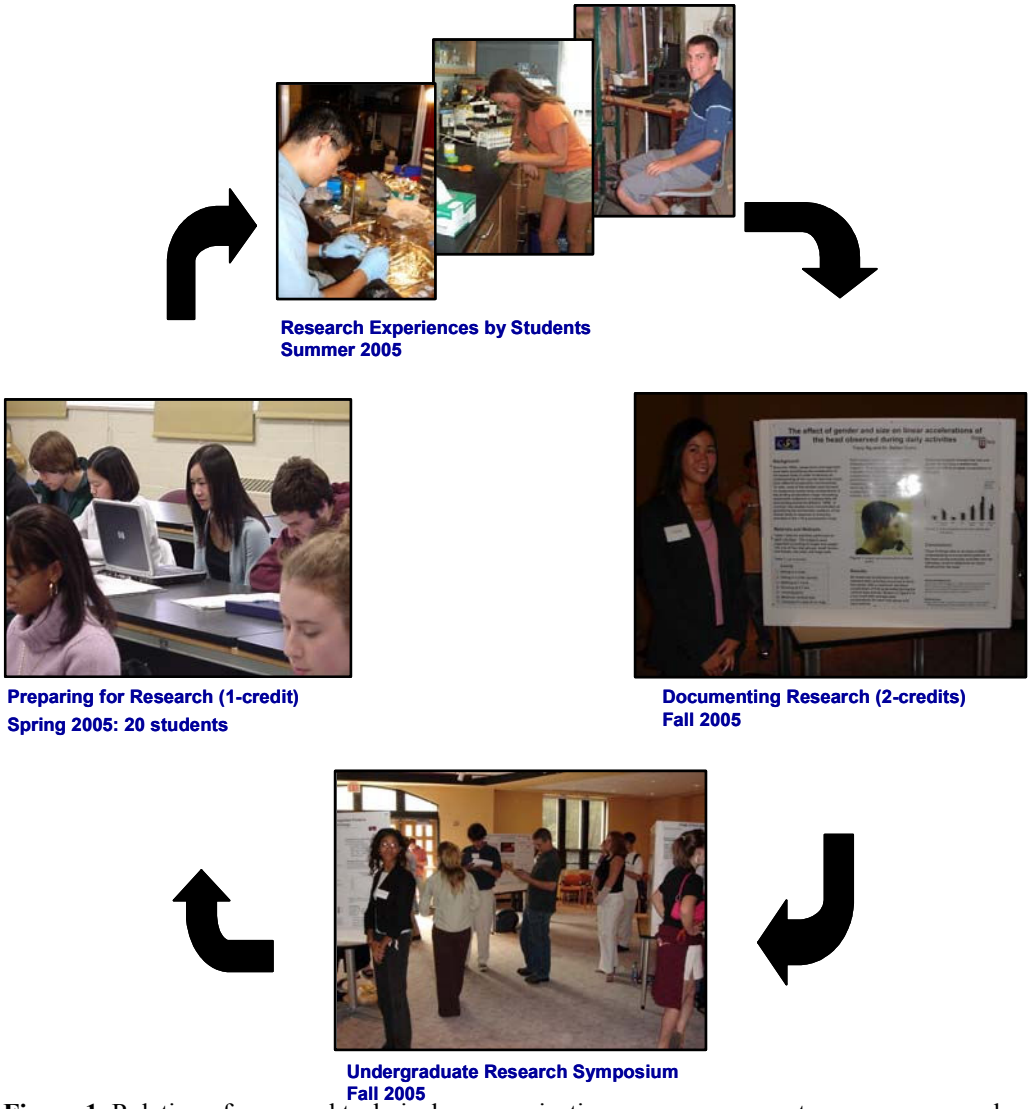

Figure 1. Relation of proposed technical communication course sequence to summer research experience. The purpose of the course sequence was to deepen the research experience and to attract other undergraduates to such research experiences. For the degree plans of most of the participating students, the course sequence served as either a substitution for a required technical communication course or a technical elective.

The College of Engineering at Virginia Tech was the testing site for this course: The College has a large and diverse undergraduate engineering population from which to draw students, the College has many respected laboratories in which undergraduates could perform research, the College has the Center for Enhancement of Engineering Diversity that is committed

to helping undergraduates, especially those in underrepresented groups, obtain research experiences, and the College is a leader in technical communication.

Designed to have no more than 25 undergraduates in the College of Engineering at Virginia Tech, which is a typical ceiling for a technical communication course, this course sequence was tested to answer the following four questions:

(1) How readily would undergraduates, particularly undergraduates from underrepresented groups in engineering, enroll for such a course?
(2) For such a course, what percentage of students in the course would be able to find summer research positions in the time allotted?
(3) Would the spring and fall segments of the course significantly enrich the summer research experience?
(4) Would students in this course sequence develop their technical communication skills as students do in a typical technical communication course?

The first question was addressed by the interest shown in the course by undergraduate engineers at Virginia Tech. Also considered was the diversity of those students and the quality of those students, as evidenced by their grade point averages (GPAs). The second question was answered by examining the statistics from this pilot course. The third question was addressed by surveys to students immediately after their summer experience and at the end of the fall semester portion of the course.

The purpose of answering this fourth question was as follows. If technical communication instructors and curriculum committees across the country are to be persuaded to adopt such an option in their technical communication courses, they need to be convinced that the writing and speaking skills acquired by the students in the research-option course will be on a level with the skills acquired by students in a traditional course. To answer the final question, we considered three different assessments. The first was a self-assessment survey by the students. The second was tracking whether students were able to publish any of their work in the professional conferences and publications of their disciplines. The third was an assessment of the writing and presentations of these students by the instructor, who has taught a standard three-credit technical communication course to more than 1200 students at four different universities: the University of Texas at Austin, San Jose State University, the University of Alabama, and the University of Wisconsin–Madison.

Phase 1: Recruitment of Pilot Offering of the Course Sequence

In the Fall 2004 semester, recruitment began in earnest for the pilot technical communication course to be tested. The recruitment consisted of three efforts. The first was sending email announcements of the course to those students who would be eligible for such a course. In general, eligibility meant having a GPA above 3.5, which is the level that many national laboratories require for acceptance into their summer research programs. In creating the distribution lists for these emails, special attempts were made to include underrepresented groups in engineering. These emails were sent out just before the registration period of the Spring 2005 semester, in which the course sequence was to begin.

Second, an information session was held in the College on undergraduate research. This session informed undergraduates about the benefits and opportunities for undergraduate research

on Virginia Tech's campus, at other engineering colleges, and at the national laboratories. In addition, the research-course sequence was discussed as a means to help obtain and deepen such a research experience. Associated with this effort was the creation of a special web page that listed research opportunities for engineering undergraduates at Virginia Tech:

http://writing.eng.vt.edu/research.html

Third, on October 14, 2004, we held a pilot research symposium in the College of Engineering at Virginia Tech for the following two reasons: (1) to attract qualified undergraduates to the pilot research-course sequence that we were going to test, and (2) to gain experience for such a symposium that would serve as the culmination of the course sequence in the following year.

Shown in Table 1 is a list of the tasks that led to the pilot symposium [11]. Forty-two abstracts were received by the deadline on September 6. All the abstracts were accepted either as for a formal presentation or poster. One feature of this symposium was the use of undergraduates to fill the positions of symposium chair, session chairs, and judges. A reason for this inclusion was to increase the number of undergraduates who would gain experience from the symposium. Figure 2 presents the symposium proceedings, and Figure 3 presents a photograph of the poster session. The web page for the symposium is as follows:

http://www.writing.eng.vt.edu/symposium.html

Although the attendance by other undergraduates to this symposium was not as high as we had hoped, we learned several lessons [11] that should increase attendance for next year's symposium.

Table 1. Preparation tasks for the pilot symposium (all dates in 2004).

Milestone Date	**Description**
July 15	Selection of a symposium chair
July 17	Creation of symposium web page: http://writing.eng.vt.edu/symposium.html
July 17	Announcement of call for abstracts
September 6	Abstracts due to symposium chair
September 17	Announcement of accepted talks and posters
September 24	Submission of revised abstracts
September 26	Posting of revised abstracts on the web
September 27	Help sessions for the preparation of slides and posters
October 11	Workshop for presenters to obtain feedback on slides and posters and training for symposium judges and session chairs
October 14	Symposium

2004 Virginia Tech Symposium for
Undergraduate Research in Engineering

The 2004 pilot symposium for undergraduate research in the College of Engineering at Virginia Tech will occur on **Thursday, October 14**, in Owens Hall on the campus of Virginia Tech. The event is sponsored by the National Science Foundation, the Environmental Protection Agency, the Center for Excellence in Undergraduate Teaching (CEUT), and the following three departments: Civil and Environmental Engineering, Electrical and Computer Engineering, and Mechanical Engineering. Everyone is invited to attend.

For more information on the presentations, please visit our webpage at: **http://www.writing.eng.vt.edu/symposium_program.html**.

Presentations (Owens Hall)

Session 1: Mechanical Engineering (8:00-9:15 a.m.)
Ranalli, Joseph, Sponsor: Department of Mechanical and Nuclear Engineering, Penn State University
Keim, Kaitlin, Sponsor: NASA-Langley
Borka, Sara Pechtel, Sponsor: Mechanical Engineering Department, Virginia Tech

Session 2: Electrical and Computer Engineering (8:00-9:15 a.m.)
Anderson, Amy, Sponsor: Department of Electrical and Computer Engineering, Virginia Tech
Markham, Penn, Sponsor: College of Engineering, Virginia Tech
Krishnamurthy, Siddhartha, Sponsor: Department of Electrical and Computer Engineering, Virginia Tech

Session 3: Mechanical Engineering (9:30-10:45 a.m.)
Simmers, Eddie, Sponsor: Mechanical Engineering Department, Virginia Tech
Akinli, Cengiz, Sponsor: Virginia Space Grant Consortium
Schwartz, Kyle, Sponsor: Vibrations and Acoustics Laboratory, Virginia Tech

Session 4: Electrical and Computer Engineering (9:30-10:45 a.m.)
Somers, Marc, Sponsor: Department of Electrical and Computer Engineering, Virginia Tech
Goodwin, James, Sponsor: Department of Electrical and Computer Engineering, Virginia Tech
Chorzempa, Michael, Sponsor: Department of Electrical and Computer Engineering, Virginia Tech

Session 5: Civil and Environmental Engineering (11:00-12:15 a.m.)
Weaver, Christopher, Sponsor: Civil and Environmental Engineering Department, Virginia Tech
Betz, Robin, Sponsor: Civil and Environmental Engineering Department, Virginia Tech
Wallenfelsz, Joseph, Sponsor: Civil and Environmental Engineering Department, Virginia Tech

Session 6: Biological Engineering (11:00-12:15 a.m.)
Ng, Tracy, Sponsor: Mechanical Engineering Department, Virginia Tech
Davis, Frances, Sponsor: Biomedical Engineering, Virginia Commonwealth University
Blaszak, Tom, Sponsor: Departments of Veterinary Medicine, Electrical and Computer Engineering, and Chemistry, Virginia Tech

Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Posters (Owens Hall)

Biological Engineering (1:30-3:30 p.m.)
Ash, Joseph, Sponsor: Toshiba Stroke Research Center, State University of New York at Buffalo
Campbell, Ian, Sponsor: Department of Radiation Oncology, Wake Forest University Baptist Medical Center
Campbell, Ian, Sponsor: Mechanical Engineering, Virginia Tech
Dames, Enoch, Sponsor: National Institutes of Health
Laney, Doug, Sponsor: Los Alamos National Laboratory

Civil and Environmental Engineering (1:30-3:30 p.m.)
Dickerson, Thomas, Sponsor: Center for Geospatial Technology, Virginia Tech
Prince, Emily, Sponsor: Civil and Environmental Engineering, Virginia Tech
Ikuma, Kaoru, Sponsor: Civil and Environmental Engineering, Virginia Tech

Electrical and Computer Engineering (1:30-3:30 p.m.)
Anderson, Chris, Sponsor: Bradley Department of Electrical and Computer Engineering, Virginia Tech
Antonov, Lyudmil, Sponsor: Department of Electrical and Computer Engineering, Virginia Tech
Bachetti, Edwin, Sponsor: Department of Electrical and Computer Engineering, Virginia Tech
Belcher, Justin, Sponsor: Computer Science Department, Virginia Tech
Chung, James, Sponsor: Department of Electrical and Computer Engineering, Virginia Tech
Henderson, Kevin, Sponsor: Department of Electrical and Computer Engineering, Virginia Tech
Nkei, Bertrand, Sponsor: Oak Ridge National Laboratory, Department of Energy
Roney, Matthew, Sponsor: Department of Electrical and Computer Engineering, Virginia Tech
Riabtsev, Alexei, Sponsor: Department of Electrical and Computer Engineering, Virginia Tech

Mechanical Engineering (1:30-3:30)
Beal, Colin, Sponsor: Physics Department, Virginia Tech
Chen, Rui, Sponsor: Virginia Space Grant Consortium
Muecke, Karl, Sponsor: Mechanical Engineering, Virginia Tech
Murras, Tiffany, Sponsors: Mechanical Engineering & Aerospace and Ocean Engineering, Virginia Tech
Saint Raymond, Marc, Sponsor: Mechanical Engineering Department, Virginia Tech
Simmers, Eddie, Sponsor: Mechanical Engineering Department, Virginia Tech

Awards Ceremony (Owens Hall, 3:30-3:45 p.m.)

Figure 2. Program for the pilot undergraduate symposium on engineering research.

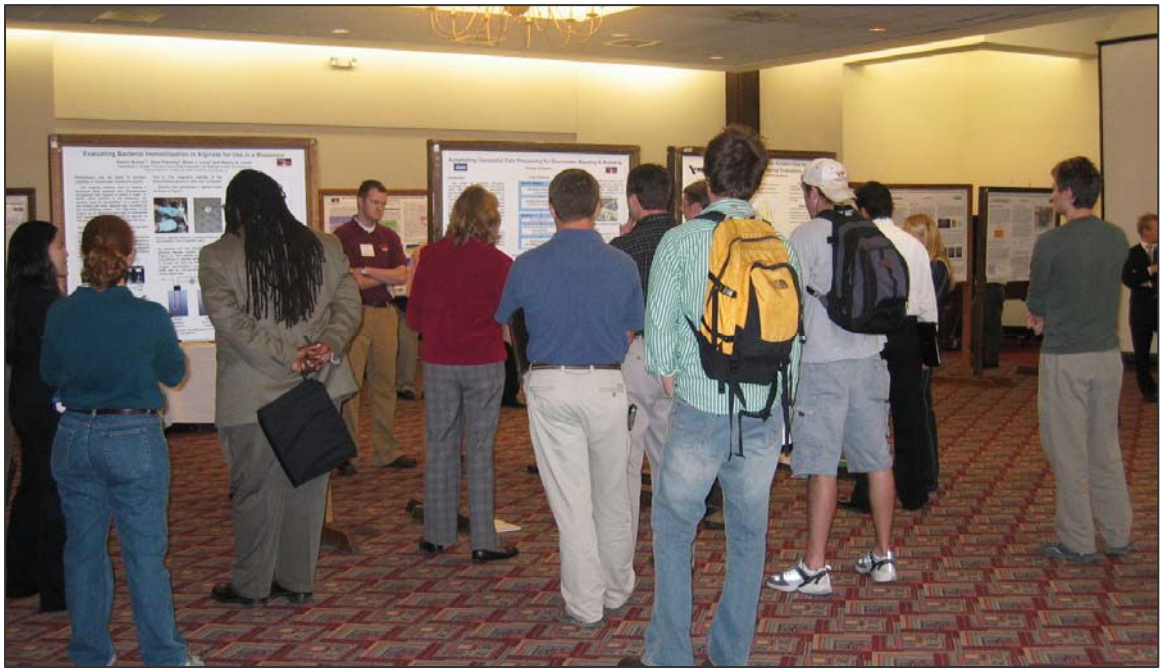

Figure 3. Poster session of the pilot symposium for undergraduate research in engineering.

Registration for the pilot technical communication course required instructor approval. One reason was to make sure that those who registered would be qualified to secure an undergraduate research position. The final number of students in the course was 20. Table 2 presents that statistics on the students who were accepted into the course—more students applied than were accepted. Of particular note are the high GPAs of the students in the course: average of 3.70/4.00 and median of 3.77/4.00. The highest GPA was 3.97, and the lowest was 3.03. Ten of the students had GPAs above 3.9. Note that a couple of students who had GPAs below 3.5 were admitted into the course, because their resumes revealed that they would have a good chance of securing a research position. Either they had research experiences in the past or they showed a high likelihood of securing a summer research position for next summer.

Table 2. Statistics on the students who registered for the research-course sequence.

Characteristic	**Description**
Total number allowed in course	25 students
Total number registered for the course	20 students
Average GPA of students registered	3.70
Median GPA of students registered	3.77
Gender breakdown	11 male; 9 female
Ethnic diversity	2 African-American; 4 Asian; 1 Hispanic; 1 African
Number from groups underrepresented in engineering	11 students

Also of note was the diversity of the students in the course. Nine of the students were women, four were Asian, one was Hispanic, two were African-American, and one was African. In addition, five other women expressed interest in the course, but had to withdraw their names because of scheduling conflicts. Of the 20 students registered for the course, 11 were from groups that are underrepresented in engineering. This high number of students from such groups indicates that the research-course sequence has an appeal to students from these groups. In addition to the gender and ethnic diversity of the students in the course was the diversity in regard to discipline of the students. The following areas of engineering were represented in this course: aerospace engineering, chemical engineering, computer science, electrical and computer engineering, engineering science and mechanics, general engineering, material science and engineering, and mechanical engineering.

Phase II: Spring Segment of Course Sequence—Preparing for Research

During the Spring 2005 semester, the investigators taught the first segment of the course sequence, Preparing for Research, to 20 undergraduates. The goals of the course were as follows: (1) to put the students in position to obtain a funded research experience, (2) to give students a head start on that experience by having them complete a literature review on the topic that they believed they would research, and (3) to teach the students best practices for research.

The course, which consisted of classes on research practices and communication, is summarized at the following web page:

http://www.writing.eng.vt.edu/courses/research1.html

During the semester, three guest speakers came in to talk to the students: two professors who have active research programs and one graduate student who had just won an award for having the best master's thesis in the College.

The first main assignment of the semester called upon students to apply to at least two research positions—either through email, through web applications, or through formal correspondence. To that end, we devoted the first two class periods of the course to writing correspondence and resumes. The remaining assignments led to writing a literature review about the topic that the students anticipated that they would research over the summer. Beginning with job correspondence is typical in a traditional technical communication course [7–9].

As mentioned, all the students secured offers for funded research positions. Two students chose, instead, to take co-op positions with companies. Although all students secured funded offers for research positions, students generally were not sure of their positions until March or April. For that reason, the second and final main assignment of the semester was a challenge for several students: to write a literature review on the research that they hoped to accomplish during the summer. As is customary for technical communication courses, this assignment was anchored in a proposal. For this assignment, students were not obligated to propose the research that they would actually end up doing—some did not know the project until their first week of the summer—but a topic in the general area that they hoped to pursue.

From the writing instructor's viewpoint, the quality of the writing in the job correspondence assignment was higher than in the traditional technical writing courses he had taught. Students wrote clearly and brought in cogent evidence for their assertions. The reason that we attribute for this higher quality was that students had an actual position to which they were applying, and therefore a clearer sense of the audience, purpose, and occasion than most students in a technical communication course. In contrast, the quality of the writing for the proposal was not as high. In a traditional technical communication course, the students write a proposal about the literature review that they are to perform. In this research course, though, the scope of the proposal assignment was much more ambitious—the students were proposing actual experiments and computations that they would perform and included a literature review as part of the proposal's Statement of Problem. Given that the scope was larger and that many students were not sure what their projects would be, students had a difficult time focusing their proposals. That lack of focus was evident in the proposal submissions. In future offerings of the course sequence, we intend to help those students who do not yet know their projects by allowing them to focus on the proposal's Statement of Problem and to submit the remaining part of the proposal (the Objectives, Methods, and Schedule) in an outline form. That way, the students still can gain experience writing a literature review and assembling a proposal.

The students were surveyed at the beginning of the semester and again at the end. Presented in Figure 4 are responses by the students to some of the questions at the end of the semester. From the end-of-semester survey, we learned that the students particularly appreciated the presentation by the graduate student. Our assessment was that students could identify more with the graduate student than with the faculty members—hearing the faculty talk about their research experiences was more intimidating to the undergraduates than listening to the graduate student.

The end-of-semester survey revealed that the research course influenced the students to apply for a research position that was significantly more competitive than they would have otherwise. That so many students obtained research positions at prestigious universities supports the self-assessment of the students. Also found in the survey was that the research course provided a better understanding for the students of what graduate school would be like as well as making the students more likely to attend graduate school—two goals of the course sequence.

Because of what I learned in this course (EngE 4984: Preparing for Research), my application for a research position was significantly more competitive.

Strongly Agree	4 (20%)
Agree	9 (45%)
Not Sure	5 (25%)
Disagree	1 (5%)
Strongly Disagree	0 (0%)
Other:	1 (5%)
no answer	0 (0%)

Because of this course, I have a better understanding of what research in graduate school will be like.

Strongly Agree	6 (30%)
Agree	13 (65%)
Not Sure	0 (0%)
Disagree	1 (5%)
Strongly Disagree	0 (0%)
Other:	0 (0%)
no answer	0 (0%)

Because of this course, I am more inclined to attend graduate school.

Strongly Agree	3 (15%)
Agree	9 (45%)
Not Sure	3 (15%)
Disagree	1 (5%)
Strongly Disagree	0 (0%)
Other:	4 (20%)
no answer	0 (0%)

Figure 4. Results of three questions from the end-of-semester survey in the first course (Preparing for Research) of the research course sequence.

Phase 3: Summer Research Experiences

During the Summer of 2005, the students had their research experiences. Given below are the institutions that hosted those experiences:

Virginia Tech (8 students)	MIT
Georgia Tech (2 students)	Penn State
Bucknell	University of South Carolina
East Tennessee State University	Vanderbilt University
University of Illinois	Woods Hole Oceanographic Institution

As mentioned, more than half of the students obtained positions at institutions other than Virginia Tech. Also, as mentioned, two of the students in the course decided to accept co-op positions with companies rather than to accept research positions. However, these students have the option of obtaining a research experience the next summer (Summer 2006) and then taking the second portion of the research sequence in Fall 2006.

At the end of the summer, we surveyed the students to find out their experiences. Presented in Figure 5 are results from selected questions of that survey. Overall, students had very positive experiences in their research positions. Of particular interest in the survey was that three students specifically commented on how valuable the library portion of the spring course (Preparation for Research). That portion had not been rated as highly in the end-of-course survey. However, these three students indicated that assembling journal articles about their research topic was their first main task in their summer research experience and that they believed the experienced they had in the spring research course put them in a good position to accomplish that task.

Also of note was that several students commented that they had to give a formal presentation during the summer. Given that, we are considering how to include some sort of presentation experience in the spring research course. The students commented that they had received positive or very positive comments on their writing and presentation; nonetheless, we believe that by devoting one class period to presentations, we can place the students in a better position to succeed on these presentations.

Phase IV: Fall Segment of Course Sequence—Documenting Research

During the Fall 2005 semester, 15 of the original 20 students enrolled for the second course of the sequence: Documenting Research. The goals of the course were as follows: (1) to give the students the opportunity to document their summer research experience, (2) to teach the students how to make a professional presentation, and (3) to teach the students how to document a project in a poster and a formal article.

The course is summarized at the following web page:

http://www.writing.eng.vt.edu/courses/research2.html

The course consisted of classes on communication. During the semester, students learn lessons about communication. They would also bring in drafts of four main documents and receive a peer-critique of those documents.

Characterize your summer research experience using the following choices and explain your choice in the comment section.

Very positive	6	(46%)
Positive	7	(54%)
Neutral	0	(0%)
Negative	0	(0%)
Very negative	0	(0%)

Which of the following topics did you encounter during your summer research experience?

Conducting your own literature search	11	(85%)
Reading journal articles	12	(92%)
Discussing journal articles	10	(77%)
Writing a article	3	(23%)
Writing a report	8	(62%)
Writing a proposal	3	(23%)
Creating and presenting a poster	2	(15%)
Creating and presenting a talk (i.e., PowerPoint presentation)	8	(62%)
Formulating a research question	3	(23%)
Formulating a research plan	6	(46%)
Performing a laboratory experiment	8	(62%)
Performing a computational analysis	8	(62%)
Developing a theory	4	(31%)
Attending a conference	6	(46%)
Presenting at a conference	2	(15%)
Receiving formal instruction (i.e., lectures) on communication	6	(46%)

Which of the following Spring 2005 course material was useful in your summer research position?

Guest lectures on research	10	(77%)
Class periods and assignment on resumes and cover letters	4	(31%)
Class periods and assignment on proposals	11	(85%)
Class period on ethics	4	(31%)
Class period on library research	6	(46%)
Assignment to attend external seminar	2	(15%)
Comment:	3	(23%)

Figure 5. Results of three questions from the end-of-summer survey on the research experiences of the students in the course sequence.

The first main assignment of the semester called upon students to write an abstract of their summer research for a symposium—the format for the abstract followed the format for abstracts to be submitted to the College's undergraduate research symposium. Because the assignment was due just before the deadline of abstracts for the symposium, the students were in an excellent position to submit their abstracts to the symposium, and all 15 students did, in fact, submit abstracts to the symposium. As assessed by the project's writing instructor, the quality of the writing for this assignment was high. We attribute the high quality of writing in this assignment to the depth that the students achieved in their research over the summer.

The second main assignment of the semester called upon the students to create a poster of their research projects. Because every student in the course had submitted an abstract to the undergraduate research symposium and all those abstracts were accepted, these posters were not only submitted in computer file form as an assignment, but also were printed out and displayed at the symposium. As assessed by the project's writing instructor, the quality of the writing for this assignment was very high. Students did an excellent job of presenting much of the research visually and avoiding the common mistake of posters of having too much text for the audience to read. We attribute the high quality of writing in this assignment to the depth that the students achieved in their research over the summer. In comparison with students in a traditional technical communication course, students in the research sequence had more time to find strong graphics to communicate their work. Moreover, students had more time to discern what evidence is most persuasive at supporting their assertions.

The third main assignment called upon the students to make a formal presentation of their summer research. This assignment called upon the students to create a set of presentation slides that stood alone as a set of notes. Rather than following the topic/sub-topic style of slides that is so common in research presentations, the students were asked to aim higher and create slides that followed an assertion/evidence design [12]. This design is characterized by a succinct sentence headline supported by visual evidence rather than a bullet list. As assessed by the project's writing instructor, the quality of the presenting for this assignment was very high. Students did an excellent job of presenting the research memorably and persuasively. We attribute the high quality of communication in this assignment to the depth that the students achieved in their research over the summer. In comparison with students in a traditional technical communication course, students in the research sequence had more time to find strong graphics to communicate their work. Moreover, students had more time to discern what evidence is most persuasive at supporting their assertions.

The fourth and final main assignment called upon the students to write a journal article that documented their summer research. Students were allowed to follow the format of any journal or conference proceeding to which they intended to submit their work. If the students did not intend to submit their research for publication, they were asked to follow the format of a journal or conference proceeding in the discipline (for example, the IEEE format for those students pursuing degrees in electrical engineering). As assessed by the project's writing instructor, the quality of the writing on this assignment was mixed. Some students wrote a level higher than would be typically achieved by students in a technical communication course. We attribute this higher level to the depth that the students achieved in their research and the time that the students had to create effective graphics and to craft persuasive arguments. However, some students submitted documents that appeared to be hurried. Because this assignment was longer than all the other documents, some students did not budget enough time for the

assignment. A lesson learned here was that students should have been submitting part of this assignment for review throughout the semester—perhaps the introduction sometime between the abstract and poster assignments and the methods section between the poster and presentation assignment. That way, those students who were not yet experienced in completing a long document would be compelled to spread the writing task out over the entire fall semester.

Given at the end of this semester was another survey. Overall, students felt that the presentation portion of the fall research course was very strong; however, students felt that the writing portion could have been stronger. A lesson from this survey was that the article needed to be emphasized more at the beginning of the fall course and perhaps mentioned in the spring course. Having two or three strong examples from this pilot course as examples for future students will let those students know where the "bar rests" in terms of what makes for a strong final article.

Phase V: Recruitment for the Next Offering of the Sequence

In the Fall 2005 semester, recruitment began in earnest for the second cycle of the research course sequence. The recruitment consisted of three efforts. The first was sending email announcements of the course to those students who would be eligible for such a course. In general, eligibility meant having a GPA above 3.5, which is the level that many national laboratories require for acceptance into their summer research programs. In creating the distribution lists for these emails, special attempts were made to include underrepresented groups in engineering. These emails were sent out just before the registration period of the Spring 2005 semester, in which the course sequence was to begin.

Second, an information session was held in the College on undergraduate research. This session informed undergraduates about the benefits and opportunities for undergraduate research on Virginia Tech's campus, at other engineering colleges, and at the national laboratories. In addition, the research-course sequence was discussed as a means to help obtain and deepen such a research experience.

Third, on October 14, 2005, we held a research symposium in the College of Engineering at Virginia Tech for the following two reasons: (1) to highlight the undergraduate research that had been done the past year in the College (that included the research done by students in the pilot research course sequence), and (2) to attract qualified undergraduates to the pilot research-course sequence that we were going to test. Lessons learned from undergraduate research symposium given the previous year were incorporated. More than 40 undergraduates presented posters at this year's undergraduate research symposium, and more than 150 other undergraduates attended. In addition, three students, all from the research course sequence, served as symposium chairs. The web page for the symposium was as follows:

http://www.writing.eng.vt.edu/symposium.html

From these three recruiting efforts, twenty-two students enrolled for the 2006 offering of the research course sequence. As had been the case for the 2005 offering, several more applied than were accepted. Overall, the pool of students appears to be talented, as evidenced by the average of GPA of 3.7. Judging from the resumes, we assess that the pool appears to be diverse,

as evidenced by the pool's inclusion of five female students. Once the semester begins and the class meets, we will be able to assess the racial diversity of the class,

Conclusions

This paper has presented our testing of a research course sequence as a substitute for the traditional technical communication course. The purpose of this option, which is for those students who are qualified academically to pursue graduate education, is to promote and foster research among those undergraduates. *The overall result of this test was that the pilot course sequence was a success.* Specific results were as follows:

(1) we were able to recruit a talented and diverse group of students for the pilot course sequence—average GPA was 3.77, and11 of the 20 students came from underrepresented groups in engineering;
(2) all twenty students in the spring course of the sequence (Research Preparation) received funded offers for summer research experiences, and all students surveyed indicated that their summer research experiences were either positive or very positive;
(3) fifteen of the twenty students took the second part of the sequence (Documenting Research);
(4) all of those students in the second course presented posters at the College's Undergraduate Research Symposium, and several have submitted their research for professional publication (either conferences or journals);
(5) the College's Undergraduate Research Symposium had more than 40 participants and attracted than 150 undergraduate visitors—this Symposium helped us recruit another talented and diverse pool of students for the second cycle of the course; and
(6) For 13 of the 15 students completing the sequence, the course did not add any credits to their degree plan—the Departments of those students either accepted the course sequence as a technical elective or as a substitute for the English Department's Technical Writing, which was required.

The project did not occur without challenges. Given below are the lessons that we have learned from this project:

(1) some engineering departments that already require the English Department's Technical Writing course were slow to accept this course as a substitute;
(2) some engineering departments, particularly the smaller ones (Engineering Science and Mechanics and Material Science Engineering), have refused to have the course count for any credit in their curricula, thus making it difficult to recruit those departments' students; and
(3) although most students in this course produced quality documents and presentations, the quality of each course's final assignments (the literature review in the spring and the journal article in the fall) would be improved if the students submitted drafts of portions of each assignment throughout the semesters rather than a draft of the entire assignment at the end.

In 2006, we will run the course sequence a second time with a second group of students. For this second running of the course, some students from the first course offering will serve as mentors, providing advice about research experiences to pursue and strategies to follow. In

addition, we will continue to monitor the progress of the students who took the first course to determine the effects of the experience on whether they attended graduate school and whether they obtained graduate fellowships.

In the future, the course will work more closely with the Virginia Tech Center for the Enhancement of Engineering Diversity to make those students better aware of this opportunity. Moreover, in the future, should this course sequence prove successful for this level of students (GPA of 3.5 or above), attempts will be made to lower the GPA requirements to determine whether the sequence could serve a larger group of students, some of whom will have a lower academic preparation.

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