



## **Enticing Undergraduate Students to Pursue Graduate Research at an Undergraduate-Focused Institution**

**Dr. Aaron P. Wemhoff, Villanova University**

Dr. Aaron Wemhoff earned his Ph.D. from UC Berkeley in 2004. He started work as an Assistant Professor in the Department of Mechanical Engineering at Villanova University in 2008 after working for 3 years at Lawrence Livermore National Laboratory.

# Enticing Undergraduate Students to Pursue Graduate Research at an Undergraduate-Focused Institution

## Abstract

A course was created with the goal of enhancing the visibility of the Mechanical Engineering Department graduate research program at a university containing high-quality senior undergraduate students. The course includes standard lectures where graduate students present their research to undergraduate students, and specialized lectures on library resources and academic careers. This course was designed to motivate undergraduate students to remain at their undergraduate institution for a research-based graduate degree, to improve communication skills for existing graduate students, and to supplement ABET criteria not frequently seen in core courses. The students exhibited a high attendance rate, but many students lost interest when the speakers spoke at too high a technical level. Student surveys showed that the course improved their ability to decide on whether to pursue graduate research, and whether this research would occur in the Mechanical Engineering Department. The course surveys also suggested that the students were drawn away from professional post-graduate degrees towards research-related graduate degrees. Also, nearly 1 in 5 students actively sought out at least one presenter or faculty advisor to discuss their research project further, showing a substantial increase in departmental research interest by the current undergraduate students. Finally, all students recommended the course to rising seniors given the right circumstances.

## I. Introduction

In recent years, the College of Engineering at Villanova University has increased its emphasis on graduate research programs, thereby supplementing its traditional focus on undergraduate education. This is reflected in the increase in externally-funded projects, resulting in a push towards developing a nationally-recognized graduate program. The Department of Mechanical Engineering has played a key role in this movement, where the number of Ph.D. graduates has grown from the program's inception approximately 10 years ago to an anticipated 9 graduates in 2014.

One important element of growing a graduate program lies in the recruiting and retention of quality graduate students. The Villanova undergraduate population is of strong quality, and therefore they are specifically targeted in our efforts. Furthermore, our undergraduate focus on strong engineering fundamentals tends to steer undergraduates towards attending graduate school<sup>1</sup>. This is particularly important as recent studies have suggested that international students are increasingly favoring larger research programs<sup>2</sup>. The Villanova undergraduate student body is predominantly U.S.-born, which tends to generally resist attending graduate programs due to economic reasons: students graduating with a BSME degree can earn more money immediately upon graduation if they enter the workforce, and graduate students often require loans to pay for education or to supplement their stipend<sup>3,4</sup>. This is reflected in the fact that the growth in international graduate students studying in the U.S. in 2007-8 was double that of domestic students<sup>5</sup>. In addition, the fraction of international students pursuing doctorates in science and engineering is 24% higher than domestic students<sup>6</sup>. Finally, the Council of Graduate Schools (CGS) reports that applications have declined in recent years for domestic students, whereas

international applications have risen by 4.7% from 2009-10<sup>7</sup>. Compounding this problem is the fact that the National Center for Education Statistics (NCES) has predicted a jump in graduate enrollment of 57% in PhD programs nationwide from 2008-2009 to 2020-2021<sup>8</sup>, and therefore increased competition may hinder the quality of our entering graduate students.

Other universities have employed a variety of approaches to grow their graduate programs using their own undergraduates. The New Jersey Institute of Technology (NJIT) grew their PhD program from 14 in 1991 to 75 in 2006. The majority of their strategies were imposed as administrative policies at the college-level<sup>9</sup> such as an achievement program<sup>10</sup> that encourages undergraduate students to pursue research opportunities as a gateway to graduate studies. Similarly, the University of Arkansas developed a student intern research experience program that combines a co-op experience with undergraduate research to enhance the desire of the students to pursue a graduate degree<sup>11</sup>.

Crede and Borrego<sup>5</sup> showed that undergraduate students (1) do not have a strong grasp of the graduate school application process, (2) tended to have concerns over the length of time required to obtain a PhD, and (3) lacked confidence in their undergraduate curriculum's capability to enable them to decide on whether or not to attend graduate school. This study focuses on the third deficiency above. The only current Villanova mechanical engineering discussion on research is during the students' sophomore year in the form of a brief overview of various departmental research programs. Therefore, ME 5003 Senior Research Seminar was developed to provide undergraduate students the opportunity to learn more about graduate research in the department.

Other programs have used a similar approach. For example, Hajek and Fentiman<sup>12</sup> retooled their undergraduate nuclear engineering course to recruit new graduate students to their program at Ohio State University. In addition, Arizona State University implemented a program where undergraduates listen to graduate students discuss their research, and industry members with graduate degrees discuss their work and how it differs from those jobs requiring only a bachelor's degree<sup>13</sup>.

The chosen format for ME 5003 was defined by maximizing undergraduate enrollment. A one-credit pass-fail course format was chosen as it was best suited to attract students. Fortunately, one draw for enrollment is by those students in search of a one-credit course to maintain full-time status. The university requires students to take 12 credits to maintain full-time status, and the standard course audit for senior mechanical engineering undergraduates in their final semester is 14 credits, three of which stem from a university "free" elective. Many students have already taken the free elective earlier in their academic career, leaving them with only 11 credits and in search of a one-credit course for full-time status.

ME 5003 features a number of invited lectures, most of which are by current graduate students. This provides the side benefit of improving the graduate students' communication ability. The majority of ME graduate students stem from international backgrounds, and as a result most students lack confidence and practice in presenting their research in an English-based environment. The new course provides an opportunity for these students to present their research at a basic level to undergraduate students. The advantage to having a lower-level

audience is that they may be less intimidating than an audience of experts, such as at a conference.

One final benefit of holding ME 5003 is to enhance certain ABET criteria that are not often seen in core Mechanical Engineering courses:

- **Criteria i:** Graduates have a recognition of the need for, and an ability to engage in life-long learning. ME 5003 provides insight for the undergraduates to learn about graduate student life and to prepare them to look beyond their coursework. At a minimum, the course shows undergraduates that a great deal of knowledge is still available to them beyond their basic undergraduate education.
- **Criteria j:** Graduates have a knowledge of contemporary issues. The students are exposed to cutting-edge research that spans across all of mechanical engineering, so ME 5003 directly addresses this criterion.

## II. Method

ME 5003 was held for the first time in Spring 2013. The course meets once a week for an hour. The course features both standard and specialized lectures. The standard lectures follow the following schedule:

1. The principal instructor reviews the main points from the previous class.
2. The guest speaker, generally a graduate student, provides a 30-40 minute lecture on their research.
3. The students and principal instructor ask questions to the guest speaker pertaining to the research.

To keep the students engaged, the speaker provides a 10-question fill-in-the-blank worksheet. The students then fill out the worksheet as the speaker presents his/her work, and they turn it in to the principal instructor at the end of the class for grading.

Students are graded based on their attendance in class (50%), the participation in the question/answer session following the talk (25%), and the worksheets (25%). The students lose attendance credit if they are observed not paying full attention to the speaker during the talk. To pass the course, an overall grade of 60% or higher is needed.

The selected graduate student speakers are near the end of their academic careers since their knowledge and research progress has been sufficient to put together a quality presentation. Several speakers incorporate slides from their thesis or conference presentations to make the preparation feasible. At least one speaker is chosen from each of the four principal areas of mechanical engineering research at Villanova: Dynamics/Control, Thermal/Fluids, Materials/Mechanics, and Bioengineering. However, the research areas in Dynamics/Control and Thermal/Fluids are more extensive in the department, so additional speakers were drawn from these two areas. The advantage to this approach instead of an “even representation” approach is that more student speakers are available and it provides a more accurate representation of ongoing departmental research. However, this approach puts the minor research areas at a disadvantage for recruiting new graduate students.

Special topics lectures are also implemented to break up the standard lecture routine. In Spring 2013 two such lectures were implemented:

1. Library Resources for Research. A representative from the university library instructed the students on how to perform citation searches. This work is important as it shows students how to learn outside of the classroom.
2. Faculty Careers. The principal instructor provided an overview on life as a faculty member, including information on the tenure process, grant acquisition, publishing, and work life. This was hoped to motivate students to pursue graduate study perhaps with a mindset toward an academic career. Current graduate students are also invited to join the audience as studies have suggested that they are not well-prepared for academic careers<sup>14</sup>.

Standard introductory and conclusive lectures are also provided by the principal instructor to provide an overview of the departmental research and to collect student feedback. At the end of the semester, students are solicited to provide ideas for future research topics.

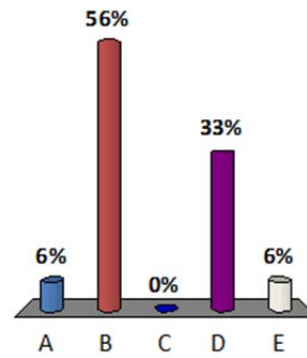
### III. Results

Several personal observations were made from the Spring 2013 class:

1. Student attendance was high: the average attendance rate was 95.3%.
2. Some students had trouble staying focused. This was largely due to the level of complexity of some presentations. In general, Masters-level students presented at a better level of technical content for the undergraduate audience compared to the PhD-level presenters. The reason for this is that many Masters-level students were former Villanova undergraduates, and thus it was easier for them to relate to the audience. To address the problem of presentation complexity, all presenters were required to submit their presentation prior to the class meeting for review. This strategy somewhat alleviated the problem.
3. The students responded well to relaxed presenters, presentations with a low level of complexity, and applied research over fundamental research. The students also appreciated student-presenter interaction and active learning, so these will be encouraged in the future.
4. The students displayed an even interest for all research areas of mechanical engineering.

Surveys for the undergraduate students were provided at the beginning and end of the semester. These surveys were made anonymous by using clickers. Figure 1 shows the motivation used by the students to register for the course. The responses show that approximately half of the students showed essentially no interest in ME graduate research. These students were in the class to earn the “easy credit” to gain full-time status. Additional survey questions indicated that 100% of the class was planning to graduate in Spring 2013, one-third of the students were enrolled in the department’s 5-year BS-MS program, and approximately one quarter of the students in the class had performed undergraduate research in the department.

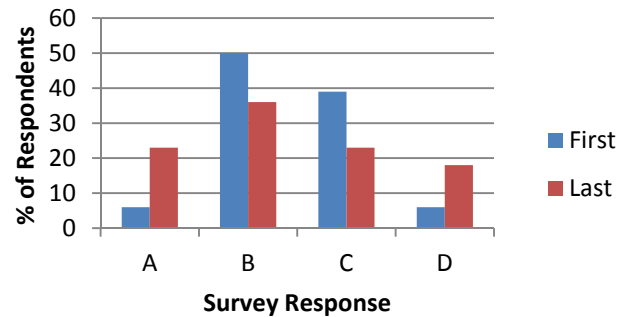
- A. To satisfy curiosity regarding graduate research ongoing in the ME Dept
- B. To fulfill the minimum of 12 credits required for full-time status
- C. Both A & B, with A having more meaningful impact
- D. Both A & B, with B having more meaningful impact
- E. Both A & B equally



**Figure 1.** Responses to the question “Why did you decide to take this course?” answered anonymously by students at the first class meeting.

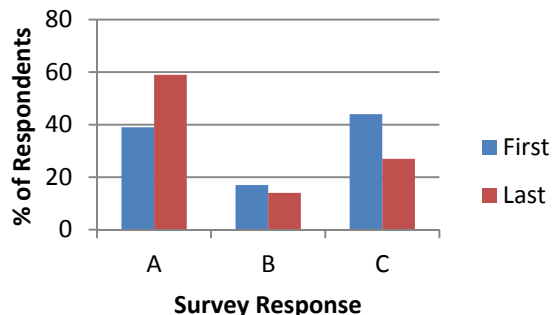
A number of questions were also asked at both the initial and final class meetings. These questions, also answered anonymously using clickers, are provided in Figs. 2-6. Figure 2 shows that the level of interest in mechanical engineering graduate research changed significantly as the semester progressed. The number of students with high interest in the research rose fourfold, while the number of students indicating no interest tripled. This trend shows that the course allowed students to decide whether or not to pursue graduate research, which is also reflected in Figs. 3 and 4 as the number of students undecided as to pursue graduate studies dropped by approximately one half.

- A. High interest
- B. Moderate interest
- C. Low interest
- D. No interest



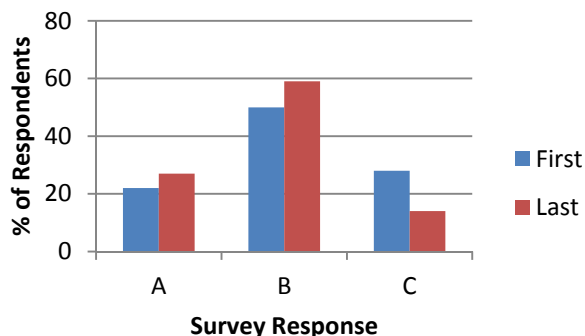
**Figure 2.** Responses to the question “What is your level of interest in ME graduate research?” answered anonymously by students at both the first and last class meetings.

- A. *Yes*
- B. *No*
- C. *Maybe/undecided*



**Figure 3.** Responses to the question “Are you currently planning on attending graduate school at any university?” answered anonymously by students at both the first and last class meetings.

- A. *Yes*
- B. *No*
- C. *Maybe/undecided*

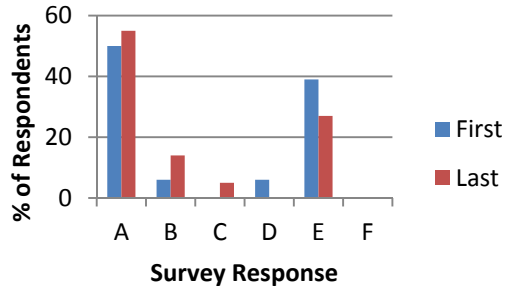


**Figure 4.** Responses to the question “Are you currently planning on attending graduate school in the Villanova ME Department?” answered anonymously by students at both the first and last class meetings.

Figures 3 and 4 also show an increase in students choosing to pursue graduate school, but the increase in interest for pursuing graduate school in the Villanova Mechanical Engineering Department did not rise significantly. These results therefore suggest that many students gained interest in graduate research but have determined to look elsewhere for graduate studies.

Figure 5 shows the areas of interest for graduate studies by the class. The course focuses on mechanical engineering graduate research, so, as expected, the course persuaded more students to consider pursuing research instead of professional degrees. Interestingly, the gain in interest for research in non-mechanical engineering fields rose more than that for mechanical engineering. One possible explanation for this is that one of the areas of presented research is in bioengineering, which some students may have considered outside the guise of mechanical engineering when completing the survey.

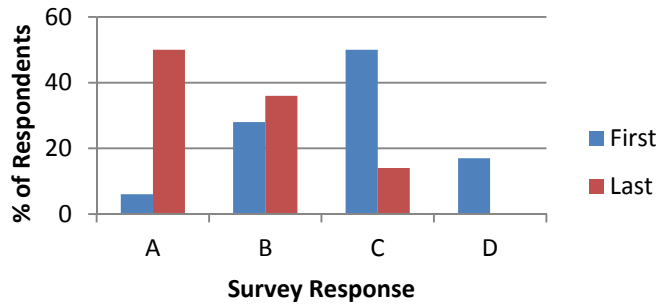
- A. Mechanical engineering
- B. Other engineering
- C. Medicine
- D. Law
- E. Business (MBA)
- F. Other



**Figure 5.** Responses to the query “If you were to attend grad school somewhere, it would be in the field of:” answered anonymously by students at both the first and last class meetings.

Figure 6 shows the change in student knowledge level in ongoing mechanical engineering research at Villanova. As expected, the trend shifted significantly towards having a high or moderate level of research knowledge. It is expected that those with low research knowledge at the end of the semester were deterred by the high level of complexity exhibited in some presentations.

- A. High
- B. Moderate
- C. Low
- D. None

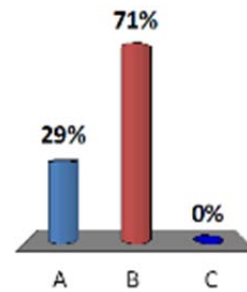


**Figure 6.** Responses to the question “What is your current level of knowledge of ongoing research in the Villanova ME Department?” answered anonymously by students at both the first and last class meetings.

The last class meeting featured two additional questions. First, students were asked under which circumstances they would recommend taking the course. Figure 7 shows one positive outcome of the survey, where 29% of the students would recommend the course to other students regardless of their credit count, which, when compared to Fig. 1, suggests that the course exceeded the expectations for at least one quarter of the class. The remaining 71% of the students were likely not interested in pursuing graduate research but rather wanted to pursue a professional degree or no graduate degree. The second question asked students if they actively sought out at least one presenter or faculty advisor to discuss their research project further. The response indicated that nearly 1 in 5 students performed this task, indicating an increase in interest of specific research projects.



- A. *I would recommend it regardless of course load*
- B. *I would recommend it only if they needed the 12<sup>th</sup> credit*
- C. *I would not recommend it even if they needed the 12<sup>th</sup> credit*



**Figure 7.** Responses to the question “Would you recommend this course to a rising senior under the following circumstances?” answered anonymously by students at only the last class meeting.

To assess ABET criteria, students were given a short quiz on the last day of class. The quiz answers were analyzed on a 1-3 scale (1: novice, 2: apprentice, and 3: proficient). The class was shown to have an overall score of 2.45/3.0 for Criteria i and 2.50/3.0 for Criteria j. Therefore, one can conclude that these ABET Student Outcomes were strong at the end of the semester.

The undergraduates also had suggestions for future special topics. These included graduate student socialization, additional graduate programs and career paths, obtaining research funding, and graduate service programs. To address these issues, the second instance of the course planned for Spring 2014 will feature presentations by law, business, and sustainable engineering programs. In addition, the course will contain a “life as a grad student” panel session where the undergraduate students can ask questions to the graduate students regarding their daily work schedules. This is an important improvement as studies have suggested that socialization is highly valued by graduate students<sup>14</sup>, which could especially affect underrepresented groups<sup>15</sup>.

The panel will also feature a discussion on the motivation that drives students to pursue research. The panelists will discuss which aspects of their individual research projects are attractive, whether it is experimental, analytical, or computational. In addition, the importance of research will be discussed as how it benefits society.

The undergraduate students also provided many suggestions for improvement. A lot of these focused on the presentations being at too difficult a level and presenters being too nervous. Other suggestions included sending students an overview of the presentation beforehand and more active involvement with the audience. To address these concerns, in Spring 2014 a summary statement will be sent to the students beforehand, and presenters will be encouraged to solicit more interaction with the audience.

Feedback was also requested from the speakers. In a provided survey, nearly all presenters said that their participation improved their presentation skills. The speakers said that the level of audience engagement varied significantly, where the undergraduate surveys showed a connection between the speaker’s communication ability and the audience engagement. Finally, the experience enhanced the desire for all graduate student speakers to teach in the future.

The preparation time for the presenters varied dramatically from as little as 20 minutes up to three days. For short preparation times, the slides were generally derived from either a thesis

defense or conference presentation. Students with long preparation times did not complain but rather stated that the slides they used in the course would later be folded into their thesis defense.

#### IV. Concluding Remarks

The first offering of the course resulted with both positive and constructive feedback. The positive feedback included a high student enrollment and attendance, a significant gain in students with a high interest in mechanical engineering graduate research, and a motivation for some students to seek out researchers to learn more about their work. In addition, all of the students stated that they would recommend the course to rising seniors given the right circumstances.

The constructive feedback showed that some presentations were too complex for the knowledge level of the undergraduate audience, and therefore efforts were taken to mitigate this problem. In addition, the number of undergraduate students showing no interest in pursuing mechanical engineering graduate research increased significantly, showing that the course allowed students to narrow their career path choices by exposing them to various research projects. Finally, there was only a slight increase in students expressing the desire to pursue Villanova mechanical engineering graduate research.

Other engineering departments and research clusters have expressed interest in creating courses such as ME 5003. Therefore, one goal is to continue to examine similar programs around the country<sup>12,13</sup> to continuously update the course as new pedagogical information becomes available. Another goal is to encourage the undergraduate students to examine their own skills and perhaps find a match with a faculty mentor, which will also be implemented in Spring 2014.

#### V. Bibliography

1. Ro, H. K. (2011) Predicting Graduate School Plans Based on Students' Self-Assessed Engineering Knowledge and Skills. Presented at *2011 ASEE Annual Conference*.
2. Schmidt, P. (2009) Doctoral Universities Pull Ahead in Competition for Foreign Graduate Students. *The Chronicle of Higher Education* 55 (32), A29.
3. Jha, M. K.; Amory, R. (2012) Examining the Explanatory Variables that Impact Graduate Engineering Student Enrollment. Presented at *2012 ASEE Annual Conference*.
4. Colwell, J. L. (2012) Looking Ahead: Some Trends in Graduate Education and their Impact on Engineering and Technology. Presented at *2012 ASEE Annual Conference*.
5. Crede, E.; Borrego, M. J. (2011) Undergraduate Engineering Student Perceptions of Graduate School and the Decision to Enroll. Presented at *2011 ASEE Annual Conference*.
6. National Science Foundation, *Doctorate Recipients from US Universities*, in *Survey of Earned Doctorates*, 2010.
7. June, A. W. (2011) New Graduate-Student Enrollment Dips for First Time in 7 Years, *The Chronicle of Higher Education*.
8. As reported in *Inside Higher Ed*, September 22, 2011.
9. Kane, R.; Gonzalez-Lenahan, C. (2007) The Doctoral Pathway, an Institutional Journey of Development. Presented at *2007 ASEE Annual Conference*.

10. Hirsch, L.; Carpinelli, J.; Kimmel, H.; Perna, A.; Narh, K. (2009) Measuring the Impact of Undergraduate Research Programs on Engineering Students' Attitudes Toward Graduate Studies. Presented at *2009 ASEE Annual Conference*.
11. Rossetti, M. D.; Clausen, E. C.; Gattis, C. S.; Hale, M.; Needy, K. L. (2013) On the Development of a Student Integrated Intern Research Experience as a Pathway to Graduate Studies. Presented at *2013 ASEE Annual Conference*.
12. Hajek, B. K.; Fentiman, A. W. (2003) Recruiting Graduate Students through an Introductory Nuclear Science and Engineering Course and a Newly Implemented Undergraduate Minor Program. Presented at *2003 ASEE Annual Conference*.
13. Anderson-Rowland, M. (2008) *Thinking About Graduate School*. Presented at 2008 ASEE Annual Conference.
14. Austin, A. (2002) Preparing the Next Generation of Faculty: Graduate School as Socialization to the Academic Career. *The Journal of Higher Education* 73 (1), 94-122.
15. Lucero, C. (2004) Graduate Student Socialization in Science and Engineering: A Study of Underrepresented Minorities' Experiences. Presented at *2004 ASEE Annual Conference*.