

## **Work in Progress: Developing an Undergraduate Theory and Methods of Research Class for Honors Students**

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**Abstract:** Our institution has focused on expanding the Honor's College experience in an effort to improve recruiting and retention. Within the Engineering College, the goal is to focus the Honors experience on undergraduate research with an aim of broadening research opportunities and competitiveness of student applications for summer research programs, NSF REUs, internal/external research funding applications, participation in undergraduate research conferences, and preparing the students for graduate school. Historically, many students have received credit for completing undergraduate research, but this is often a "stand-alone" course with no additional preparation and ill-defined outcomes. In an effort to improve the undergraduate research experience, we will be initiating a Theory and Methods of Research course for the undergraduate Honors students as pre-requisite for undergraduate research during the Fall 2019 semester.

The course will be broadly focused by providing a general approach to research and graduate school preparation. Course topics will include: finding a research mentor, literature search skills, using the scientific method for approaching a research problem, developing a research methodology, writing a funding proposal, delivering a research presentation, and selecting and applying for graduate school. This presentation will present the motivation for this work, course details, learning objectives, course schedule, and course assignments. In addition planned assessments and student outcome tracking for the course will be presented.

## INTRODUCTION

In an effort to improve recruiting and retention, our institution has focused on expanding and broadening the Honor's College experience. Honor's Colleges and undergraduate research experiences are considered High Impact Practices (HIP)[1] and are broadly used in many colleges and universities to improve recruiting and retention. Within the College of Engineering and Applied Science, the goal of the Honor's experience is to focus on undergraduate research. As part of this focus, all Engineering Honor's students will be required to take 3 credits of undergraduate research, complete a senior thesis, and deliver a research presentation.[2]

The university's Honor's program itself would like to increase the number of students involved in undergraduate research, as well as increase the number of students applying for and receiving admission to graduate school, NSF REUs, other undergraduate research funding, and regional and national conference presentations. In order to achieve these goals, the Engineering College has elected to complement the undergraduate research with a Research Methods course. The focus of the course is two-fold: to increase the student's ability to apply for and receive competitive funding, admissions, and conferences, and to improve the research experience and productivity of the subsequent undergraduate research laboratory course.

Undergraduate Research Methods courses are fairly common in the social sciences (psychology, sociology, political science, and criminal justice studies)[3-5]. These courses are focused on developing, using, and interpreting surveys. They typically consist of three main components: survey design, internal review board (IRB) approval and CITI training, and statistics and statistical analysis of the data.

While these undergraduate research methods are not as broadly available in the hard sciences and engineering, some are being offered.[6-8] Topics to improve the research experience are also starting to be incorporated into summer research experiences for undergraduates (REUs).[9] In contrast, similar research methods courses for graduate students are becoming more common and are broadly offered.[10-12] In contrast to the social science courses, the graduate courses in engineering typically include such content as literature searches, reading the literature, delivering presentations, scientific method, research ethics, proposal writing (including a research plan), patents, copyrights, and research notebooks. Many of these topics would also be relevant to an undergraduate research methods course in the hard sciences and engineering. As such, many of these topics are starting to find their way into traditional apprenticeship model undergraduate research courses where the students work in their mentors laboratory.[13, 14] However, it appears that the student is commonly left to obtain this research methods knowledge individually from their research mentor. In addition, there is a combined type of research methods course. In this style of course, the students are group mentored on research methods while at the same time conducting research under the instructors mentorship.[6] However, there are still un-resolved questions associated with undergraduate research. First, as demand grows for undergraduate research, in the current "apprenticeship mode" of sending students into the lab without additional training, the strain of this additional work on the faculty becomes evident.[15] In addition, as Gray has asked, "What skills do students need to participate in undergraduate research?", "How do these skills differ by discipline?", and "Where in the curriculum do students develop these skills?"[16] These last two

items indicate one potential solution, a common introduction to research methods covering many applicable topics through a standard course.

Thus, the College of Engineering and Applied Science has developed and will be offering an undergraduate research methods course for the students in our honor's program. The course goal is to provide a group mentoring experience to prepare students for success in the subsequent undergraduate research course with individual research advisors/mentors. Secondary goals include increasing the number of submissions and receipt of graduate school admissions, NSF REUs, undergraduate research funds, and undergraduate research conference presentations.

## **METHODS**

Research Methods will be taught as a 3-credit undergraduate course during the Fall Semester, 2019. This course will be ES 3890 (ES for Engineering Science) and will be cross listed under each program in the college. The course will meet for 42 class periods of 50 minutes each. The initial course offering will be restricted to Engineering Honor's students. This course is not required for Engineering Honors.

The general goals for this course are: (1) to provide a general approach to scientific research and graduate school preparation, and (2) to prepare the students for the subsequent laboratory experience course, ES 4580 Undergraduate Research (again, cross listed across the college), course for Honor's students. These broad goals were then separated into individual learning objectives as reflected below.

Two required textbooks will be used for the course: *The Craft of Research* by Booth, Colomb and Williams[17], and *The Craft of Scientific Presentation* by Alley.[18] In addition, *On Being a Scientist: Responsible Conduct in Research* will be used for the research ethics discussion.[19] Lecture materials, assignments, and assessment tools will be posted on the course webpage at: [https://uwyo.libguides.com/honors\\_research\\_methods\\_es3890](https://uwyo.libguides.com/honors_research_methods_es3890)

Pre-course and post-course assessment is planned to determine self-reported levels of (for example) experience on various course elements, science attitude questions, and overall evaluation of the experience. The previously developed and validated Classroom Undergraduate Research Experience (CURE) Survey will be used for this assessment.[20] This tool is focused on the classroom aspects of undergraduate research. The objective is also to perform student self-assessment before and after the subsequent laboratory research experience course. This assessment will be conducted using the Survey of Undergraduate Research Experiences (SURE III) survey.[21] This tool is focused on the student's actual laboratory experience.

Pre- and post-course feedback from the students will also be obtained to develop the initial offering of the course and to refine future offerings of the course. When the Honor's program is fully implemented, the Honor's Students will take undergraduate research under a different course number than the standard, existing undergraduate research course number. As noted, this Theory and Methods course is not required for the Honor's program, although the subsequent Honor's research course is required. Thus, there will be three separate groups of

students performing undergraduate research: (1) conventional (non-Honor's) undergraduate researchers, (2) Honor's undergraduate researchers, and (3) Honor's undergraduate researchers completing this Theory and Methods course. This presents an opportunity to compare these groups of students and their desired outcomes (NSF REU applications and acceptances, summer research funding applications and acceptances, regional and national presentation abstract submissions and acceptances, graduate school applications and admissions). A data acquisition and tracking plan for this is being developed.

## **RESULTS AND DISCUSSION**

Two required textbooks are planned for the course: *The Craft of Research* by Booth and Colomb,[17] and *The Craft of Scientific Presentation* by Alley.[18] The Booth book is focused on developing research ideas, developing a research methodology, developing an argument through evidence and reasons, and writing up the research. The Alley book is focused on the presentation of the work through both poster and oral presentations. *On Being a Scientist* also provides a tool for discussing research ethics as a number of vignettes are presented which allow for a broad class discussion of the ethical issues, people involved, questions to ask, and possible solutions. This is available for free in .pdf form from the National Academy Press website.[22]

The planned class schedule for the initial course offering is shown in Table 1. Planned lectures fall into the following categories: (1) Finding your research interest and finding a mentor, (2) reading papers, and writing papers and proposals, (3) scientific methods for developing a hypothesis and research plan, (4) research ethics, (5) graduate school familiarity and applying for graduate school, (6) presenting your research plans, and (7) professional skills.

Table 1: Course Outline

Week	Class	Topic	Week	Class	Topic
1	1	Introduction/Syllabus	9	1	Research Ethics
	2	Why Undergrad Research		2	Research Ethics
	3	Finding a Mentor		3	Research Ethics
2	1	Holiday	10	1	Instructor out of town/guest
	2	Literature Searches		2	lectures/to be determined
	3	Reading the Literature		3	
3	1	Oral Presentations	11	1	What is graduate School?
	2	Oral Presentations		2	Finding a Graduate School
	3	Poster Presentations		3	Applying for Graduate School
4	1	Scientific Method	12	1	Careers with Graduate Degrees
	2	Scientific Method		2	Thanksgiving
	3	Scientific Method		3	Thanksgiving
5	1	Student Presentation	13	1	Research Notebooks
	2	Student Presentation		2	Research Notebooks
	3	Student Presentation		3	Citation Management Software
6	1	Student Presentation	14	1	Student Led Ethics Discussions
	2	Student Presentation		2	Student Led Ethics Discussions
	3	Student Presentation		3	Student Led Ethics Discussions
7	1	Undergraduate Research Opportunities	15		Final Exam week
	2	Proposal Writing			
	3	Proposal Writing			
8	1	Proposal Writing			
	2	Paper Writing			
	3	Paper Writing			

Assignments for the course and the objectives for each assignments are shown in Table 2. The student work for the course falls into the following broad areas: (1) Finding your research interest and finding a mentor, (2) reading papers, and writing papers and proposals, (3) scientific methods for developing a hypothesis and research plan, (4) research ethics, (5) graduate school familiarity and applying for graduate school, (6) presenting your research plans, and (7) professional skills.

Table 2: Course Assignments

Number	Topic	Skills/Concepts Reinforced
1	Finding a Mentor	Faculty/Student Interaction
	Research Interests	Self-Reflection
	Identifying Potential Mentors	Web research
	Meeting Mentors	Oral and Written Communication
2	Literature Search	Library, Written Communication, Literature Comprehension
	Find Relevant Papers	Library, Searching Skills
	Insert Into Reference Manager	Practical Skills
	Literature Synopsis	Written Communication
3	Presentation	Oral Communication, Research Methods, Scientific Method
4	Ethics Discussion	Oral Presentation, Research Methods, Library Skills
5	Seminar/Proposal/Defense	Written communication, Research Integration, Exposure to Graduate Expectations
6	Hypothesis and Research Plan	Scientific Method, Research Integrations, Written Communication
7	Laboratory Safety	Safe laboratory practices
8	Proposal	Library, Scientific Method, Written communication
9	Poster Presentation	Oral Communication, Scientific Methods, Literature Skills, Research Integration

Following an introduction lecture, two lectures will be devoted to understanding the benefits and results of undergraduate research together with finding a research mentor. This will be complemented with several assignments to help the students identify their mentor. First, a reflective statement will be used by the students to focus their research interests. This will be followed by identification of potential mentors across the college with student comments on the positives and negatives of each of their research interests. Finally, the students will meet with several potential mentors and then write a synopsis of each researcher and their project. This will conclude with the students deciding who their choice is and why that mentor was selected. A subsequent lecture later in the semester will discuss standard undergraduate research opportunities such as the university course, summer research programs, and NSF REU type opportunities.

An early lecture on literature searching and literature searching tools will allow the students to find manuscripts on their advisors work and related work. Once identified, the students will then write a synopsis on each paper and how it relates to or can be used for the student's project. Finally, to initiate research skills, the students will enter each manuscript into a reference manager.

While the above process of determining a research mentor and starting the literature process is ongoing, there will be two lectures on oral presentations and one on poster presentations. These lectures will provide practical examples to assist in subsequent development and delivery of both types of presentations. Three lectures will then be devoted to the scientific method. This will contribute to the student assignment to develop a research hypothesis and a research plan.

The first presentation will be an oral presentation by the students to present a synopsis of their literature search and how the literature can contribute to their research. This reinforces the earlier lecture on reading the literature. It also further develops the literature synopsis assignment. Finally, it will give the students their first practice at a scientific presentation. The goal is to keep these presentations short to allow for immediate feedback by the instructor and their peers.

After the above mentioned lecture on undergraduate research opportunities, students will select a funded research opportunity and complete a mock application. The goal is for the students to learn how to develop and write these applications, including a personal statement and a research plan. It is anticipated that the students will be encouraged to further develop and revise these proposals and then submit them under their mentor's guidance during the subsequent semester in their research course. To prepare the students for this work, three lectures will be devoted to proposal writing. Two subsequent lectures will cover writing papers. While the students are not far enough along to write up their research, thinking about writing papers and the structure of papers will contribute to learning about the research process and hopefully encourage them to think what work it will take to contribute to a future manuscript.

Three lectures will be focused on research ethics. "On Being A Scientist"[19] from the National Academies will be used for these lectures as it provides multiple theoretical research vignettes that can be used for class discussions. These lectures will be complemented by the student assignment to lead a research ethics discussion. Students will be paired-up or divided into small groups. They will then select a historical research ethics topic, perform a literature search, prepare a synopsis for the class, and then lead a discussion in the classroom to discuss the case and present alternative approaches to prevent future recurrences of the issues.

The instructor is typically out of town in late October or early November for a professional conference. This time will be filled with guest speakers or project time to work on their ethics discussion, proposal, or poster presentation. The students can also complete the on-line laboratory safety assignment during this time. The following four lectures will expose the students to graduate school, including "What is Graduate School," "Finding a Graduate School," "Applying for Graduate School," and "Careers with Graduate Degrees." This will cover topics such as: 1) the focus of graduate school is the research, not just more courses, 2) apply to a school where the faculty do research in your area and not just a big-name school, and 3) who should I get to write letters (with the implied goal of cultivating this letter writer while you are an undergraduate). This is complemented with a student assignment to attend a graduate seminar and either a proposal or final defense. This will expose students to the results of research at the graduate level and beyond. The assignment will be a reflection on the presentation with the student identifying similarities with topics covered in this course.

Post-Thanksgiving lecture topics will include research notebooks. The semester will conclude with the student led ethics discussions and the final poster presentation. The poster presentations will occur during the scheduled final exam time. For the poster presentation, all work from the semester will be combined. The students will present a short synopsis of their research mentor and their mentor's work. However, the main body of the poster will cover the student's research hypothesis and their research plan. This will also include contributions from the literature and how the literature influenced the plan.

Assessment plans are still developing. As noted the CURE survey will be used before and after this research methods course.[20] The goal is to then also use the SURE survey both before and after the subsequent laboratory research course.[21] As noted above, due to the different possible paths students (both Honors and non-Honors) can take through the curriculum, there is an opportunity to compare and contrast the experiences of these students. Tracking of the students in these different paths to quantify other metrics such as NSF REU applications, other summer research experiences, research funding applications, and applications and acceptances to present at regional and national conferences will also be used to assess the course. Finally, within the course, it is planned to have assessment of several of the assignments. The three likely targets for this are the presentation, proposal, and poster presentation. An interesting possibility is to assess the required presentation at the end of the laboratory research course and compare the students from this course with the students who did not take this course.

## CONCLUSIONS

As a work-in-progress, an undergraduate Theory and Methods of Research course is being developed for the Honor's program in our College of Engineering and Applied Science. The goal of the course is twofold, 1) to improve the quality of the subsequent laboratory research experience, and 3) to improve the competitiveness of applications for summer research programs, NSF REUs, research funding applications, participation in research conferences, and graduate school applications. This course will be offered for the first time during the Fall 2019 semester.

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