



Work in Progress: Preparing Students for Undergraduate Research Online and In the Classroom - Framework, Participant Reflections, and Lessons Learned

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Introduction

The science and engineering communities have identified benefits for students who participate in undergraduate research by integrating students into research projects either for academic credit or paid participation [Russell et al. 2007; Espinosa 2011]. However, there has been less written on how the engineering and science communities both prepare these students for research experiences (develops their research skills) and how to navigate the application process for research opportunities. This training is particularly important for students whose networks may not provide this navigational capital, such as first-generation college students and students from historically underrepresented minorities (Espinosa 2011; Bangera and Brownell 2014).

A scan of institutional websites revealed that many institutions provide pre-research and research skills development as individual seminars that focus on a specific skill (such as finding research articles) or on applying to particular research opportunities (such as Research Experience for Undergraduates programs funded by the National Science Foundation). Some institutions cluster these seminars into a series. Moreover, the National Science Foundation recently has invested in both developing coursework (EURO: Enhancing Undergraduate Research Opportunities, DUE# 1123068) and training faculty/staff on how to assemble pre-research coursework (DUE#1623697). These programs focused on teaching general research skills to undergraduate students instead of engaging them in disciplinary research activities (Burkett, et al 2013; Schneider, et al 2016). However, most existing programs do not provide robust training materials for pre-research and research skills development for beginning undergraduates.

While one of this paper's coauthors attended the workshop on assembling pre-research coursework held in 2017 (DUE#1623697), we did not initiate a formal pre-research program at Clemson until early Spring 2020. To support undergraduates impacted by the COVID-19 pandemic by cancelations or delays of their summer research positions or internships, the authors initiated an online research skills development series at Clemson University, a large public land-grant research university in the southeastern United States. This paper provides a high-level overview of the 'Research Foundations' program we developed and offered during the summers of 2020 and 2021. It also documents how we evolved this program into an academic course offered during the Fall 2021 and Spring 2022 terms. Finally, it presents our analysis of both applications and exit surveys from which we identify students who chose to participate in the program/courses, their reasons for participating, how the students perceived the value of the program at the close of the program, and how they perceived that the program helped them prepare for research participation.

Overview of the Research Foundations program

As outlined by others (Washburn and Bragg 2022), the stay-at-home orders enacted during the COVID-19 pandemic negatively impacted the training of university students through in person research experience or internship cancelations, closing of research laboratories, etc. In a limited number of cases, in person research experiences were transitioned to virtual when institutions had already developed models for remote workers such as some of the undergraduate research positions offered by Oak Ridge National Laboratories in Summer 2020. Therefore, we developed and offered a virtual pre-research seminar series called 'Research Foundations' to provide undergraduate students in engineering, computing, or science a significant, virtual opportunity related to research. In addition, we offered students the opportunity to earn an endorsement if they attended all the seminars and completed all the

activities designed to supplement the seminar topics. We used the term ‘endorsement’ strategically to acknowledge the skills gained by the participating students publicly rather than the term ‘certificate,’ which can only be used when a stand-alone organized series of courses are completed for a credential and the series has been approved at the university and state level. No fees were charged to students enrolled at the university or who were scheduled to participate in a canceled summer research program which would have been hosted by the university.

Using prior published studies, the program directors identified a series of learning outcomes designed to enable students to make decisions related to starting research experiences and pursuing graduate degrees. The stated learning outcomes were:

- *Explain what research is and identify members of the research community*
- *Explain the scientific method*
- *Identify pathways to seek undergraduate research experiences*
- *Create professional correspondence seeking research positions*
- *Communicate their experience and background in a professional manner*
- *Complete initial online safety and responsible conduct of research training*
- *Describe the required techniques for record-keeping and documentation during research projects*
- *Describe how research is disseminated through journal articles and conference presentations*
- *Describe pathways to pursue a research career and the application for advanced degrees in STEM fields*
- *Describe the importance of inclusion and diversity within the research community*

The seminar topics (Table 1) mirrored the professional development sessions often embedded in National Science Foundation Research Experiences for Undergraduates site programs. The articulated desired outcomes for program participants were that they would be able to articulate what research is and is not, identify how to apply to undergraduate research positions, master basic research skills related to safety training, responsible conduct of research and knowledge dissemination, and understand the benefits to obtaining advanced degrees in engineering, computing, and applied science.

Table 1: *Research Foundations seminar topics.* The number indicates the sequence in which the seminars were presented and, in some cases, modified during the evolution of these offerings.

Seminars	Summer 2020 (Cycle 1)	Summer 2020 (Cycle 2)	Summer 2021	Fall 2021	Spring 2022
What is research, and who are researchers?	1	-	1	1	2 (merged)
The scientific method and types of research (inquiry vs. problem motivated)	2	1			
What can you expect to do as an undergraduate research assistant?	3	2	2	2	1
Creating your resume to apply for research positions and drafting your initial emails to potential research mentors or program administrators	4	3	4	3	3

Applying to the Clemson Creative Inquiry program	5	-	3 (merged)	4	5
Applying to undergraduate research programs supported by NSF	6	4	3 (merged)	5	6
Basic online safety training before entering a laboratory at Clemson	7	4	5	6 (merged)	9 (merged)
Professional and ethical responsibilities for research	8	14		6 (merged)	9 (merged)
Tips for time management	9	-	6	7	7
Documenting your research in laboratory notebooks and on servers/cloud	10	8	7	8	8
Finding research articles	11	9		9	10
Reading research articles and understanding the peer review process	12	10	8	10	11
Disseminating research at conferences – poster and oral presentations	13	12		12	13
The how and why of technical writing during the research process	14	13	9		
Pursuing an advanced degree in a STEM field	15	15	10	14 (merged)	14 (merged)
Paying for graduate school	16	16	11	14 (merged)	14 (merged)
Applying for a National Science Foundation Graduate Research Fellowship	17	-			
Importance of inclusion and diversity within research	-	17		15	
Applying to the Science Undergraduate Laboratory Internships (SULI)	-	5	3 (merged)		
An infinite or a finite player: who do we want to be?	-	7			
LinkedIn	-	11			
Interview of a researcher with a Ph.D.				11	2 (merged)
How to write an abstract for a conference				13	12
Interview of a graduate student who is conducting research while pursuing their Ph.D.					4

Applications for and enrollment in the ‘Research Foundations’ program

To participate in the ‘Research Foundations’ program, we asked students to complete an application facilitated through an online survey platform (Qualtrics). Applicants were asked to provide demographic information (current major, academic class standing, and gender), to identify whether their summer plans were interrupted by the COVID-19 pandemic and, if so how, and to identify their motivations for participating: ‘*Why are you applying to be part of this workshop series? Let us know a little about you, your career plans, and what you are going to do this summer*’. The application also asked if they wanted to earn an endorsement by attending all the seminars (and associated assignments) offered in the series. Responses were analyzed to determine why students chose to participate in the program but not used as a filter for participation. That is, all students were allowed into the program.

Further analysis of applications showed that participants had undergraduate research experiences canceled, delayed, or transitioned to online; internships canceled, delayed, or transitioned to online; cancellations of summer study abroad programs, and voluntary separation from scheduled internships or undergraduate research programs due to family obligations in summer 2020 and 2021.

We had much interest in the program and many qualified applicants (Table 2). Interest was so high that we offered two program cycles during the summer of 2020.

Table 2: Overview of enrollment in the summer Research Foundations program and participant outcomes.

Term	Program or Course Offered	Number of applicants and participants
Summer 2020 (Cycle 1)	‘Endorsement’ awarded to students who participated in all seminars and completed associated assignments.	<ul style="list-style-type: none">• 145 students attended select Research Foundations seminars• 33 students applied/enrolled in the ‘Undergraduate Research’ program• 25 completed the ‘Undergraduate Research Endorsement’ program
Summer 2020 (Cycle 2)	‘Endorsement’ awarded to students who participated in all seminars and completed associated assignments. The ability to see select seminars was not offered in this cycle.	<ul style="list-style-type: none">• 28 students applied/enrolled for the ‘Undergraduate Research’ program• 15 completed the ‘Undergraduate Research’ program.
Summer 2021	‘Endorsement’ awarded to students who participated in all seminars and completed associated assignments.	<ul style="list-style-type: none">• 4 students attended select Research Foundations seminars• 29 students applied/enrolled or the ‘Undergraduate Research’ program• 15 students completed ‘Undergraduate Research’ program.

Presentation modality of the Research Foundations summer programs

We sent participants links to the seminars through a learning management system (Canvas) and hosted them on a virtual conferencing platform (Zoom). We organized the structure of the program and the students accessed and submitted the follow-up activities through Canvas. Students completing the ‘Undergraduate Research’ program reported spending between 3-10 hrs./week to participate in the virtual seminars and complete associated activities.

Assessment methods for the Research Foundations program

At the close of each summer program, we asked students to complete an online exit survey that included the following prompts:

- *In your view, what were the three most impactful skills or pieces of knowledge that you gained by completing this program?*
- *Are there any additional topics that you think should be covered if this program is offered again?*
- *Are there any seminars that you covered that you think should be removed from the program?*
- *How much time per week did this program take you to complete (hrs./week)?*
- *We are thinking about continuing this program during the academic year. Do you think that it should be kept as a workshop series or converted into an academic class?*

In Spring 2022, we sent [via email] a follow-up online survey to the participants who participated in either the 'Research Foundation' program (Summers 2020 and 2021) or course (Fall 2021). The brief survey asked respondents the following questions: (1) Which program or course did you complete?; (2) Did you participate in a research project after completing the 'Research Foundations' course or program?; (3) With whom did you complete research [Name, Department, Institution]?; (4) Reflecting on the topics presented in the 'Research Foundations' course or program, what were the most impactful components, assignments, or ideas?; (5) Did the 'Research Foundations' course or program impact your preparedness to begin conducting research?; (6) Did participating in 'Research Foundations' course or program change your perception of undergraduate research?; (7) How did your perception of undergraduate research change?; and (8) Reflecting on your experience of the 'Research Foundations' course or program, would you suggest other students participate in this experience?

Results of the assessment of students immediately after their participation

We received 21 responses to the exit survey in Summer 2020 and 4 responses in Summer 2021.

Reflecting on the experience, students identified the most impactful skills or pieces of knowledge that they gained through participation as: (1) what research is, (2) what doing research in a lab would be like; (3) learning how to present themselves for admission/acceptance into a research position through emails and resumes; (4) knowledge about the variety of research opportunities for undergraduates; (5) knowledge about graduate programs (admission, financial resources, research opportunities, types of program), (6) time management skills and utilization of existing resources and (7) the importance of inclusion and diversity within research.

Students enjoyed speaking with researchers about their experiences.

'Interactive conversations with experienced researchers about research - Don't lose this component. It's not really a direct skill or piece of knowledge, but it's the best means through which they're learned. () A holistic view of what research is, and an introduction to some of its many facets.'

'I really gained a look at what it would be like doing research in a lab.'

'The reason I took this program is because I am already a part of a research team and I wanted a better idea of how everything worked. Some of the modules didn't really apply to my situation but some were very helpful and informative. First, the courses that covered lab procedures and etiquette will help greatly once I begin my research. Also I have a much better idea of how to properly perform online research.'

'I also learned what to expect from undergrad research and got a ton of good advice on finding a professor to work with.'

Many comments also highlighted 'skill and methods used to conduct effective research' such as 'lab safety protocol' to 'writing technical papers' and 'keeping research notebooks'. Their comments also showed that the students were building their mastery of the common terminology utilized by the larger research community which should support their integration into this community after the course.

One student, who was nearing the end of their undergraduate program, also reflected that they learned how to describe prior research relative to REU and SULI experiences.

'I learned a lot about the differences and benefits of REU and SULI type programs. Unfortunately, I am too old to start them, but now I know what I am up against and how I can talk about how my research has been similar. Although it is discussed in other classes, hearing another lecture on how to be a leader is always welcome. It is especially vital in a lab setting. My resume was reviewed and improved in this class which I am very grateful for.'

Students appreciated gaining knowledge about graduate programs, paying for graduate school and tips to succeed once in graduate school, the graduate school application process, research positions in graduate school, and the funding process.

'The most useful information that I learned was about applying to grad school or research positions, notably how the system works, what to expect, and tips for the process. The sort of information not easily found online.'

'I also learned a lot about how graduate programs work as that was not an avenue I had even considered until this summer.'

While students identified that the program had a significant time commitment, most pushed back on removing any seminars. A typical response to this prompt was, 'I don't think any need to be removed because they all well addressed research and things that would be helpful to students.' However, a few students suggested that expansion of documentation from a physical lab notebook to discussing how to document computational or theoretical work.

'because I have found that some things don't really apply to a theoreticians lab notebook.'

'I do not work in a chemical lab, all of my work is outdoors so some of the information did not pertain to me.'

The response of the 'Undergraduate Research' program students in Summers 2020 and 2021 regarding offering the material as a course was varied, with some students opposed, some expressing mixed feelings, and others being for the conversion into a for-credit experience.

'An advantage to making this seminar a class is the opportunity to connect a lot more students with potential lab mentors and research partners on a larger scale, encouraging a stronger research academic community within Clemson.'

The course would provide a ‘recognizable credit’ for the time they put in, clearly communicate to students the time commitment they need to spend outside the seminars to finish work, provide students additional incentive to either start or finish the program, and allow the administrators to spend more time on each topic.

‘As far as the work involved, I think the format of this series already rivals a 3-credit hour class (easier than an average ME class, but still).’

However, the program facilitation was viewed by others to keep the stress lower than a formal class, allowed students at a high credit load already to still participate (not put them over the 21-credit limit), allow students who are not sure they are fully interested in research to participate, show to others that the student is going beyond a requirement. Finally, not making the summer offering a course, was seen as making the material accessible to all backgrounds.

‘Since the workshop is not a class, it shows that a student sought out an extra workshop and the free attendance as a workshop makes this accessible to all students of all backgrounds.’

Transitioning the ‘Undergraduate Research’ program into a 1-credit academic class

We transitioned the program into a 1-credit academic class in Fall 2021 and Spring 2022. We offered it to engineering, computing and science undergraduates interested in pursuing research. Despite using the same advertising efforts as we did during the pandemic, the enrollment in this class was unexpectedly small, with 10 students enrolling in Fall 2021 and 8 students enrolling in Spring 2022 (Table 3). At this time, we have not completed an analysis of the small enrollment numbers, however, the authors hypothesized that it may be influenced by the course time (Mondays at 9 AM), current focus on recruiting students with no research experience instead of those with limited research experience, and the relative utility of this course compared to those required for graduation for the undergraduates.

Table 3: Overview of enrollment in the summer Research Foundations program and participant outcomes.

Term	Number of applicants and participants
Fall 2021	<ul style="list-style-type: none"> • 17 students applied for the course • 10 students enrolled in the course (6 in-person and 4 online) • 9 students completed the course
Spring 2022	<ul style="list-style-type: none"> • 9 students enrolled in the course (no application required, all in-person) • 7 students completed the course

We required applications from students enrolling in Fall 2021. The applications required students to report any prior research experience, class standing, major and why they were interested in participating in the class. In Table 4, the responses of all applicants are compared to the students who enrolled in the course.

Table 4: Comparison of applicants to enrollees for “Research Foundations” course offered in Fall 2021.

Fall 2021 Course (1 Credit)		Applicants		Enrolled/ Completed	
Number of students		17		9	
Previously conducted research		No.	Percent	No.	Percent
	Yes	2	11.8%	2	22.2%
	No	15	88.2%	7	77.8%
Major of student	Biological Sciences	7	41.2%	6	66.7%
	Bioengineering	1	5.9%	1	11.1%
	Chemical and Biomolecular Engr.	1	5.9%	0	0.0%
	Chemistry	1	5.9%	0	0.0%
	Genetics & Biochemistry	3	17.6%	0	0.0%
	Microbiology	1	5.9%	1	11.1%
	Physics and Astronomy	1	5.9%	1	11.1%
	Psychology	2	11.8%	0	0.0%
Class standing	First year	2	11.8%	0	0.0%
	Second year	8	47.1%	3	33.3%
	Third year	3	17.6%	2	22.2%
	Forth year	4	23.5%	4	44.4%

Those students reported that they were applying to learn more about what research was, identify if participating in research should be part of their future, help find a research project or opportunity, and gain laboratory skills they missed during the transition of laboratories to virtual modes during the COVID-19 pandemic. This perhaps shows that, while there was a need for access to research skill programming when social distancing eliminated many in person research programs, this need has dramatically reduced as the pandemic protocols have shifted back toward normal. In addition, it may point to a preference by students for programming that is more flexible than a traditional class where they cannot ‘pick and choose’ topics. However, this may allow students inadvertently miss out on key topics needed for their future research endeavors. Due to the low enrollment in Fall 2021, we did not require an application for Spring 2022.

Due to the limitations in the semester’s length, we reduced the number of seminars as we transitioned the series into a 1-credit course (Table 1). This resulted in the merging of seminars related to safety, professional responsibilities, and ethical responsibilities into a single session, and merging information about financial resources for graduate school into the session related to pursuing advanced STEM degrees. However, we also added a new focus on interviewing researchers at the principal investigator and graduate student roles as a new seminar. In this activity, the enrolled scholars needed to find researchers in their own programs and then request interviews to ask the following questions:

- What is research and how it is related to knowledge?
- When did you start conducting research (high school, undergraduate, graduate student) and when you first 'feel' like a researcher?

- What is your favorite part of the research process (hypothesis generation, experimental design, dissemination, etc.)?
- How much time do you dedicate to research each week for research and what do you do (read articles, run tests, etc.)?
- What is your advice for a new researcher within our field?
- What has been one of your most rewarding research projects during your career and why?

This new seminar is based on the findings from Faber et al. 2021, which included a model of undergraduate research experience. This study identified the importance of reflective activities by undergraduates during research experiences and suggested having undergraduates interview established researchers about when they first felt like researchers, their training to become an established researcher within a field, etc.

Assessment to determine research preparedness after completing program or course

In total, 16 participants responded to the Spring 2022 follow-up survey request (4 from the course, 6 from the 'Research Foundations' program in Summer 2020, and 6 from the 'Research Foundations' program in Summer 2021). 85% of these respondents indicated that they would suggest other students participate in the program and 77.8% reported that it impacted their preparedness to begin conducting research. This was equal to the number of students who participated in research after the course (62.5%). 78.8% also reported that the program changed their perception of undergraduate research. When asked about how their perceptions changed, several students identified accessibility.

'...it is much more accessible than what you think.'

'Anyone can conduct undergraduate research. I thought it required more skills or certifications to conduct research.'

'I didn't realize how many "entry level" undergraduate research positions there were. I didn't have any research experience prior to this program and all of the opportunities seemed so daunting and required some level of experience.'

In addition to accessibility, another student wrote that participation normalized their view of undergraduate research.

'My perception of undergraduate research became more complete and normalized to others' experiences beyond my own.'

Discussion

To support undergraduates impacted by the COVID-19 pandemic, the authors initiated an online research skills development series at Clemson University. The initial response (high number of applicants) led the authors to transition offering the content as an academic course. Student responses in surveys indicate that this program changed the way students viewed the research enterprise and their opportunities. Surprisingly, the paper also documented a drastic change in the interest/participation in the 'Research Foundations' program from Summer 2020 to 2022. The reason for this has not been identified and could be due to changes in the environment (pandemic, etc.). Further work is needed to identify how to increase participation through updated advertising methods such as presentations at first year orientation sessions, utilization of email campaigns, presentation in first-year laboratory classes, etc.

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