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AAEA Agricultural & Applied Economics Association

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Applied Economics Teaching Resources

Applied Economics Teaching Resources (*AETR*) is an online, open access, and peer-reviewed professional publication series published by the Agricultural an Applied Economics Association (AAEA).

The aim is to provide an inclusive outlet for research, teaching and Extension education scholarship encompassing but not limited to research articles, case studies, classroom games, commentaries, experiential learning, and pedagogy. The goal is to support and advance teaching and Extension education within the scholarly areas of agricultural and applied economics, and agribusiness economics and management. AETR seeks to publish articles that are diverse in both scope and authorship. It serves as a platform for addressing and contributing to our understanding of important societal issues, including inequality and discrimination, as well as how shifts in pedagogy (e.g., growing reliance on remote and hybrid learning modalities) may impact accessibility and inclusion.

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Applied Economics Teaching Resources

AAEA Agricultural & Applied Economics Association

Research Article

Dare to Experiment: The Synergistic Relationship Between Undergraduate Research and Experimental Economics

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Abstract
Little attention has been given to the synergistic relationship that can exist between experimental economics research and undergraduate research experiences. In this article, we highlight the successes and challenges from working with more than 70 undergraduate research assistants at the University of Delaware's Center for Experimental and Applied Economics (CEAE) since 2007. We describe our approaches for funding and engaging undergraduate students and efforts, including our layered mentorship network, to support CEAE's mission to cultivate a diverse and inclusive research community. We present the results of a survey of CEAE's alumni to understand how their research experiences influenced their undergraduate education and their post-graduate educational and career endeavors. Synthesizing the reflections of students and the experiences of lead researchers, we outline ten key recommendations regarding how faculty and administrators in agricultural and applied economics programs can design and implement successful undergraduate research experiences, strengthening the pipeline of researchers in our field.

1 Introduction

The value of using economic experiments in the classroom has been acknowledged for decades in agricultural and applied economics (Barnett and Kriesel 2003), and in economics more broadly (Hoyt and McGoldrick 2019). However, little attention has been given to the myriad opportunities that exist for unique undergraduate research experiences in experimental economics labs. At the University of Delaware's Center for Experimental and Applied Economics (CEAE), we have found that engaging undergraduate students in experimental economics research studies outside of the classroom can produce win-win opportunities for students and researchers. Students gain experiential learning opportunities and often receive financial compensation, while researchers gain support for conducting experiments and benefit from fresh ideas, perspectives, and questions. CEAE has supported more than 70 undergraduate research assistants in the past sixteen years. In sharing the process that we have followed to foster undergraduate research, we aim to contribute ideas to a growing conversation about how to facilitate meaningful research experiences for undergraduate students in agricultural and applied economics.

Economic experiments offer many opportunities for student engagement in undergraduate research, including engaging students early in their undergraduate programs and for students from other disciplines. In other subfields of economics, opportunities for undergraduate research assistants may be more limited. In part, this is because researchers often struggle to find synergies between the knowledge and skills required to conduct research and the potential contributions of undergraduate students with limited training (Hoyt and McGoldrick 2017). In contrast, even students with little economics training can directly support certain aspects of developing an economic experiment (e.g.,

[1] Senior authorships are shared between Nelson-Poteet and Xie, and listed alphabetically. Messer and Palm-Forster are listed alphabetically.

programming and pre-testing) and collecting data. Students can also learn data analysis skills, learn about research administration and accounting in an academic setting, and/or gain experience communicating experimental results. Students develop more knowledge and skills over time and can handle increasingly complex research tasks. Additionally, having a cohort of undergraduate students all working on experimental projects allows for economies of scale in terms of mentoring and managing a team of research assistants (Hoyt and McGoldrick 2017). Experiments offer a unique platform for students to simultaneously be "learning economics" and "doing economics," much like community engagement projects have been used in other contexts (as described by Henderson 2016).

The goal of this paper is to highlight the opportunities, successes, and challenges in engaging undergraduate students in experimental economics research, and to provide insights and recommendations for researchers in agricultural and applied economics who are interested in developing undergraduate research experiences. To accomplish this goal, we surveyed past undergraduate research assistants to learn about the value of their experiences engaging in experimental economics research (e.g., conducting literature reviews, developing experimental programs, implementing lab and field experiments, and even co-authoring peer-reviewed publications). We also asked them to describe how their undergraduate research experience influenced their undergraduate education and the next steps in their professional lives. As a follow up to the survey, we conducted in-depth interviews with four former students to gain a deeper understanding of the findings from the survey and students' experiences with CEAE.

The vast majority (32 students, about 91 percent) of survey respondents were satisfied with their undergraduate research experience, and no respondents indicated any level of dissatisfaction (the other three students answered "neither satisfied nor dissatisfied"). The overall satisfaction came from how respondents felt about their work, the support they received, and the benefits they obtained. The majority of respondents (31 students, about 89 percent) felt their work was meaningful and that their thoughts and insights were valued by people working with them on the research. All respondents gained a better understanding of research, and the majority of respondents reported improved research skills such as explaining scientific concepts related to their work (27 students, about 77 percent) and summarizing scientific results/impacts (26 students, about 74 percent). Although most respondents' tasks were related to research projects, the research experience also improved respondents' professional abilities and skills. Respondents indicated that they improved their decision-making skills (33 students, about 94 percent), ability to work independently to problem-solve (32 students, about 91 percent), and knowledge of professional workplace expectations (32 students, about 91 percent). Working with CEAE also affected respondents' post-undergraduate life paths by increasing their interest in pursuing a career in applied economics. For instance, the CEAE experience prompted several talented students to remain at our university or join another program to pursue a graduate degree.

Based on our experiences as lead researchers and the results of the survey and interviews, we discuss the advantages and challenges of working with undergraduate research assistants, and we offer ten recommendations for faculty and administrators who seek to enhance undergraduate research by connecting them to experimental economics studies. These recommendations are reflective of CEAE's commitment to making research accessible to undergraduate students from diverse backgrounds with varying levels of economics knowledge and training. We also emphasize the value of engaging undergraduate students in their first or second year of study—the marginal net benefit of engaging undergraduates early in their program is higher than many assume and contributes to economies of scale and scope (Wagner 2015). Undergraduate research experiences increase students' interest in pursuing further education and careers in STEM fields; therefore, this approach is also designed to strengthen the pipeline of agricultural and applied economists.

2 Background

2.1 Background of UD's Center for Experimental and Applied Economics

Founded in 2007 as an experimental economics laboratory and formally named by the University of Delaware (UD) as an official "center" in 2014, the CEAE is based in the Department of Applied Economics and Statistics within the College of Agriculture and Natural Resources. The center has benefitted from investments from both the department and college in terms of space (the lab is approximately 2,000 sq. ft. and includes office space, a kitchen, and storage), equipment (computers, stationary and mobile lab facilities, and eye-tracking software), and staff (lab coordinator and research manager). Additionally, a large source of financial support for CEAE infrastructure and CEAE-supported research has been provided through external grants, such as those from the United States Department of Agriculture (USDA) and the National Science Foundation (NSF).

First and foremost, CEAE is an active and growing research community. The community is comprised of faculty, staff, postdoctoral researchers, graduate students, undergraduate students, and occasionally high school students who contribute to applied economics research studies. The CEAE leadership team includes the director, two staff members, and postdoctoral researchers, and the center is guided by an advisory council. CEAE's mission is "*to nurture a diverse and inclusive community engaged in innovative, evidence-based research and dissemination of results to inform policy and promote sustainability at the nexus of agriculture and the environment.*" CEAE fulfills this mission by training and mentoring students and early career scholars and by facilitating innovative experimental and applied economics studies. When we use the phrase "CEAE research," we are referring to research that has been supported by CEAE resources, which includes studies led by many affiliated researchers over the past sixteen years. Affiliated researchers include faculty, postdoctoral researchers, and students in the Department of Applied Economics and Statistics and other academic units across the UD campus. CEAE has also supported affiliated researchers beyond UD through the support of multi-institution-sponsored research projects.

Most of the research supported by CEAE uses laboratory and field experiments to study economic behavior impacting agriculture, the environment, natural resources, and rural/urban communities. This research informs the design of improved policies, markets, and products that benefit individuals and society. Affiliated researchers have conducted more than 130 studies, which have included more than 60,000 participants. Almost all of these studies have involved working with undergraduate students in various capacities, such as collecting data, reconciling expenses, and/or communicating the results via social media or other means. More than 100 faculty and PhD researchers at UD and researchers at more than 30 institutions have collaborated in research facilitated by CEAE. To date, these studies have resulted in more than 110 papers in peer-reviewed journals and have informed a chapter on experimental and behavioral economics for the *Handbook of Agricultural Economics* (Palm-Forster and Messer 2021) and a commissioned report for the National Academy of Sciences summarizing the application of behavioral economics to climate change policy (Messer, Ganguly, and Xie 2023). Affiliated researchers have also been active in professional meetings and have presented their research more than 450 times.

CEAE research has been repeatedly recognized by external funding agencies, such as USDA, NSF, National Oceanic and Atmospheric Administration, and U.S. Environmental Protection Agency. To date, the CEAE leadership has been a Principal Investigator or co-Principal Investigator on 77 grants worth more than $77 million, including Delaware's $23 million NSF-EPSCoR Track-1 project entitled, "Water in the Changing Coastal Environment of Delaware" (aka Project WiCCED) that started in 2018. Since 2014, CEAE has served as the co-headquarters of the USDA-funded Center for Behavioral and Experimental Agri-Environmental Research (CBEAR), which has twice been named a USDA Center of Excellence. In most of these grants, funds are budgeted specifically to hire undergraduate research assistants. We have

also found that having large, ongoing research projects has enabled us to readily tap into our university's internal internship programs such as those offered by the Delaware Environmental Institute (DENIN) and the Delaware Water Resources Center. The success rate for undergraduate students that we have sponsored to receive these internal sources is approximately 80 percent.

A layered mentorship program, called the CEAE Mentoring Network, supports our mission to cultivate an inclusive academic community of applied economics researchers. Since its launch in 2019, this program has evolved to emphasize layered and peer mentorship rather than one-to-one mentor-mentee pairs. Undergraduate and graduate students are assigned to mentorship groups, led by postdoctoral researchers. Within the groups, students are both mentees and mentors and engage in peer-to-peer mentorship. Participants are given some general guidance for engaging in the program, but groups are given the autonomy to structure their activities and interactions in a way that best supports the goals of the group. This independence was particularly important in 2020 and 2021 when many people were working remotely due to the COVID-19 pandemic and subsequently started transitioning back to campus. There are about 15–20 participants in the mentorship network each semester.

One way that we uphold CEAE's mission *to nurture a diverse and inclusive community* is through our approach to engaging and training undergraduate students as research assistants. Undergraduate research assistants have served in numerous roles within CEAE. Working collaboratively with graduate students, postdoctoral researchers, staff, and faculty, undergraduates have assisted with experiment programming, data collection, communications, and administrative support. The experiences of undergraduate research assistants can differ substantially depending on project timelines and student interests. Research assistants may support multiple aspects of the research process from experimental design through the communication of results. Some students lead undergraduate thesis projects, while others have more narrow roles in projects led by other researchers.

2.2 Pathways for Undergraduate Research

CEAE has established multiple pathways for undergraduates to engage with research. Students can begin working as research assistants via (a) our volunteer program, (b) academic-year or summer internship programs supported by units on-campus or via externally funded projects, (c) paid hourly positions, and/or (d) undergraduate thesis courses.

The CEAE volunteer program (aka the "CEAE talent pool") has provided a low-stakes entry point for students who are curious about research, but unsure if they want to commit to an internship or longer-term position. Volunteer positions also provide an opportunity for CEAE leadership to learn about the students, observe their work ethic and level of commitment to their role, and determine if they are a good fit for a paid position.

Internship positions have been a fruitful way to identify students with research interests across the university and beyond. We actively seek opportunities to partner with other units on campus to engage undergraduate interns with combined support from the university and from externally funded projects (as described above). We have also engaged with external programs that recruit students from other universities, including historically Black colleges and universities. These programs have added to the diversity of our undergraduate team and provided opportunities to learn from different perspectives. Additionally, because these internship positions are typically funded through programs outside of CEAE, they offer a mechanism to hire additional undergraduate research assistants without the need to raise additional CEAE funds.

Paid hourly positions offer a flexible option for hiring research assistants to perform various research support tasks. Generally, we have sought to pay interns approximately 20 percent higher than the prevailing wage on campus. Many of our paid hourly students started as volunteers, interns, or teaching assistants. Hourly positions allow us to retain outstanding students. As a student gains more experience in CEAE, their hourly rate increases (typically by semester).

Depending on the path through which a student is working with CEAE, they will have opportunities for training, mentorship, and professional development. Much of this training occurs through their experiences as an undergraduate research assistant as they learn on the job. Additionally, all students are invited to participate in the CEAE Mentoring Network. Students are also encouraged to gain experience communicating their research through poster sessions and research communication competitions (e.g., DENIN's Pitch90 competition[2]). Students supported by internship programs are typically invited to engage in a professional development series, which includes focused sessions on topics such as opportunities for graduate school. These students are also invited to present posters and/or talks in undergraduate research symposia that are held each semester and at the end of the summer.

3 Survey and Interviews of CEAE Undergraduate Research Assistants

3.1 Survey

To better understand undergraduate students' experiences working with CEAE, we developed a qualitative survey that collected information about students' backgrounds (e.g., major, undergraduate enrollment dates, and demographics), their responsibilities within CEAE, satisfaction and benefits gained from working with CEAE, life paths after graduation, and opinions on mentoring and diversity in CEAE. The survey consisted of 30 questions and took about 15 minutes to complete.

The survey was available on Qualtrics from June 28 to July 31, 2023. CEAE staff maintain a database of all previous undergraduate research assistants. Initial invitations were sent out to all 73 former students via emails and personal LinkedIn messages on June 28, and one reminder was sent out on July 12. After the survey was closed on July 31, we randomly selected five respondents who completed the survey and opted into the raffle to receive a $50 Amazon e-gift card (students were informed about this incentive in the invitation).

3.2 Interviews

In addition to the survey, four one-on-one, approximately 30-minute interviews were conducted with former undergraduate researchers in CEAE to help us gain a deeper understanding of the survey findings. All interviewees were paid $50 for their participation. The interview questions explored how and why the student got involved with CEAE, the benefits and challenges they faced during their time with CEAE, if working with CEAE influenced their perspective on applied economics and research, and if their experience impacted their post-undergraduate program life path.

Interviewees were selected in a manner that ensured a diversity of perspectives was represented. All four of the primary paths undergraduate students follow to work with CEAE were represented (teaching assistants recruited for paid hourly positions, summer interns, students completing an undergraduate thesis, and applicants to the CEAE talent pool). Both UD and non-UD students were represented, as were both economic and non-economic majors. A variety of skill sets were also represented, ranging from computer programmers to data collectors to designers of experiments.

4 Results

4.1 Survey

A total of 35 students completed the survey, resulting in a 48 percent response rate. The years respondents were enrolled in their undergraduate programs ranged from 2010 to 2023. The majority of the respondents (32 students, about 91 percent) studied at UD for their undergraduate program. The other three students (about 9 percent) were enrolled at another undergraduate institution during their time as a CEAE research assistant. About half of the respondents studied an economics-related major

[2] https://www.denin.udel.edu/pitch90/

(i.e., agricultural and natural resource economics, economics, environmental economics, or environmental and resource economics). The other half of the respondents studied non-economics majors (e.g., accounting, biological science, and gender and women's studies). Nineteen respondents (about 54 percent) identified as female, and the remaining 16 respondents (about 46 percent) identified as male. A majority (24 students, about 69 percent) of respondents identified as white or Caucasian. Only one respondent was an international student. This is similar to the general enrollment profile within UD's College of Agriculture: as of 2022 Fall, 70 percent of undergraduates were female, about 71 percent were white, and 3.1 percent were international students.[3]

The most common responsibility of the respondents was data collection, with 29 students (about 83 percent) reporting they collected experimental data at some point during their time with CEAE (Figure 1). Respondents were commonly tasked with multiple responsibilities, with 27 students (about 77 percent) indicating that they had at least two responsibilities. Data collection (i.e. collecting experimental data) was commonly combined with two other tasks for students: experimental design and/or collecting background information (e.g., reviewing relevant literature and collecting news articles). In particular, 19 students (about 54 percent) collected background information in addition to collecting data, 13 students (about 37 percent) assisted in experiment design in addition to data collection, and 11 students (about 31 percent) engaged in all three tasks. Combining responsibilities helps research assistants better understand their research projects and communicate with research participants during data collection.

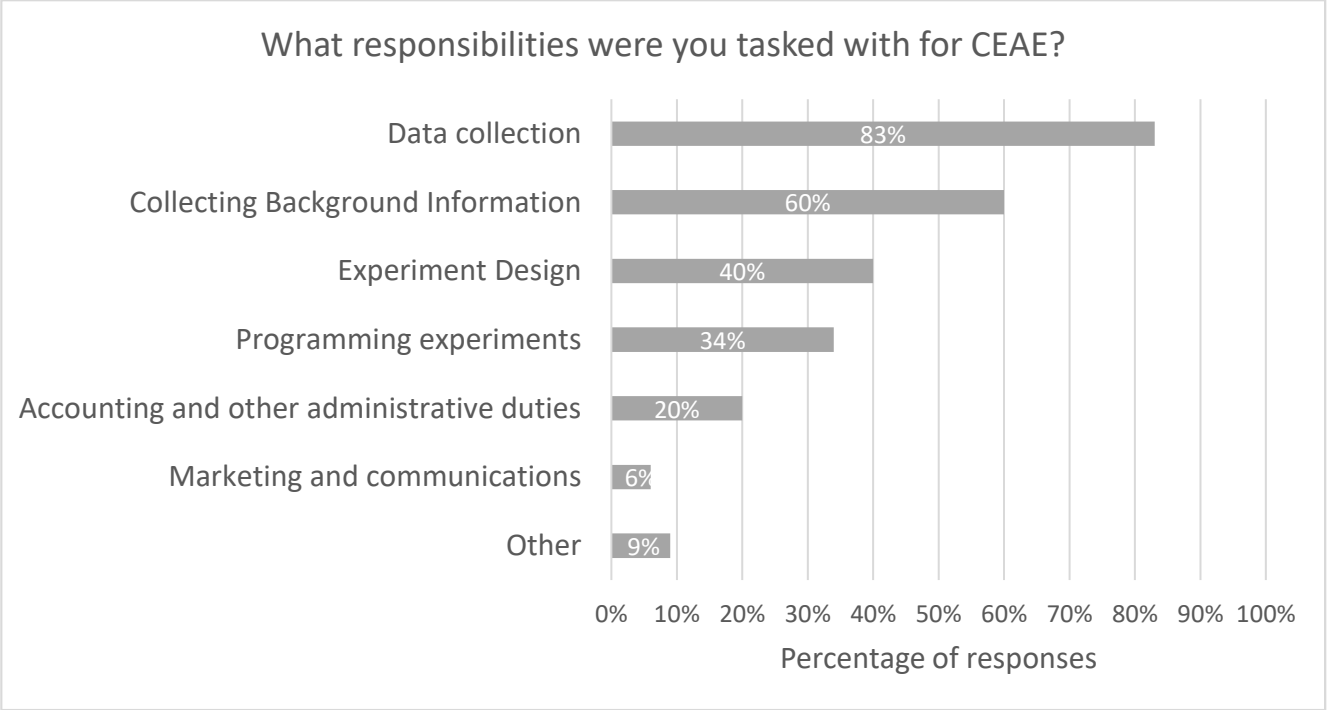

Figure 1: Responsibilities That Research Assistants Were Tasked with at CEAE.

[3] Source: https://ire.udel.edu/ir/diversity/.
https://bpb-us-w2.wpmucdn.com/sites.udel.edu/dist/e/2019/files/2023/01/29-ugdiversity_college_2022-23.pdf

The majority (30 students, about 86 percent) of the respondents were paid for their work at CEAE at some point, and of the 30 respondents who were paid, most (28 students, about 93 percent) were either somewhat or extremely satisfied with the compensation they received. This is consistent with our philosophy of trying to attract exceptional students and retain them as we consistently sought to pay hourly wages that exceeded other jobs on campus by approximately 20 percent. Among the remaining five respondents who were not paid, one respondent received course credits and the other four were volunteers. In addition, many respondents worked on a team with other undergraduates and talked to other undergraduates working for CEAE. Some research assistants (18 students, about 51 percent) also helped recruit and train new undergraduate research assistants.

A major focus of the survey was to understand undergraduate research assistants' satisfaction and perceived benefits from working with CEAE. The vast majority (32 students, about 91 percent) of the respondents were satisfied with their experience in CEAE, and no respondents indicated any level of dissatisfaction. Twenty-one students (about 60 percent) were extremely satisfied with their experience, and 11 students (about 31 percent) were somewhat satisfied. The other three students (about 9 percent) reported being neither satisfied nor dissatisfied. Most respondents thought that the project(s) they contributed to would advance the field of applied economics (27 students, about 77 percent) and have real-world impacts on practices and policies (29 students, about 83 percent).

Overall satisfaction with their undergraduate research experience may come from how respondents felt about their work, the support they received, and the benefits they obtained. As shown in Figure 2, the majority of respondents agreed that the work they specifically did was meaningful (31 students, about 89 percent), their thoughts and insights were valued (31 students, about 89 percent), they were respected and valued (30 students, about 86 percent), and their tasks required problem-solving and critical thinking (32 students, about 91 percent). Fewer (21 students, about 60 percent) respondents agreed that they had input on the direction of the project. This is not surprising because undergraduate researchers support the Principal Investigators for projects, who are typically faculty, postdoctoral researchers, and graduate students. Respondents indicated that they received effective support from CEAE leadership (directors, postdocs, and staff) and affiliated researchers in balancing their research assignments with their class work, physical and mental health, and social life.

Working with CEAE provides undergraduate research assistants with opportunities to have a better understanding of research and gain research skills (Figure 3). Research experience with CEAE improved all respondents' understanding of the research process. This can be partially attributed to the fact that most respondents (27 students, about 77 percent) were tasked with multiple responsibilities throughout the research process and engaging in multiple stages of research projects. The majority of respondents improved their ability to explain scientific concepts related to their work (27 students, about 77 percent) and summarize scientific results/impacts (26 students, about 74 percent). As undergraduate research assistants in CEAE usually work in a research team, they learn how to explain scientific concepts and summarize scientific results from discussions with their team members. Twenty-four students (about 69 percent) improved their skills in delivering an oral presentation or developing poster presentations. Undergraduate research assistants who were funded through internships usually delivered a poster or oral presentation at the end of their internships—this provided them with opportunities to learn and improve presentation skills. However, not all undergraduates (particularly those with limited hours and responsibilities) have opportunities to present research in poster or oral presentation formats.

Compared to understanding, abilities, and skills related to research, respondents' professional abilities and skills experienced even more growth (Figure 4), along with their collaborative skills (Figure 5). The majority of respondents agreed that their research experience with CEAE improved their decision-making skills (33 students, about 94 percent), ability to work independently to problem-solve (32 students, about 91 percent), knowledge of professional workplace expectations (32 students, about

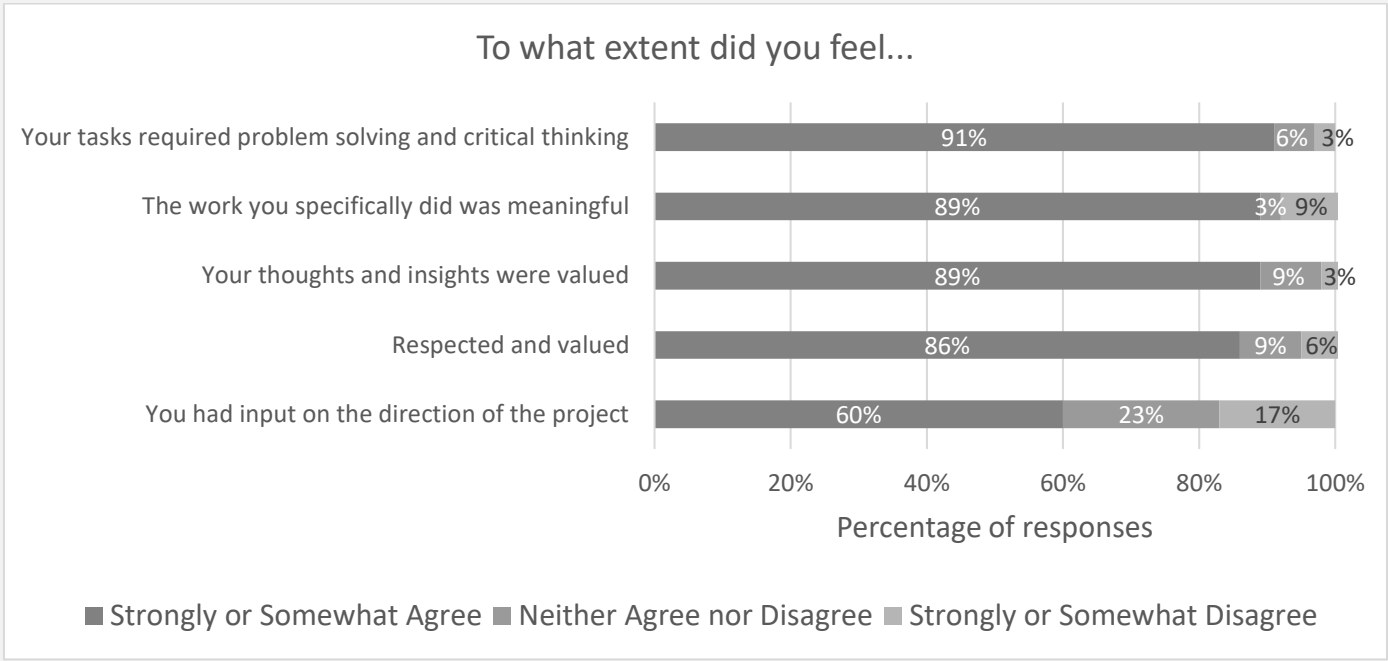

Figure 2: Undergraduate Students' Research Fulfillment in CEAE.

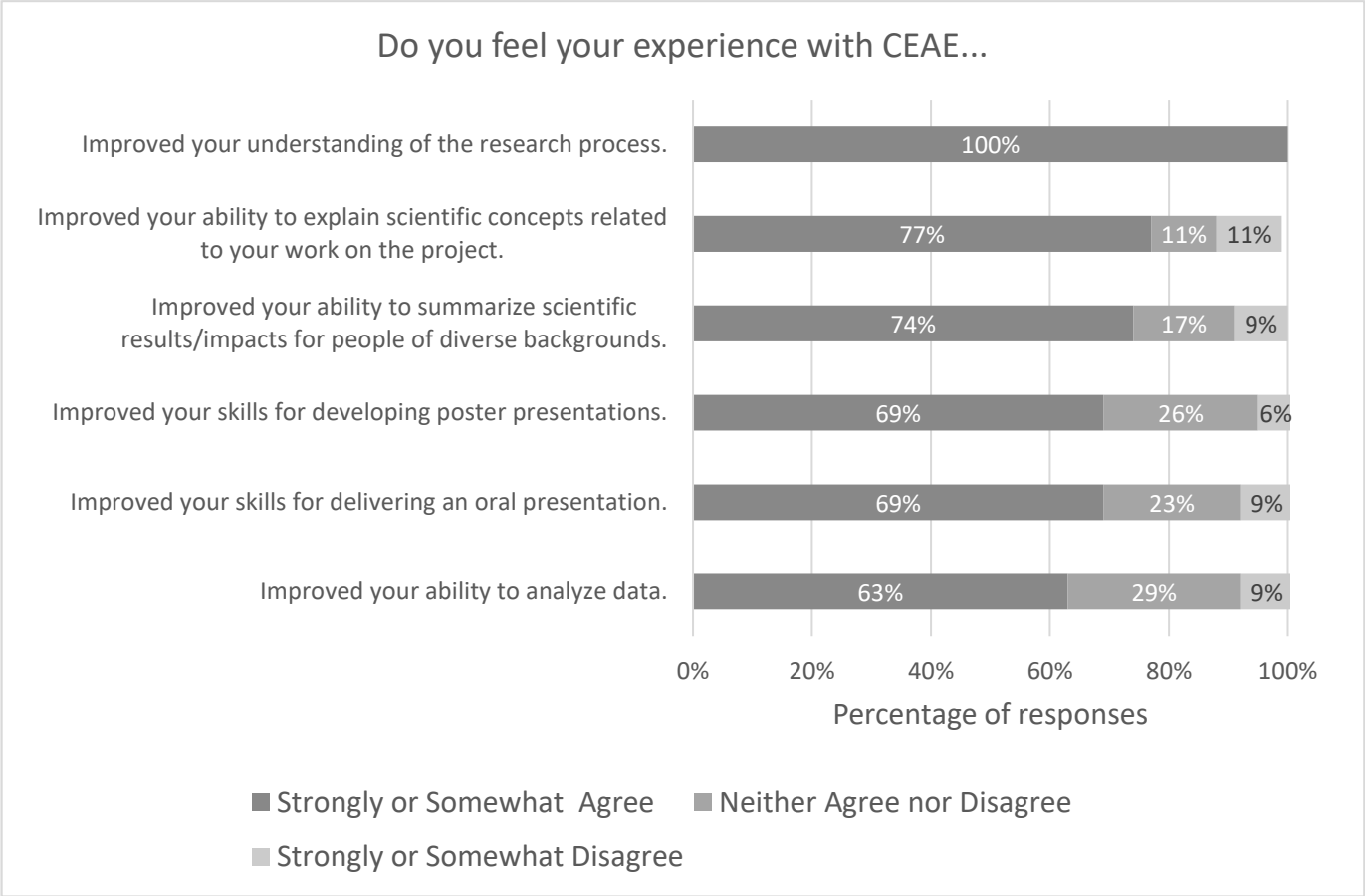

Figure 3: Research Skills Developed by CEAE Undergraduate Students.

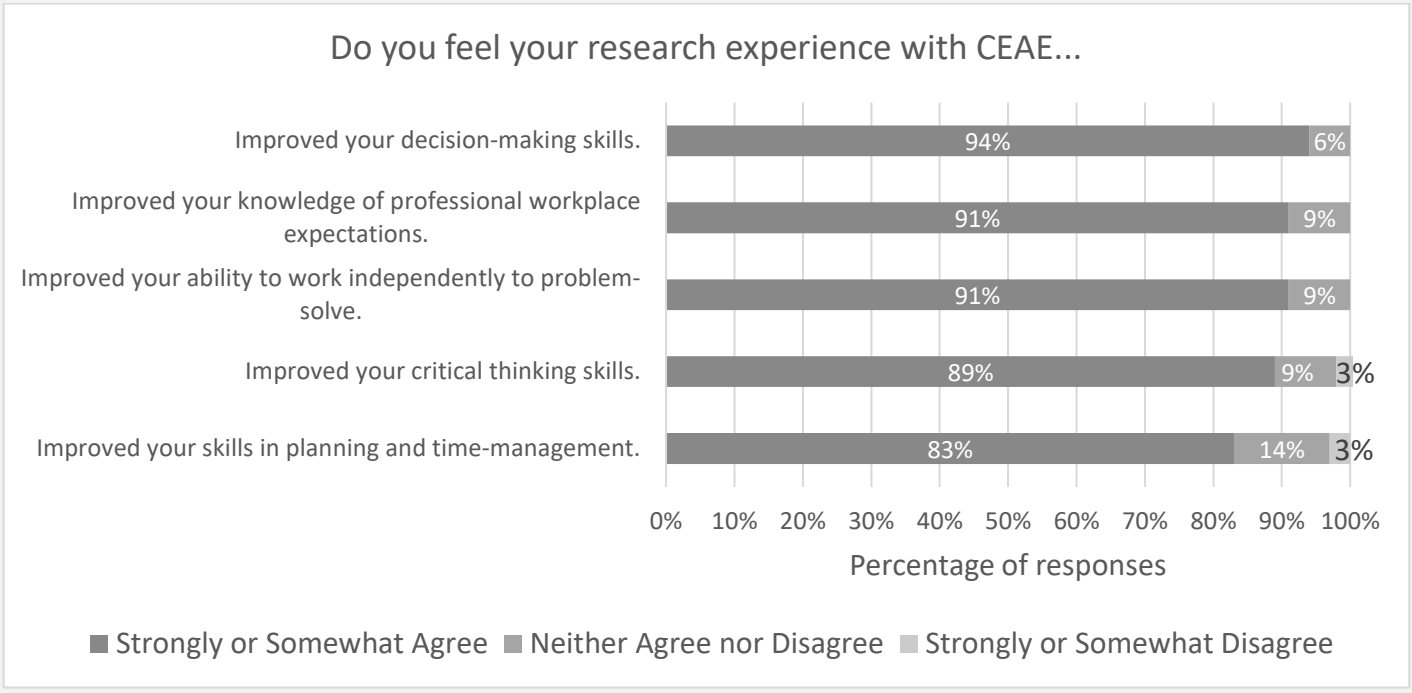

Figure 4: Professional Skills Developed by CEAE Undergraduate Students.

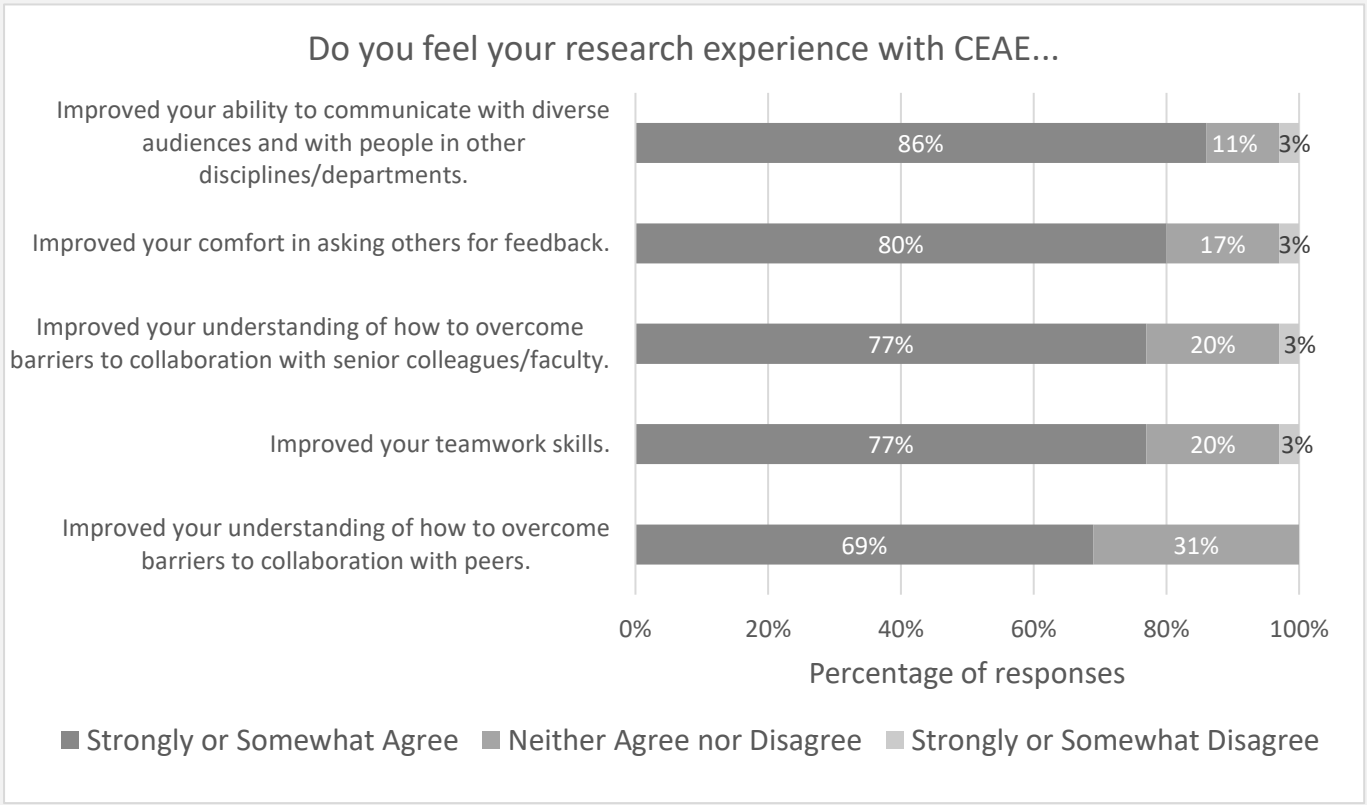

Figure 5: Collaborative Skills Developed by CEAE Undergraduate Students.

91 percent), critical thinking skills (31 students, about 89 percent), as well as planning and time-management skills (29 students, about 83 percent). A high portion agreed that their research experience with CEAE improved their professional skills related to communicating with diverse audiences (30

students, about 86 percent), seeking feedback (28 students, about 80 percent), teamwork (27 students, about 77 percent), and overcoming barriers to collaboration with senior colleagues (27 students, about 77 percent) or peers (24 students, about 69 percent). These findings show that, although their tasks were research project-oriented, undergraduate students gained professional skills by working as research assistants under professors and postdocs. They can apply those skills (especially those related to independent working) to their career. Even though research projects involve collaboration and teamwork, most routine tasks are conducted independently. That is likely the reason why respondents gained more skills and abilities working independently than working with their team members.

As introduced above, the CEAE Mentoring Network supports CEAE's mission to cultivate an inclusive academic community of applied economics researchers through a "layered mentoring" format. In the survey, we asked whether respondents received and/or provided mentoring. Twenty-six students (about 74 percent) received mentoring, 9 students (about 26 percent) provided mentoring, and 8 students (about 23 percent) were not involved in mentoring. Eight students (about 23 percent) both received mentoring and provided it. Compared to postdoctoral researchers and graduate students in the mentorship network, undergraduate research assistants are juniors and therefore mostly received mentorship from other members in their mentorship groups. Since the "layered mentoring" format also includes peer-to-peer mentorship, we see that a small portion of respondents also provided mentoring.

CEAE leadership invests in initiatives to increase diversity within the CEAE community, including recruiting diverse members (e.g., undergraduate research assistants, graduate students, postdoctoral researchers, and research participants); supporting a layered mentorship program; investigating research questions related to diversity, inclusion, and equity (e.g., environmental justice); and collaborating and building partnerships with diverse communities and institutions. To understand undergraduates' perceptions of the effectiveness of these efforts, we asked respondents to indicate which of these actions have contributed to improving diversity in the field of applied economics (Table 1). Respondents indicated that CEAE has contributed to improving diversity mainly through recruiting, especially recruiting undergraduate research assistants and graduate students. Recruiting postdoctoral

Table 1: Avenues for Promoting Diversity in CEAE and Applied Economics.

In what ways has CEAE contributed to improving diversity in applied economics?	Number of Selections
Recruiting Undergraduate Research Assistants	30 (~86%)
Recruiting Graduate Students	25 (~71%)
Recruiting Postdoctoral Researchers	18 (~51%)
Collaborating and Building Partnerships with Diverse Communities and Institutions	16 (~46%)
Recruiting Research Participants	15 (~43%)
Investigating Research Questions Related to Diversity, Inclusion, and Equity (e.g., Environmental Justice)	14 (40%)
Layered Mentorship Program	8 (~23%)
CEAE Has Not Contributed to Improving the Diversity of the Field of Applied Economics	2 (~6%)
I Am Not Sure	3 (~9%)

researchers and research participants, as well as collaborating and building partnerships with diverse communities and institutions are other approaches that respondents felt CEAE was taking to promote diversity in applied economics. Seven respondents (20 percent) indicated that they were "unsure" if CEAE supported diversity, indicating that there may be value in more clearly communicating with undergraduates about why it is important to promote diversity in our field and what efforts CEAE takes to contribute to this effort. Three of the seven respondents (about 43 percent) who selected "unsure" worked in CEAE for only one semester. For comparison, of the 28 respondents who indicated CEAE supported diversity, only four (about 14 percent) worked for one semester in CEAE. This result suggests that differences in awareness may be related to how long the student engaged with CEAE.

We further asked whether respondents felt that CEAE leadership (directors, staff, and postdocs) was both supportive of people from diverse backgrounds and appreciative of the diverse perspectives contributed by respondents. The majority of respondents (28 students, 80 percent) felt that CEAE leadership was supportive of people of diverse backgrounds. Respondents were also asked whether they felt their diverse perspectives were appreciated. About a quarter of respondents (9 students, about 26 percent) selected "unsure," which we expect may indicate that either they did not believe the question applied to them or could not recall.[4] Of the 26 respondents who definitively answered the question, 25 selected "yes" and one selected "no."

We also sought to understand whether and how the benefits that undergraduate research assistants gained from working with CEAE carried over to their next stages in their professional life after their graduation. For this analysis, we considered responses from the 34 survey participants who no longer attend an undergraduate program. Thirty-one out of 34 respondents (about 91 percent) have had a job placement after their undergraduate program, and they currently have a job placement today. Among these 31 respondents, fifteen (about 48 percent) pursued graduate studies (master's or PhD) immediately after their undergraduate programs, and another third took jobs in the private sector (12 students, about 39 percent of all respondents). Among the 23 respondents who have a current job placement that does not include graduate study, positions cover a wide range of sectors from the private sector (12 respondents) to the public (10 respondents) and nonprofit sectors (1 respondent). Their placements represent the general job placements of students in UD's College of Agriculture and Natural Resources.[5]

Although many factors contribute, we asked whether working with CEAE affected respondents' life path decisions after graduating. Most respondents found that their experience with CEAE: (1) increased their interest in pursuing a career in applied economics and (2) helped clarify both the field they wanted to study and if graduate school was a good choice for them. Specifically, we asked for the respondents' likelihood of pursuing the education and career options before and after working with CEAE. CEAE experience made undergraduate research assistants more interested in further exploring applied economics, on average (Figure 6). This effect was greatest with those originally with a low likelihood of pursuing education and career options in applied economics. In particular, 13 out of 23 (about 57 percent) respondents who were originally unlikely to pursue graduate education in applied economics changed to somewhat likely or very likely after working with CEAE. Twelve out of 22 (about 55 percent) respondents who were originally unlikely to pursue graduate education in applied

[4] One such respondent stated at the end of the survey, "I enjoyed my work with CEAE, but it was a long time ago so I don't have the best memory when it comes to management and leadership."

[5] We planned to compare placements of CEAE students to placements for agricultural and applied economics students in general; however, we could not find data about the overall placements of undergraduate students in our field. Over 25 years ago, Zepeda and Marchant (1998) recommended that collecting and communicating placement data could improve enrollment and increase diversity in agricultural economics programs by strengthening recruitment efforts and supporting students' career preparation and expanding their professional networks. Collecting this data is also imperative if we want to examine how focused educational initiatives (e.g., undergraduate research programs) impact placement outcomes.

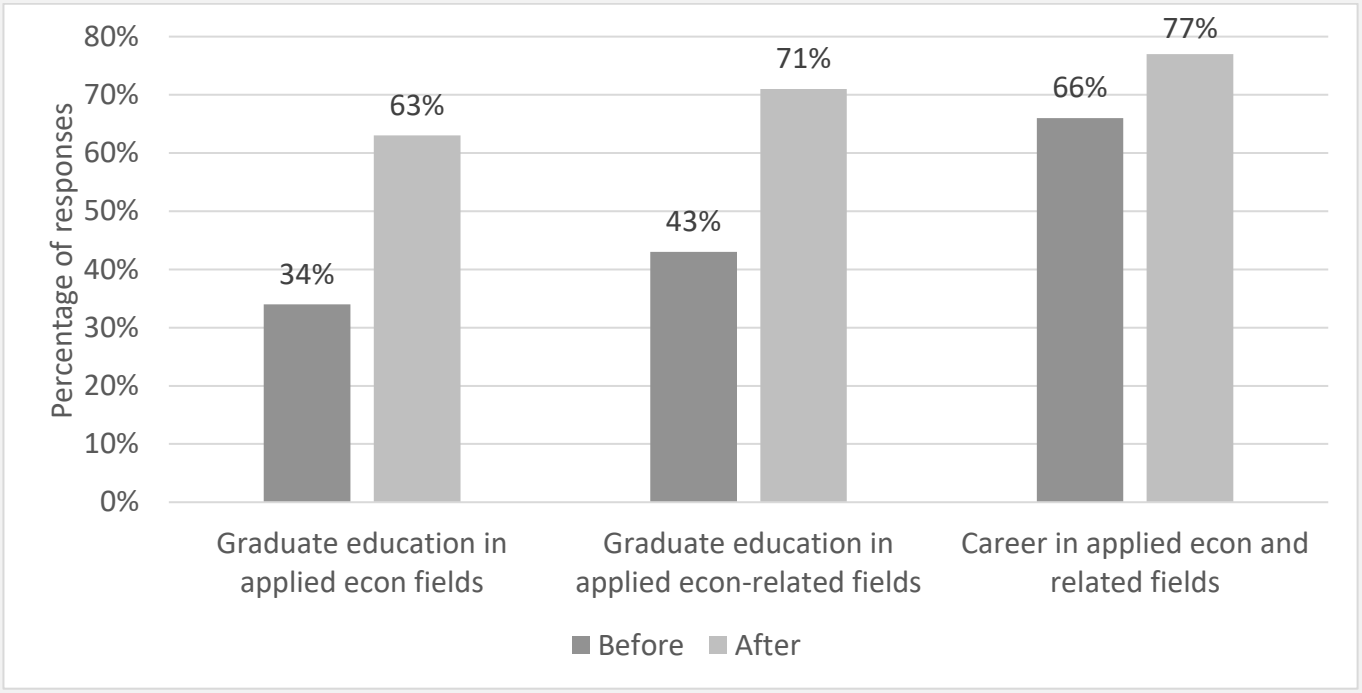

Figure 6: Percentage of Respondents Indicating They Were "Somewhat Likely" or "Very Likely" to Pursue Graduate Education and Careers in Applied Economics Before and After Working with CEAE.

economics-related fields changed to somewhat likely or very likely. Six out of 12 (50 percent) respondents who were originally unlikely to pursue a career in applied economics or related fields changed to somewhat likely or very likely. All undergraduates who originally felt they were very likely to continue engaging with applied economics felt the same way after their experience.

4.2 Interviews

High levels of satisfaction with undergraduate research experiences in CEAE were reported in the interviews, and these results were consistent with the high level of satisfaction that was reported in the broader survey. Interviewee #1 was a programmer hired through a job listing while attending a local technical community college. The student later transferred to UD and then worked at UD after graduating. Interviewee #2 was a research assistant recruited through the talent pool studying an economics-related field at UD while working with CEAE. They double majored in two economics degrees, completed an undergraduate thesis, and entered the private sector after graduating. Interviewee #3 was a research assistant recruited due to their work as a Teaching Assistant who studied an economics-related field at UD while working with CEAE. They attended graduate school in an economics-related field at UD after graduating. Interviewee #4 was a research assistant recruited through an internship listing who studied a non-economics-related field at a different university than UD while working with CEAE. They entered the workforce after graduating but are likely to attend graduate school (potentially to study an economics-related field) in the future.

One major theme that emerged was the value of hands-on exposure to applied economics and research. The experience of actively doing the work seemed to have a large impact on the way students understood and felt about applied economics. Interviewee #3 shared that, "*doing the hands-on work…. [was how I] got really interested in applied economics, because I was actually teaching it rather than just learning it,*" and interviewee #4 explained that their CEAE experience showed them, "*the field of economics was much broader than what I envisioned.*" They went on to say their CEAE experience "*was*

really key to me understanding what the research process was like. Really participating in the data collection process gave me a new understanding of what it takes to collect data."

Even for students with a strong economic background, the additional exposure seemed beneficial. As interviewee #2 (who double majored in two economics degrees) shared, "*When you are in class learning about these things it is all theory, you are not really applying any of it. When you are doing these experiments, you interact with participants in studies and get to realize that the theories can be true. You get to apply it to real life.*" The students seemed to desire such an experience even before their time with CEAE, as all of them listed gaining experience as a reason they chose to work for CEAE.

In addition to experience and pay, all interviewees reported gaining new skills. The skills ranged from economic measurement techniques to programming skills depending on the job they held, but all of them reported being given tasks that required them to learn new skills. Interviewee #4 also spoke at length about the confidence the new skills and experience gave them, saying, "*I came back [to college] confident and reinvigorated. That was something the professor I had been [previously working on research with] thought was really cool, and so she brought me on to do another project because she thought I grew a lot as a researcher. That was definitely an influence from [CEAE]. More broadly, when I was looking for jobs after undergrad, I felt very confident that I wanted to do research and I can very, very specifically say that it was because of [CEAE]. It was not just that I had experience, it was that I had such a positive experience at the Center[CEAE] that I felt like I wanted to keep doing that.*"

Interviewees also appreciated the process CEAE uses to grow students' professional skills by involving them in multiple aspects of research. Interviewee #2 said "*Starting off I think you are given more simple tasks and, if you are able to handle it, [you are given more tasks]. For me, back when I first started in the talent pool, it was mostly data collection stuff and then we progressed…[later]. I was able to do more planning of the experiment and data collection. Going into senior year I started doing more data analysis.*" Interviewees discussed how their tasks forced them to learn or expand their professional skills. Interviewee #1 mentioned that the programming experience and work made them "*better as a programmer just working and doing the stuff that they wanted me to do. I had to do stuff I would never have done before from a programming standpoint.*" Interviewee #4 commented that their time with CEAE "*was really key to me understanding what the research process was like. Really participating in the data collection process gave me a new understanding of what it takes to collect data.*"

All interviewees identified CEAE as influencing their post-undergraduate life path to some degree and the connections that students made at CEAE played a key role in shaping life paths. Interviewee #3 decided to stay at UD for graduate studies to continue working with CEAE-affiliated professors. Interviewee #1 felt the connections they made through working with CEAE helped them obtain their current position. Interviewee #2 cited the professional experiences as being key to getting future positions. Additionally, interviewees #2, #3, and #4 shared that exposure to graduate students, and graduate student work helped clarify if they wanted to go to grad school, at least for applied economics.

All interviewees still use at least some of the skills and perspectives they obtained/honed with CEAE. Interviewees #1 and #3 reported still using general people skills such as being comfortable talking to strangers or being comfortable leading and mentoring. Even interviewee #2 (who now works in an unrelated field) reported that their exposure to applied economics has "*influenced my perspective on current events… learning about incentives has changed my perspective on what goes on in the news.*" Other students more directly apply their experience. Interviewee #3 shared an anecdote, saying, "*I lead a monthly office hours and the topic [the week of this interview] was about behavioral economics. I actually used part of a presentation I made for the Center [CEAE] and presented it as a learning session.*"

CEAE's outreach/overlap with other programs both at and outside of UD was the reason all interviewees found CEAE at all. Interviewees #2 and #3 found CEAE by taking elective courses taught by CEAE-affiliated professors. Interviewees #1 and #4 found it through job/intern listings at other universities. A bonus of this undergraduate recruitment technique is that a more diverse group of academic interests is reached than if only students already involved in applied economics were

contacted. At least among the interviewees, the main reason they had not engaged with applied economics research before joining CEAE was a lack of exposure. Focused recruitment efforts outside of economics enhance the diversity of students and the perspectives they share, which enriches undergraduate research experiences and supports stronger, more thoughtful research.

5 CEAE Leadership Reflections and Recommendations

Through reflection on our experiences developing and engaging with the CEAE undergraduate research program, we highlight several key advantages and challenges associated with undergraduate research in applied economics. Additionally, we offer ten recommendations for developing effective programs that offer benefits to both students and the lead researchers.

Advantages:

- *Educational Alignment:* Incorporating undergraduates in research roles is more than just practical—it reinforces the educational vision of our institution. Research is an integral component of higher education, and by involving undergraduates, we foster an environment of inquiry and innovation.
- *Beneficial Outcomes for Students:* Multiple studies have illuminated the positive outcomes for undergraduates who immerse themselves in research (Russell, Hancock, and McCullough 2007). Engaging in real-world projects cultivates critical thinking, problem-solving, and teamwork skills. Notably, minority and first-generation students often experience amplified benefits, including bolstered self-confidence and heightened academic achievement.
- *Cost-Effectiveness:* Engaging undergraduates often represents a prudent financial choice. Compared to the costs associated with employing graduate students, postdocs, or staff, undergraduates offer an affordable yet effective alternative for many research tasks.
- *Scalability*: Conducting field experiments, especially in large festival-like settings, often requires assembling a large team of people who can work on these projects. Being able to hire a group of undergraduates to conduct this research can be quite helpful and can extend the reach of graduate students, postdoctoral associates, and faculty.

Challenges:

- *Skill Gap:* Undergraduates, though enthusiastic, often enter our program without advanced skills in experimental design, data analysis, or academic writing. This necessitates dedicated training sessions and close supervision.
- *Training Overhead:* With the regular admission of new undergraduate students into our research team, there is a recurring need for orientation, training, and mentoring. This continual onboarding can be time-consuming and requires dedicated resources to ensure that students are well-equipped for their roles. One of our recommendations is to hire students early in their first two years of undergraduate study so that they can help train future undergraduate students.
- *Turnover Rate*: Given the transient nature of undergraduate education, there is an inherent turnover as students graduate or move onto different opportunities. This necessitates consistent recruitment and transition processes to maintain continuity in research projects.
- *Unrealistic Expectations:* Some students who are inspired by the environmental and socially engaged research that is conducted in CEAE are disappointed to find themselves standing outside on a hot day recruiting study participants or being inside on a computer entering data or reconciling receipts for participant support. While necessary, these tasks are not as exciting as students may have hoped. To help this situation, we have often hired students majoring in accounting to work on the logistical elements as they seem more content with these tasks. We also have found that students who hold leadership positions in student organizations are

particularly good at collecting data and engaging potential participants, as they tend to be extraverted and pay attention to small logistics that can make a good experiment (or party). to capitalize on these advantages and to address these challenges, we have developed the following ten recommendations that again come from our experiences and our approach to creating a synergistic undergraduate research program. Whenever possible, we have highlighted the recommendations that were also directly supported by the data collected from CEAE alumni.

1. **Do not underestimate the skills of the top undergraduate students.** Top-tier undergraduate students frequently perform on par with, if not exceeding, the capabilities of many graduate students, staff, and even postdocs in a diverse array of tasks. Yet, undergraduate students cost dramatically less, and engaging them in research contributes to their own personal and professional development and strengthens the pipeline for our field. From our survey responses, we saw that respondents were commonly tasked with multiple responsibilities, showing that they were capable of conducting various tasks for research projects, from administrative and accounting duties to experimental design. In addition, interviewee #2's senior thesis contributed to a research paper.

2. **Develop a volunteer program ("talent pool").** To improve talent identification, offer opportunities for undergraduate students to engage in research on a volunteer basis. This initial phase serves as an evaluative period, allowing both the students and the research team to assess mutual fit. It also allows students who are interested to get involved mid-semester, even when existing funds have been committed to others. Second, use this talent pool for selecting candidates for future funded positions. This method not only streamlines the recruitment process but also ensures a higher likelihood of engagement and productivity from those who transition from volunteer roles to funded positions. Interviewee #2's experience was a successful example of the talent pool. They were initially recruited via the talent pool. With a successful "trial run," they were hired to fulfill more responsibilities and lead more research activities.

3. **Pay above-market wages.** University campuses are full of extremely talented young people who are often eager to connect to meaningful projects. As students transition from the talent pool to paid positions, we recommend paying at least 20 percent higher than wages available to these students in other settings. Interview #1's initial motivation to work at CEAE was to get a job that pays well for undergraduate students. Among 30 respondents who were paid for their undergraduate work, 28 respondents (about 93 percent) in our survey were extremely satisfied (16 students, about 53 percent) or somewhat satisfied (12 students, 40 percent) with the compensation they received for their work. These indicate that above-market wages not only facilitate the recruitment of top-tier students, but also serve as a retention tool for those already bringing value-added efforts to research projects.

4. **Recruit students from multiple majors.** Conducting successful experiments requires a diversity of skills, thus we recommend hiring undergraduates from a diverse set of majors (not just economists or students interested in the topical area). This approach enriches the research team, enhances problem-solving capabilities, and ensures that the students are engaged in their specific tasks. For example, interviewee #4 was from a non-economic background and only did qualitative, rhetoric-based research before joining CEAE. They described that their non-economic background helped them better engage people in recruiting participants. They were also able to be creative in applying prior knowledge and skills to economic research. In addition, half of our survey respondents studied an economics-related major and the other half studied non-economics. This not only shows that students from non-economics majors were attracted to our work, but also echoes our experience that students from multiple majors can bring different perspectives and contribute to different tasks,

especially given that our research projects aiming to solve real-world issues are interdisciplinary in essence.

5. **Hire undergraduate students in their first or second years.** We recommend the recruitment of students during their first or second years of their undergraduate study. The development of research projects takes more than just one semester or year. Because of this, we have found that hiring undergraduate students early on will give them more time to gain different responsibilities, a better understanding of the research process, exposure to more opportunities, and the development of various skills. This early integration allows for time to cultivate their research abilities and, importantly, to establish an internal mentorship system. Through such a system, more experienced undergraduate researchers pass down their accumulated knowledge and skills to their younger counterparts, thereby enhancing both individual and collective research efficacy.

6. **Hire undergraduate researchers on a semester-by-semester basis.** Hiring on a semester-by-semester basis offers faculty and research staff the flexibility to assess student engagement, seek funding for students, and seamlessly part ways with individuals in a low-conflict manner who are not fully invested in the research endeavors. Importantly, our experience suggests that this approach does not adversely affect the retention of top-performing students, who often feel rewarded for their high productivity. Interviewee #2 was initially hired into the talent pool but was gradually tasked with more responsibilities by semesters, and their research experience eventually helped them with producing a senior thesis.

7. **Nurture a diverse group of undergraduate researchers.** Foster an inclusive setting where undergraduate students not only feel valued for their contributions but are also encouraged to bring their diverse perspectives to the table. We advocate for proactive measures that both honor these varying viewpoints and provide targeted support for students' career development.

8. **Develop a layered mentoring program.** To facilitate the holistic development of undergraduate students, we recommend the implementation of a tiered mentorship initiative. This model not only allows students to gain valuable insights from multiple mentors at various career stages, but also fosters an interconnected community of academic growth and support. This model has also shown to be successful in our experience. From the survey, we saw that most respondents (26 students, about 74 percent) received mentoring, and a small portion (9 students, about 26 percent) of respondents provided mentoring. The latter highlights the uniqueness of a layered mentoring program. Interviewee #1 mentioned that they were welcome to reach out to the previous student in the mentorship program. Interviewee #3 specifically said that getting mentored was one of the most valuable experiences they had, and they use the skills they gain mentoring other CEAE undergraduates in their jobs today.

9. **Leverage external funding to increase internal funding.** Based on our professional experience and leadership approach, we recommend the strategic utilization of external grant awards as a leverage point to obtain internal institutional funding dedicated to undergraduate research endeavors. This approach often enables the externally funded project to achieve more research tasks and ultimately be more successful.

10. **Encourage students to present their work.** We recommend undergraduate researchers disseminate their work through presentations at academic forums, conferences, and even competitions. Such experiences are invaluable for their professional development and serve to elevate the overall quality of undergraduate research experiences. Encouraging students to present

their work also helps students realize their contributions to the field and the impacts of their work, as well as improve their presentation skills. This was observed in the survey responses as most respondents thought that the project(s) they contributed to would advance the field of applied economics (27 students, about 77 percent) and had real-world impacts on practices and policies (29 students, about 83 percent). Additionally, 24 students (about 69 percent) improved their skills in delivering an oral presentation or developing poster presentations. Moreover, interviewee #3 discussed how they still draw from an old CEAE presentation for presentations they give at work.

6 Conclusion

This article describes approaches that we have found effective for synergizing experimental economics research and undergraduate research experiences at CEAE based on lead researchers' experiences working with undergraduate students, as well as survey responses and interviews with previous undergraduate research assistants. Through the survey and interviews, we learned about undergraduate research assistants' experiences engaging in economic experiments at CEAE, how their research experiences influenced their undergraduate education, the next steps in their professional lives, as well as how these experiences developed their research and professional skills. Both survey responses and interviews showed that undergraduate research assistants were satisfied with their experiences with CEAE, and their work was meaningful and impactful. In addition to gaining a better understanding of the research process and improving research skills through multiple responsibilities, undergraduate research assistants also improved their professional abilities and skills that they continue to use in their post-graduation endeavors. Working with CEAE also affected respondents' decisions about their life path and stimulated their interest in pursuing further education opportunities and a career in applied economics.

Based on our experiences, survey responses, and interviews, we highlighted the advantages and challenges of our undergraduate research program and suggested ten recommendations. While our ten recommendations are inspired by our experience in CEAE and working in experimental economics research, we believe that these recommendations can be applied broadly to agricultural and applied economics programs given the similar "hands-on" features in experimental economics and applied economics research. Moreover, these recommendations will attract more undergraduate students to the applied economics field and develop undergraduate students' research skills, which likely will improve the recruitment and quality of graduate students and strengthen the pipeline of diverse researchers in agricultural and applied economics. Tracking this pipeline and student placements is critical to evaluating the success of undergraduate research programs and other student-focused initiatives, and we echo earlier calls for improving how we collect and communicate pipeline and job placement data for agricultural and applied economics on a national scale (Hilsenroth et al. 2022; Zepeda and Marchant 1998).

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Teaching and Educational Methods

Engaging Undergraduate Students in Research: From Cross-Discipline Programs to Published Articles

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Abstract
This paper discusses the effective integration of undergraduate students into research, ensuring mutually beneficial outcomes for students, faculty, higher education institutes, and society at large. Student candidates are identified through a screening process leveraging the existing institutional resources and programs. Selection criteria, including minimum grade point average (GPA), strong writing skills, and achievements in challenging quantitative courses, are employed. Once a suitable candidate is identified, research collaboration commences. We work with the student to identify a topic aligned with our projects that piques their interest and curiosity, while ensuring feasibility within the timeframe. Subsequently, we invest a month or two in guiding the student through relevant literature, building a comprehensive understanding of the chosen subject matter. As the research question evolves, we assist the student in mastering the necessary tools and methods, providing relevant programming code or directing the student to specific knowledge domains. The structured approach mirrors the collaboration with graduate students. We deliberately avoid limiting our selection to specific disciplines, promoting diversity in student engagement. This exposure broadens their understanding of applied economics research and enriches the educational experience for both students and faculty mentors. The result is the cultivation of cross-disciplinary programs that contribute to the growth and development of undergraduate research.

1 Introduction

Undergraduate research has gained increasing prominence as a feature of the higher education experience in the United States (Ambos 2020). The Council for Undergraduate Research (CUR) defines it as "a mentored investigation or creative inquiry conducted by undergraduates that seeks to make a scholarly or artistic contribution to knowledge."[1] According to CUR, this form of engagement is fundamentally a pedagogical approach to teaching and learning, emphasizing the education benefits derived from scholarly and creative inquiry at the undergraduate level. Given the diverse disciplines in higher education institutes, encompassing humanities, social science, physical and life sciences, mathematics, engineering, and the arts, each field presents unique demands and opportunities for engaging in such activities. Yet, a shared consensus emerges; undergraduate students typically need more training, support, and guidance than their graduate counterparts. Integrating undergraduate students into research requires planning and preparation (Webber, Nelson Laird, and BrckaLorenz 2013).

This study presents a student-centered approach that capitalizes on available resources in higher education institutes to cultivate successful undergraduate research experiences. By recruiting talented undergraduate students, this approach advances their education and knowledge, while concurrently being

[1] https://www.cur.org/about/what-is-undergraduate-research/#:~:text=With%20an%20emphasis%20on%20process,or%20artistic%20contribution%20to%20knowledge.

beneficial to the university and faculty involved. Utilizing undergraduate programs, we identify undergraduate students who are eager to participate in research, some of whom may be part of initiatives targeting historically underrepresented student groups, fostering diversity and inclusion. We leverage these programs to recruit students with different backgrounds and study different disciplines. Indeed, we intentionally avoid confining the selection process to specific disciplines, encouraging cross-disciplinary collaboration and learning. Other selection criterion we have employed include a minimum GPA, strong writing skills, and a track record of achievements in challenging quantitative courses.

Engaging in discussions with students to identify research questions that captivate their interests and aligning these questions with our own research has proven to be both useful and productive. After identifying the ideal candidates, we embark on a collaborative journey, where we work closely to refine research topics within students' capabilities and designated timeframes. We dedicate a month or two to guide students through relevant literature to enrich their understanding of the research topic and identify tools and methods essential for the research that students must learn and master. While these techniques might not directly correlate with the students' prior academic pursuits, they are selected to be attainable within a relatively short span of time—a few months. In this process, we may expedite the learning process by providing coding resources or directing the student toward specific areas of knowledge.

This dynamic collaboration supports undergraduate students in carving out a promising trajectory, mirroring processes undertaken with graduate students. Involving students from diverse disciplines broadens their understanding of applied economics research and enriches the educational experience for both students and faculty mentors. The result is the cultivation of cross-disciplinary programs that contribute to the growth and development of undergraduate research.

The remainder of this paper unfolds as follows. Section 2 elaborates on the benefits of undergraduate research to students, faculty mentors, higher education institutes, and society at large. Section 3 offers an in-depth discussion of the process of engaging undergraduate students in research. Section 4 concludes the paper.

2 Benefits of Engaging Undergraduate Students in Research

In this section, we elaborate on potential benefits of engaging undergraduate students in research to students, faculty mentors, higher education institutes, and society at large (see Figure 1). Recognizing these benefits can foster student-faculty interaction and advocate for increased institutional resources dedicated to undergraduate research initiatives.

2.1 Benefits to Undergraduate Students

The existing literature presents a diverse spectrum of advantages for undergraduate students engaged in research, as outlined in Figure 1. Engagement in undergraduate research not only enriches the overall educational experience (Russell, Hancock, and McCullough 2007), but also cultivates intrinsic motivation for expanding one's learning (Lopatto 2007). Moreover, a notable correlation emerges between participation in undergraduate research and improved academic performance, as evidenced by GPA (Maton, Hrabowski, and Schmitt 2000) and increased academic achievements (Cole and Espinoza 2008), ultimately contributing to an increased graduation rate (Maton et al. 2000; Barlow and Villarejo 2004; Jones, Barlow, and Villarejo 2010).

Furthermore, the undergraduate research experience hones critical thinking skills (Bauer and Bennett 2003; Kuh et al., 2007; Lopatto 2007), and fosters cognitive growth that enhances self-efficacy and confidence levels (Hunter, Laursen, and Seymour 2007; Russell et al. 2007; Ashcroft, Blatti, and Jaramillo 2020). This experiential learning nurtures proficiency in discussing research findings, delivering compelling research presentations, and applying ethical principles conscientiously (Junge et al. 2010), aligning with the skills highly sought by employers of recent college graduates entering the workforce (McClure-Brenchley, Picardo, and Overton-Healy 2020).

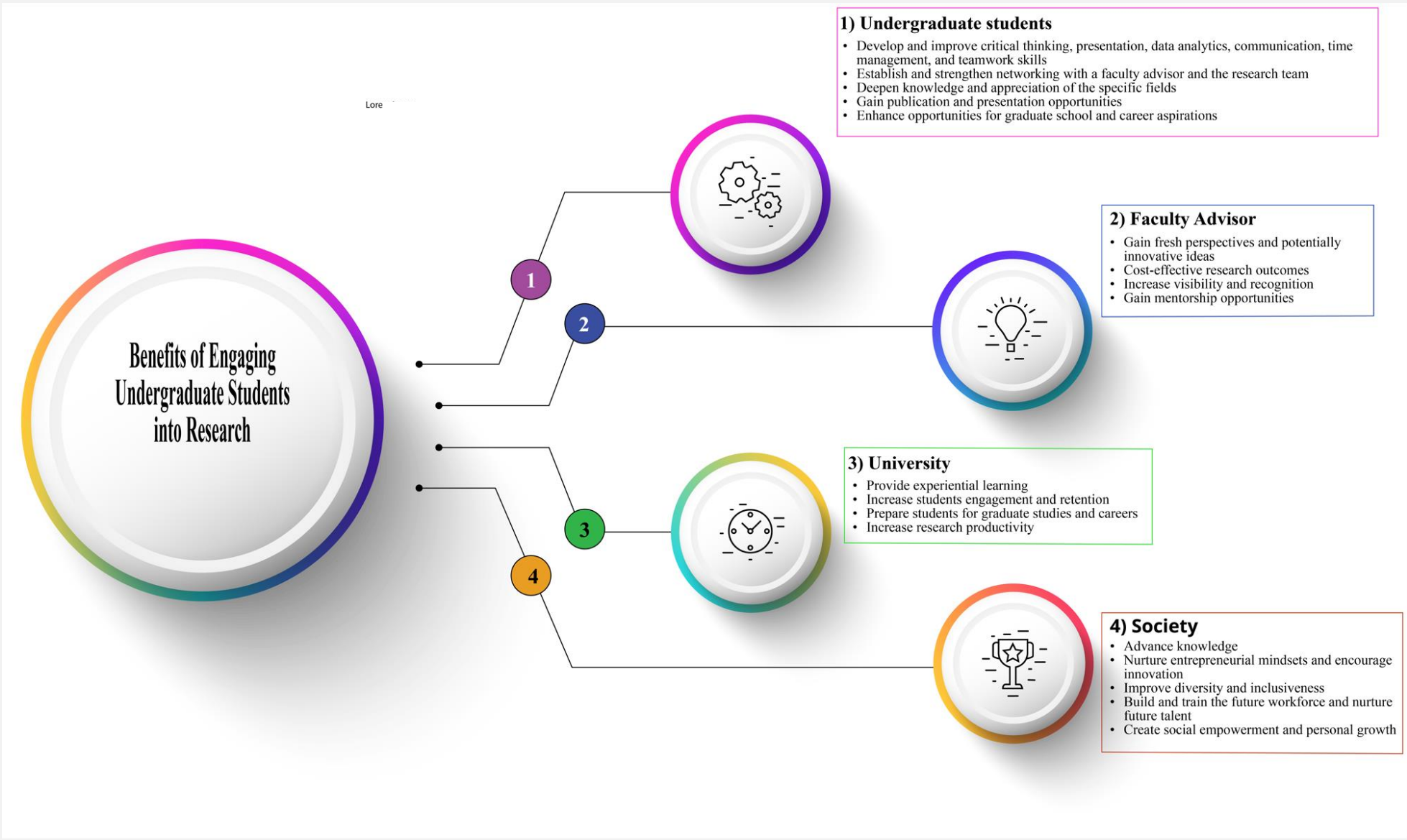

Figure 1: Benefits of engaging undergraduate students in research

Undergraduate researchers exhibit a distinct inclination toward pursuing advanced degrees, setting them apart from their non-research peers (Hathaway, Nagda, and Gregerman 2002; Bauer and Bennett 2003; Maton and Hrabowski 2004; Summers and Hrabowski 2006; Lopatto 2007; Russell et al. 2007; Blanton, Taraban, and Blanton 2008; Jones et al. 2010; Eagan et al. 2013). This inclination, stemming from an enhanced sense of fitting into the scientific community and discipline (Ryder, Leach, and Driver 1999), motivates them to pursue advanced studies and enhances their competitiveness in graduate program applications. The scholarly publications resulting from undergraduate research further amplify these benefits (Morales, Grineski, and Collins 2017).

Benefits extend to positively influencing job applications and career choices. Immersion in research offers students a deeper insight into the demands and day-to-day intricacies of conducting research, effectively facilitating socialization into the professional world (Lopatto 2004; Hunter et al. 2007; Russell et al. 2007). Consequently, this comprehensive understanding better equips students with the preparation demanded by professional pursuits (Ashcroft et al. 2020).

The advantages of undergraduate research extend well beyond graduation, as indicated by alumni surveys conducted by Bauer and Bennett (2003). These surveys show significant gains in science, math, logic, and problem-solving skills, as well as proficiency in literature, language, and mastery of context-related skills. These skills, highlighted by the National Association of Colleges and Employers (NACE; 2019; 2023), are highly sought after by employers. Furthermore, students with research experience or internship experience have advantage in their employability, as reported by NACE (2019; 2023). Engaging in research enhances employability, helping students develop qualifications, competencies, and connections that make them more desirable to employers (Carpenter et al. 2022).

The benefits of undergraduate research extend beyond research activities, including meaningful and evolving relationships that students build with their faculty mentors. These relationships significantly impact personal and professional development, fostering increased confidence and heightened competency, and shaping students' perception of themselves, their academic community, and their expectations for post-graduation endeavors (Davis and Jones 2020).

In summary, the benefits of undergraduate research extend far beyond the academic realm, positioning students for a more enriched educational journey and fortifying their pathway into subsequent professional and scholarly pursuits and being more marketable in the workforce.

2.2 Benefits to Faculty Advisors

While the benefits of undergraduate research for students are well documented, there is a paucity of research on the benefits for faculty mentors (Morales et al. 2017). Given that faculty engagement is a significant predictor of student participation in undergraduate research (Webber et al. 2013) and profoundly impacts students (Lopatto 2010), it is important to examine the rationale and effects of involving students in research.

Many faculty members genuinely aspire to influence the careers of young scholars (Zydney et al. 2002a). They firmly believe that research experiences significantly contribute to the cognitive and affective development of their undergraduate proteges, fostering traits such as intellectual curiosity, comprehension of scientific discoveries, adeptness in logical and critical thinking, and the ability to synthesize information from diverse sources (Zydney et al. 2002a; Carpi et al. 2017). This inspiration catalyzes for faculty members to engage undergraduates in research endeavors.

Undergraduate contributions to research projects can potentially improve the research productivity of faculty members (Lee and Bozeman 2005). Their unique perspectives may bring fresh, out-of-the-box ideas that lead to groundbreaking advances in research, expanding faculties' horizons. This effect is amplified when the student and faculty come from different disciplines, introducing the faculty to alternative approaches. In resource-constrained environments, leveraging resources and funding provided by higher education institutes for undergraduate research can be a cost-effective strategy for faculty members to expand and advance their research programs. Involving undergraduate

students in research can potentially increase faculty-student publications (Morales et al. 2017). Peer-reviewed publications, crucial for faculty hiring, tenure, and promotion, highly value faculty-student collaborative publications during faculty evaluations.

Interactions between undergraduate researchers and faculty members foster opportunities for mutual collegiality and the development of professional relationships that benefit both (Zydney et al. 2002a; Adedokun et al. 2010; Dolan and Johnson 2010).

When faculty members engage undergraduate students in research to address complex problems, their collective efforts often result in comprehensive and impactful findings that resonate with a broader audience. The heightened visibility contributes to the research's recognition, bolsters the institution's reputation, and fosters a sense of pride among various higher education stakeholders.

Recognizing the potential to become future faculty, graduate students perceive that their involvement in guiding undergraduate researchers offers valuable mentoring and teaching experiences (Zydney et al. 2002b; Dolan and Johnson 2010). This unique dynamic enriches their academic journey and equips them with essential skills for their future roles.

2.3 Benefits to Higher Education Institutes

A positive image of a higher education institute is a valuable intangible asset, setting the institute apart within a competitive landscape. This distinction captures the attention of prospective students and their families, while aiding in student retention. Topor (1986) introduces a framework of four essential factors—research, recognition, repetition, and recollection—to establish and enhance institutional reputation in higher education. Within this framework, the integration of undergraduate research plays an important role in positively impacting these four elements.

The existing literature indicates a positive correlation between undergraduate research and various academic and personal development aspects that provide experiential learning. Engagement in undergraduate research positively influences research productivity (Maton et al. 2000; Barlow and Villarejo 2004; Jones et al. 2010). Moreover, student participation in undergraduate research is positively associated with the retention of students, both within institutions and their perspective disciplines (Nagda et al. 1998; Cole and Espinoza 2008; Eagan et al. 2013). The advantages extend to the institutional level, benefiting schools and universities through improved academic performance, improved student retention, and increased graduation rates (Maton et al. 2000; Barlow and Villarejo 2004; Jones et al. 2010; Chang et al. 2014), as well as improved employability of students (Carpenter et al. 2022; National Association of Colleges and Employers 2019). Additionally, alumni who have participated in research demonstrate greater overall satisfaction than those without research experience (Bauer and Bennett 2003). This stratification among alumni not only bolsters the institution's reputation but also has the potential to increase endowments through gifts and donations.

Furthermore, our approach to leveraging the existing resources at the different levels of higher education institutes actively involves undergraduate students in research. This contributes to the cultivation of grantsmanship, further augmenting the institution's ability to secure funding opportunities. On the other hand, various government agencies provide financial support for undergraduate research, such as National Science Foundation (NSF) prominently through the Research Experience for Undergraduates (REU) program, the Department of Agriculture through its Research and Extension Experiences for Undergraduate (REEU) program within the Education and Development (EWD) program, the National Institutes of Health (NIH), and the Department of Education.[2]

[2] NSF's REU program: https://www.nsf.gov/crssprgm/reu/; USDA's Education and Workforce Development (EWD) Program: https://www.nifa.usda.gov/grants/funding-opportunities/agriculture-food-research-initiative-education-workforce-development; NIH's Undergraduate Scholarship Program (UGSP): https://www.training.nih.gov/research-training/pb/ugsp/; and Department of Education's undergraduate scholarship: https://studentaid.gov/understand-aid/types/scholarships.

2.4 Benefits to the Society

Engaging in research not only contributes to the existing body of knowledge but also propels the frontiers of understanding. Through rigorous investigation and research, researchers, including undergraduate students, actively contribute to the expansion of knowledge, creating a foundation for future discoveries.

Undergraduate research also provides opportunities for young talents to tackle some pressing issues that societies face and offer potential solutions to challenges, including public health crises, environment sustainability, and socioeconomic disparities. Engaged research should encompass undergraduate involvement, transforming fundamental knowledge into solutions for pressing societal issues (Whitmer et al. 2010). Involving undergraduates in research also contributes to the dissemination of research outcomes. Their fresh perspectives and insights can lead to novel ways of presenting findings, translating complex concepts into accessible language, and enhancing research outreach to a broader audience and the public.

Undergraduate research fosters a spirit of curiosity and exploration that aligns closely with entrepreneurship and innovation (White et al. 2013; McKellar 2020; Vaidyanathan et al. 2020). By engaging in research, students learn to identify gaps in existing knowledge, develop creative solutions, and test unconventional hypotheses. These skills not only enrich academic experiences but also lay the groundwork for future entrepreneurial ventures and innovative endeavors.

Engaging undergraduates in research provides them with essential skills and practical experience that aligns with the demands of the future job market (Vaidyanathan et al. 2020). Therefore, institutions contribute to building a capable and adaptable workforce ready to tackle complex challenges. On the other hand, participation in research empowers students to make meaningful contributions to society, boosting their sense of purpose and impact. The journey of personal growth can potentially equip them with the tools to positively influence their communities and the world at large.

Integrating undergraduate students into research can contribute to fostering diversity and inclusiveness in academia, research fields, and future workforce (Nonnemacher and Sokhey 2022). For example, we leverage the existing undergraduate programs focusing on research at the school and university levels, where diversity and inclusiveness are always emphasized. Encouraging students from diverse backgrounds to participate in research promotes a broader range of perspective, ideas, and problem-solving approaches, contributing to a more comprehensive understanding of complex issues and ensuring a wider array of voices are heard. It helps build the capacity needed in underserved and underrepresented communities.

In essence, involving undergraduate students in research creates a ripple effect that extends to society's betterment through knowledge advancement, innovative solutions, and the cultivation of a capable future workforce and leaders.

3 The Journey of Engaging Undergraduate Students in Research

An indispensable element in the successful execution of undergraduate research is the presence of adept and influential faculty mentors (Linn et al. 2015). Will-directed faculty guidance significantly contributes to the positive outcomes of undergraduate research endeavors (Russell et al. 2007). Among the pivotal components supporting undergraduate research, meticulous planning and thorough preparation stand out (Webber et al. 2013). From the perspectives of a faculty mentor, we delve into the narrative of involving undergraduate students in research (Figure 2), with a specific focus on insights within social science.

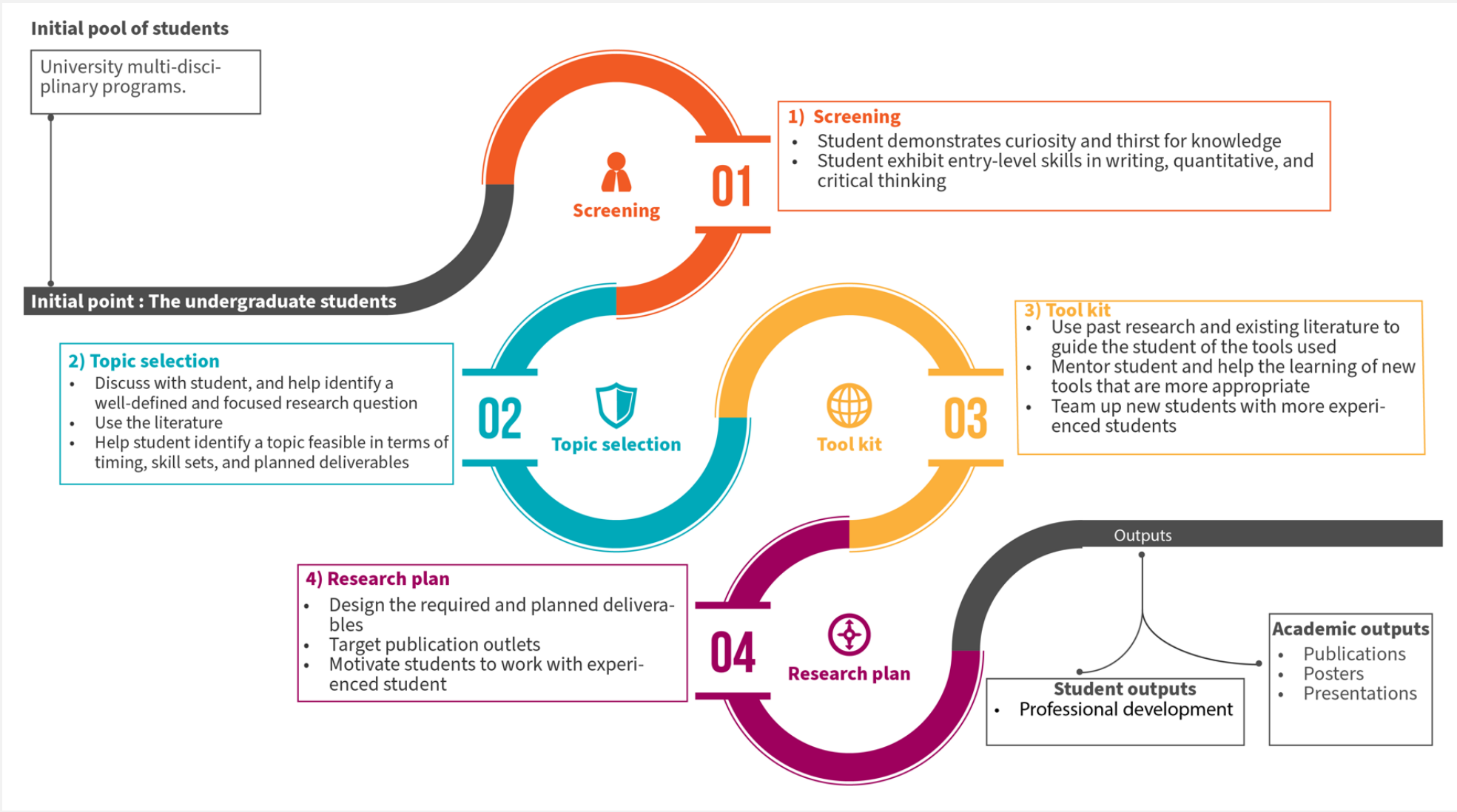

Figure 2: The procedure to guide undergraduate students in active and productive research

3.1 Identifying and Screening Candidates for Undergraduate Research

3.1.1 Leverage University Programs to Identify Candidates for Undergraduate Research

Many higher education institutes actively promote undergraduate research through a variety of programs. Take Rutgers-New Brunswick as an example. First, the Honors College is a unifying platform that brings together undergraduates from all schools, integrating research into the student experience. This commitment manifests in various ways, from the interdisciplinary first-year mission course (Forum) to the culmination of specialized, faculty-supervised Capstone projects in the senior year.

Second, Rutgers University offers a spectrum of campus-wide signature programs, each providing unparalleled opportunities for undergraduates, including Aresty Research Center, RISE at Rutgers, Ronald McNair Scholars Program (RMSP), Louis Stoke Alliance for Minority Participation (LSAMP), Innovation, Design, and Entrepreneurship Academy (IDEA), and the Undergraduate Research Writing Conference (URWC).[3] These programs cater to various student cohorts with their distinct focuses.

The Aresty Research Center, established in 2004, has already collaborated with more than 2,000 students and 1,500 faculty, contributing approximately $2.2 million to support undergraduate research endeavors. Through Aresty, undergraduates across disciplines and backgrounds engage in scholarly research under faculty mentorship and showcase their findings at the university-wide annual symposium.

Case Study: The Process of Selecting Undergraduate Students for Research Projects through the Aresty Research Center at Rutgers University

One of the university's undergraduate research programs, Aresty, ask its faculty to write short summaries of their research topics and projects, which are then circulated to students through the program. Students interested in becoming Research Assistants (RAs) explore these summaries written by faculty from multiple disciplines. They then decide which projects to apply to. The selection process emphasizes the importance of a strong GPA, proficiency in quantitative courses, and English language skills.

Selected students are interviewed by the faculty and evaluated based on the criteria discussed in the solicitation. If deemed qualified, the program facilitates matching students with appropriate projects. However, the final decision on the match is a collaborative one, requiring agreement between the student and the faculty. In addition to gaining research experience, the selected students also earn research credit through the Aresty program.

Following the matching process, the faculty organizes an introductory meeting with the selected student to understand his/her interests, strengths, and backgrounds. This initial assessment informs the development of a well-defined research question for the student.

Once the research question is identified, the faculty provides necessary resources and tools, such as selected papers in the related fields, possible data sources, and readings of potential methodologies. These resources help the student conduct a more extensive literature review and learn various methods to address the identified research question. The faculty also assists the student in writing software codes or teaching statistical software, as needed.

The faculty encourage students to engage collaboration and knowledge-sharing among students working on similar research questions or projects. This approach not only fosters independent and interdependent learning, but also potentially leads to the combination of their work

[3] Details can be found at https://newbrunswick.rutgers.edu/undergraduate-research. Last access on November 10, 2023.

Case Study continued.

into more comprehensive and complementary projects.

To help the students manage their time effectively and meet the program's deliverables, the faculty also sets milestones throughout the year, with regular weekly or biweekly meetings between the faculty and the students. Group meetings occur twice a semester, particularly if students are collaborating on a joint project.

As the project progresses, the faculty guide students through the process of presenting their findings. This may involve creating a poster or preparing a peer-reviewed paper, depending on the outcomes and their quality, as well as the program's requirements. Overall, the structured approach of the Aresty program provides students with valuable research skills and hands-on research experience in their chosen field.

RISE, a nationally renowned ten-week residential summer program, invites outstanding undergraduates from diverse backgrounds to engage in pioneering, interdisciplinary research guided by carefully matched faculty mentors. The federally funded RMSP prepares undergraduates for their doctoral studies by immersing them in essential research and scholarly activities.

The IDEA empowers undergraduates to confront complex societal challenges through research, design initiatives, and entrepreneurial activities. The URWC showcases exceptional research projects that undergraduates complete within Rutgers's writing program courses.[4]

Some programs, such as the Douglass Women in Science and Engineering (WiSE) program, specifically target underrepresented women students in science and engineering where there is a historical and continued gender disparity at the university level and in the workforce.[5] LSAMP provides research opportunities to students from historically underrepresented groups who wish to enter non-medical STEM professions.[6]

Third, Rutgers-New Brunswick features distinct Honors Programs within each school, tailored to meet the unique needs of students within that specific school. These school-based honors programs not only cater to academic enrichment but also offer research opportunities for undergraduate students. For example, the School of Biological and Environmental Science (SEBS) provides its honor students with early exposure to research experiences. Many of these students demonstrate their research capability and skills by completing a Gorge H. Cook Honors Thesis.[7] The George H. Cook Scholars Program, specifically designed for SEBS undergraduates, is an independent research and senior honors thesis program. Participating students engage in original basic and applied research in the field they choose, guided by an approved advisor. Project planning commences no later than the end of the second semester of the junior year, culminating in the presentation of results through a written thesis and an oral presentation at a research symposium during the second semester of the senior year.

Each of these programs at Rutgers has unique eligibility criteria and dedicates funding to support undergraduate research. It is worth mentioning that other land-grant universities offer comparable programs. Students who participate in these programs often develop strong bonds with faculty mentors, forged in the intimate settings of seminar-sized honors-designated courses (Kinkead 2003). The

[4] The Rutgers Writing Program provides instruction in writing, utilizing inclusive and responsive forms of pedagogy, to support students in their writing and thinking at the university and beyond. Details of this program can be found at https://wp.rutgers.edu/. Last access on February 3, 2024.

[5] Details of WiSE are provided at https://douglass.rutgers.edu/wise. Last access on November 10, 2023.

[6] Details of LSAMP are provided at https://newbrunswick.rutgers.edu/undergraduate-research. Last access on November 10, 2023.

[7] Details are provided in "General Honors Program" at https://sebshonors.rutgers.edu/general-honors/. Last access on November 9, 2023.

resulting familiarity, coupled with the innate motivation of these students, propels them toward scholarly research pursuits that significantly enhance their overall education experiences (Russell et al. 2007; Cole and Espinoza 2008).

3.1.2 Screening Candidates for Undergraduate Research

Undergraduate students exhibit various traits shaped by their personalities, backgrounds, and experiences. When screening candidates for undergraduate research, we seek specific qualities that potentially facilitate their engagement in research. Curiosity, represented by enthusiasm, inquisitiveness, and a thirst for knowledge, stands out as a pivotal trait. It drives undergraduate students to explore new ideas, concepts, and subjects within their academic journey. Many undergraduates set personal, academic, and professional goals for themselves, and work diligently to achieve them. Undergraduate education places a strong emphasis on critical thinking skills, leading students to learn to analyze information, evaluate sources, and develop well-reasoned arguments. Time management is another skill that students must master to balance coursework, extracurricular activities, social life, and potentially part-time jobs. Given the prevalence of group projects and collaborative assignments in undergraduate programs, students also develop effective teamwork and interpersonal skills through their academic experiences.

The transition to college often marks the first step toward independent living for many young adults, fostering a sense of autonomy and independence. This transition can be academically and personally challenging, demanding them to have the capability to adapt to new environments, interact with diverse individuals, and confront new challenges. It requires an agility in embracing changes and diverse perspective as well as resilience, as they encounter setbacks and overcome obstacles.

Whether in arts, sciences, or other fields, undergraduates often explore their creative inclinations. They may engage in artistic pursuits, innovative problem-solving, or entrepreneurial initiatives. Many undergraduates use their college years as an opportunity to discover new interests and hobbies beyond their academic studies. Proactive engagement, resource-seeking, and active participation in events are common traits among undergraduates.

Nevertheless, these traits vary significantly among individuals, and not all undergraduate students will manifest them to the same extent. Each student's unique background, experiences, and personal development shape the traits they exhibit during college. The challenge lies in effectively screening students, identifying those most likely to contribute positively to successful research outcomes.

Undergraduate students choose a major or field of study from various diverse disciplines, such as humanities, social sciences, natural sciences, engineering, arts, business, and more. They take courses in their chosen field, from introductory to advanced levels, earning credits for each completed course. Higher education institutes measure their progress through a GPA, providing a numerical representation of their academic performance.

To identify undergraduate students eager to participate in research, we employ a comprehensive screening process that draws upon the university's various cross-discipline programs. We initiate the process with students expressing interest in these programs, utilizing selection criteria such as minimum GPA, strong writing skills, and achievements in challenging quantitative courses. Importantly, we intentionally avoid confining our selection to specific disciplines.

During the screening process, we evaluate resumes and cover letters. We encourage students to ask questions and seek to identify a topic that genuinely excites them during interviews. This initial interaction allows us to grasp the student's interests, which we then align with our research projects, considering the student's background and strengths as reflected in their coursework and resume. Furthermore, we utilize resumes, cover letters, and interviews to identify traits in students that may contribute to their potential success in research experience.

3.2 Selection of Research Topics

Lopatto (2003) provides a comprehensive overview of the crucial elements of undergraduate research perceived by faculty mentors from esteemed liberal art colleges, including Harvey Mudd, Wellesley, and Grinnell. Among the top thirteen features, faculty mentors emphasize the significance of students formulating meaningful research questions that mirror their ingenuity and creativity. Furthermore, students can collaboratively brainstorm, meticulously design, and ultimately crystalize their research questions.

To guide the student in selecting a research topic, we employ two alternative approaches. First, undergraduate students can initiate the process by acquainting themselves with the ongoing research projects of their faculty advisor. This involves identifying specific areas that capture their interest and align with its overall project objectives. Second, an alternative approach involves delving into a literature review of a particular field of interest. Through this approach, students can identify research questions that resonate with their interests and the expertise of faculty advisor, establishing a mutual foundation for exploration.

In practice, during the first few meetings, the student usually conducts a literature review, and we engage in discussion to refine the research question progressively. This iterative process involves narrowing down the focus and utilizing data to pinpoint a specific topic for the year-long project. Individualized approaches are essential, as not every student follows the same path. For example, a senior student majoring in sociology had a strong interest in children's mental health. During the initial month, we guided him in formulating research questions that had not been fully explored in the literature and helped identify available data to address this research question. Conversely, in interviews with computer science or statistics students, we identified their keen interest in coding and statistical analysis. Building on these interests, we centered the project around using R software, creating projects that connected with our ongoing work. This requires the students to learn specific R packages (which we assist in identifying), gather and clean data, and perform statistical analysis.

In alignment with our commitment to fostering undergraduate research, we actively promote our research projects within our school and university, particularly through programs dedicated to undergraduate research. This strategy enables us to reach qualified students and engage them in project-based research based on their passions and the available research opportunities.

Throughout this process, we have recognized the importance of candid and iterative discussions with students. These dialogues serve as a crucible for refining research topics and create a dynamic space where questions are welcome. Furthermore, by openly debating new ideas, we foster an environment that encourages students to feel comfortable, enabling them to actively contribute their insights and perspectives.

Guiding students in their literature review is another crucial component. Encouraging them to delve into existing research enhances their understanding of the subject matter and empowers them to identify gaps, challenges, and potential pathways for their investigation. This practice gives students a sense of ownership over their research journey, propelling them to ask probing questions and seek innovative solutions.

Strategically decomposing a broader research question into manageable sub-questions is pivotal. This segmentation approach ensures that each facet of the research is attainable within designated timeframes and aligns with the evolving skill sets of the participating students. By breaking down the research questions into smaller, actionable components, we facilitate a systematic and structured approach that accommodates diverse proficiencies. This approach accompanies them throughout their research journey, creating an environment where we celebrate achievements of each stage as meaningful milestones.

To sum up, as shown in Figure 2, the fusion of interactive discussions, guided literature exploration, and thoughtful subdivision of research inquiries creates a robust framework that propels students toward comprehensive and impactful research outcomes. This systematic approach instills and

accumulates valuable research skills and cultivates a sense of purpose and accomplishment as students progress and achieve noteworthy milestones at each stage of their research journey.

3.3 Developing the Skill Set

When it comes to conducting research, students can leverage a diverse array of tools to gather information, analyze data, and present their findings effectively. We guide undergraduate students through these tools, directing them to resources that we believe will be most beneficial in addressing their research questions. This includes search engines and databases, data analysis, and visualization tools, as well as survey and research design methods.

We highly value two distinct but intertwined categories of skill set for undergraduate research. The first category encompasses learning skill sets thoughtfully curated to empower aspiring students to foster a noticeable enhancement in their research efficiency. These cover fundamental aspects such as selecting viable research topics, skillfully formulating hypotheses, literature review skills, and adeptly navigating data analysis. Additionally, these skill sets extend to time management, enabling students to balance their research commitment with academic pursuits. We guide students to strategically utilize resources such as databases, online repositories, and the wealth of prior research outcomes of faculty advisors. The publication process, often considered daunting for students, is demystified as students prepare their manuscripts and posters and navigate the peer review process. Moreover, we provide students with opportunities to polish their skills in research communication, collaboration, and dissemination through interactions with peers, attendance at professional conferences, and presentation of research findings.

The second category comprises technical skill sets specifically tailored for social science research, with data analysis techniques and programming skills standing out as paramount. Given that most university or school programs support individual undergraduates for one year, and students typically are required to complete their studies within that time frame, it is uncommon for us to recommend undergraduate students to enroll in a formal course for specific areas or skill sets. We equip undergraduate researchers with a comprehensive understanding of qualitative and quantitative data analysis techniques, along with interpretation techniques to draw meaningful findings from data analysis. To expedite students' mastery of programming skills, we encourage collaboration with more experienced undergraduates or graduate students. Additionally, we offer prompt assistance to help overcome challenges and refer students to online tutorial resources.

These learning and technical skill sets are valuable in ensuring the success of undergraduate research, and their benefits are well beyond individual research projects. We also guide students through various tools for writing and organizing drafts, from reference management tools to document creation and writing a scientific paper via Microsoft Word or LaTeX. Facilitating collaboration and communication between students and advisors, as well as among peers, is crucial. Our emphasis on using tools such as Google Workspace or Microsoft Teams enhances collaboration among students, enriching the outcomes of each project. Throughout the research process, these tools streamline tasks, organize information, and promote collaboration.

3.4 Establish Action Plans

Figure 2 presents some important action plans to ensure the success and productivity of undergraduate research. Activities fostering effective research include engaging in discussions with mentors, participating in group meetings, delving into guided research literature, documenting observations in weekly journals, and synthesizing insights to create research proposals, reports, presentations, posters, and even journal articles (Linn et al. 2015).

Students disseminate their research through conferences (Mabrouk 2009; Kneale et al. 2016; Little 2020), providing opportunities to present research findings through poster and oral presentations at

professional meetings and in research communities. In some circumstances, the research outputs led to published peer-reviewed journal articles. Such dissemination is a key facet of undergraduate research, as acknowledged by faculty mentors (Lopatto 2003). Since we leverage various programs for undergraduate students in a higher education institute, oral and/or poster presentations are often required. We find that such presentations at school and college levels, as well as in professional conferences, serve as highly encouraging and rewarding experiences for our students.

The entire process illustrated in Figure 2, spanning from identifying students to completing research projects, is iterative and dynamic. For example, a student expressed interest in exploring the impact of policy on adoption. Through subsequent meetings, we guided the student to relevant literature and facilitate the search for existing datasets, providing direction to sites where such data might be available. Once the students had a good grasp of the literature and available question, we introduced them to R packages deemed useful for addressing the refined research question. The faculty's proficiency in the topic, coupled with an understanding of how to approach and answer the question, plays a crucial role in guiding the students effectively. This iterative process ensures continuous refinement and adaptation, fostering a productive research environment for both mentors and students.

4 Conclusions

This paper presents a student-centered approach to engaging undergraduate students in research by leveraging existing resources and undergraduate programs to generate valuable outcomes for students, faculty mentors, higher education institute, and society at large. Our experience suggests that a student-centered research model stimulates students' curiosity and instills a sense of ownership, fostering a fruitful and rewarding collaborative endeavor that benefits everyone. While mentoring undergraduate students is more demanding, the rewards span dimensions and contribute to the enrichment of the work of all those involved.

In this paper, we have presented an argument that research experience facilitated by faculty members is highly beneficial for both students and faculty. These programs are also crucial in addressing societal biases by targeting underserved communities. Therefore, it is recommended to allocate additional funding to support and expand these programs, with a particular emphasis on targeting underrepresented undergraduates. It is also suggested to conduct further research to quantify and monetize the value of these programs, providing more precise guidance to funding agencies when allocating resources to diverse educational initiatives that involve undergraduates in research.

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Teaching and Educational Methods

FIRE Sustainability Analytics: An Innovative Approach to Engaging Undergraduate Students in Economics Research

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Abstract
In response to the growing demand for undergraduate research experiences in economics, the FIRE Sustainability Analytics program offers a compelling solution. This program provides a course-based undergraduate research experience (CURE) in empirical environmental economics for first-year students at the University of Maryland (UMD). This paper outlines the program's instructional design, highlights its role in advancing students' higher-order economic proficiencies, discusses the institutional support behind the program, describes its research projects and their outcomes, and shares insights gained from nine years of program implementation.

1 Introduction

In 2014, the University of Maryland (UMD) launched the First-Year Innovation and Research Experience (FIRE) program to provide a sequential course-based undergraduate research experience (CURE) to first-year undergraduate students. A CURE distinguishes itself from traditional research opportunities by enabling a single faculty mentor to engage an entire classroom of students in one or more research projects. Students simply enroll in a course sequence to embark on a research journey. By introducing students to research early in their college tenure, a first-year CURE can have a substantial impact on their academic trajectory.

Open to students of all disciplines, Sustainability Analytics is a research stream within FIRE affiliated with the Department of Agricultural and Resource Economics.[1] It focuses on research in empirical environmental economics with a dedicated faculty who trains and mentors cohorts of 30–40 students. Students learn the statistical software program R and develop data science skills used to organize, summarize, analyze and visualize data. They learn how to use reproducible workflows that exemplify best practices in scientific research. As their skills develop, students contribute to a new or ongoing research topic under the guidance of the Faculty Leader. FIRE Sustainability Analytics students develop strategies for communicating research results and recommendations to a variety of audiences in oral, written, visual, and digital formats. As projects are improved, they are showcased at both university-level and national conferences.

FIRE Sustainability Analytics addresses multiple obstacles that hinder both faculty and students in pursuing undergraduate research. It allows students to be involved in authentic research projects, enhances students' career readiness, underscores the value of faculty mentorship for undergraduate research, and accommodates a substantial number of students at once. This paper discusses the administration, instructional design, and institutional support for FIRE Sustainability Analytics, research projects and outcomes, and lessons learned that may help inform similar initiatives at other institutions.

[1] FIRE Sustainability Analytics is the only stream affiliated with the Department of Agricultural and Resource Economics. The Department of Cell Biology and Molecular Genetics is the only department affiliated with more than one stream.

2 Course Administration and Instructional Design

2.1 Overview

FIRE annually enrolls more than 600 students in sixteen research streams across multiple disciplines. Students accepted into UMD can join the FIRE program by enrolling in FIRE Semester 1.[2] In this General Education Scholarship in Practice course, students learn about the different research streams, including FIRE Sustainability Analytics, and develop basic research and career readiness skills. Toward the end of the fall semester, students submit their research group preferences, and thirty to forty students, who chose FIRE Sustainability Analytics, are selected to join the research group. FIRE matches students solely based on their research interests, so students can join FIRE Sustainability Analytics regardless of their academic background, performance, or selected major. This program feature helps overcome obstacles that impede students from gaining research experience through internships, research assistantships, or an honors program where selection depends on academic performance (Bangera and Brownell 2014).[3]

In the past three cohorts, FIRE Sustainability Analytics students have majored in computer science (11 percent), economics (10 percent), government and politics (9 percent), environmental science or environmental studies (8 percent), and engineering (5 percent). The remaining students (57 percent) have yet to declare a major before joining the program.

Figure 1 shows the FIRE course sequence in chronological order. Following their introduction to FIRE and being matched to FIRE Sustainability Analytics, students enroll in a two-semester course sequence that spans the spring semester of their first year and the fall semester of their second year. During the summer in between, students can choose to participate in the FIRE Research Internship, a three-credit course where students spend fifteen hours a week, for eight weeks, engaging in FIRE Sustainability Analytics accelerated research activities. After the completion of FIRE Semester 3, students can apply to become Peer Research Mentors (PRMs) who help train students in FIRE Semester 2 and lead research projects in FIRE Semester 3.

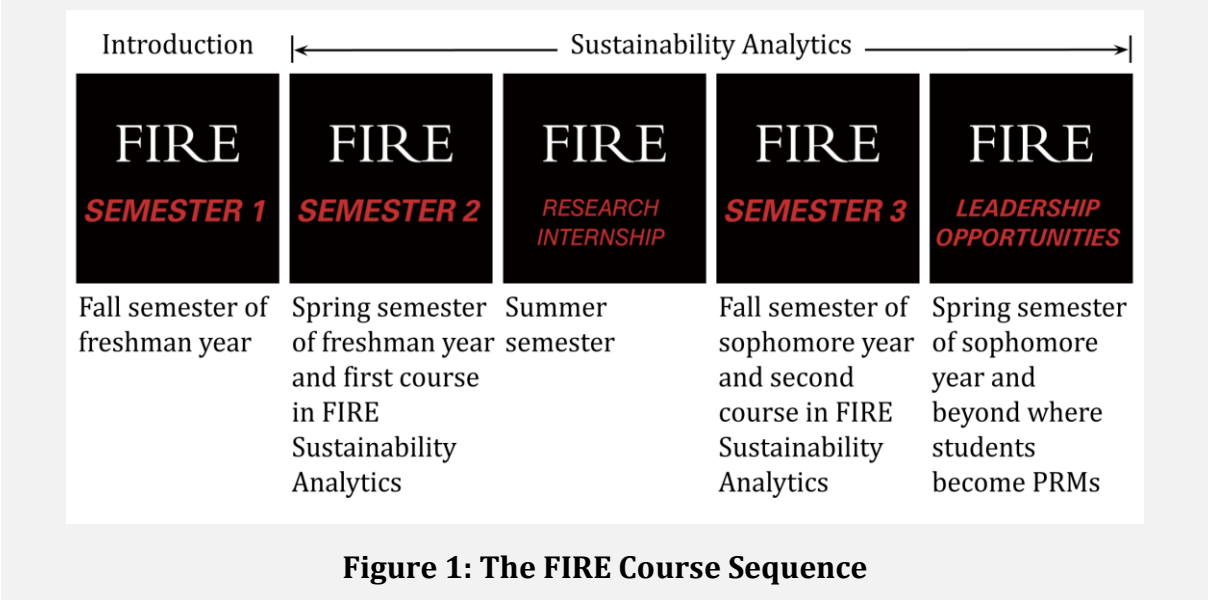

Figure 1: The FIRE Course Sequence

[2] Students not affiliated with other UMD first-year living-learning programs have two pathways to enroll. Some are invited by FIRE during the admission process. Others can submit an application to the FIRE program and join if their application is approved.

[3] FIRE was specifically designed and targeted to provide enhanced opportunities to students not admitted to UMD freshman honors programs.

In all FIRE courses, students are graded primarily on their participation and effort. There is no minimum grade that each student has to obtain to progress through the course sequence from FIRE Semester 1 to FIRE Semester 3. If a student does not pass a course sequence, a conversation is arranged to discuss the reasons behind their previous academic struggles and explore their probability of success as well as how to achieve success in the next course sequence. After FIRE Semester 3, only up to 8 students are selected to become PRMs in a year.

The rest of this section describes the curriculum for the FIRE Sustainability Analytics course sequence consisting of: FIRE Semester 2, FIRE Research Internship, and FIRE Semester 3. In addition, we summarize how course activities contribute to building Hansen's (1986, 2001) higher-order proficiencies, six learning outcomes that he argued all economic majors should achieve (Salemi and Siegfried 1999). Hansen suggested shifting the focus of economics instruction to what students can do with their learning, and he proposed that economics majors should learn how to: gain access to existing knowledge, display command of existing knowledge, interpret existing knowledge, interpret and manipulate economic data, apply existing knowledge, and create new knowledge.

2.2 FIRE Semester 2

The first course in the FIRE Sustainability Analytics sequence encompasses three primary learning outcomes. Students should:

1. Develop proficiency in R programming to clean and combine data, create tables and visualizations, and test hypotheses.
2. Gain an understanding of the environmental science problems and public policies examined in the environmental economics literature.
3. Build collaborative relationships with others who represent diverse cultures, races, ages, genders, religions, lifestyles, and viewpoints.

FIRE Semester 2 is a two-credit course that requires about six hours of a student's time per week. The course integrates three learning environments each week: a self-paced online course, a fifty-minute classroom session led by the Faculty Leader, and a lab session led by PRMs. Each week, students learn basic programming functions in R by completing assigned DataCamp[4] chapters. In each classroom session, the Faculty Leader discusses weekly plans and teaches additional programming skills to supplement the self-paced online course. Students then apply skills from the DataCamp chapters to transform publicly available data from the U.S. Environmental Protection Agency's (EPA; 2022) Clean Air Markets Program Data to replicate the data, figures, or tables created by Deschênes, Greenstone, and Shapiro (2017). This actively engages students in the process of creating a quality research paper. Together with learning how to interpret its results, students can achieve three of Hansen's higher-order proficiencies.

Supervising undergraduate students without programming skills can be time-consuming (Hoyt and McGoldrick 2017). FIRE Sustainability Analytics tackles this problem by utilizing hands-on mentoring by PRMs in the FIRE Sustainability Analytics lab. At the beginning of each semester, students are grouped with other students and a PRM with the same schedule. Students are required to go to the FIRE Sustainability Analytics lab each week to complete their paper replication assignments with their team members and a PRM. This cooperative mode of learning allows students to effectively learn the materials and simultaneously build collaborative skills (Yamarik 2007).

Students are also taught how to document their programming scripts to create a reproducible research workflow. Utilizing GitHub, students clone assignment templates mirroring specific sections of

[4] DataCamp is a commercial online learning platform for data science that provides free, unlimited access to DataCamp for Classrooms for instructors and their students.

Deschênes, Greenstone, and Shapiro (2017). Once assignments are complete, students push their work to GitHub, where updated repositories are evaluated.

At the same time, students have to learn what questions have been addressed in the field of environmental economics so that they can eventually ask and answer new questions. To learn about the forefront of environmental economics research, students take turns reviewing working papers at the beginning of each week's classroom session. At the beginning of the semester, the Faculty Leader compiles a repository of working papers from the National Bureau of Economic Research and researchers' websites. Each student chooses a paper they would like to discuss during a week of class. By summarizing their selected paper in class, students can display their understanding of existing findings. As an introduction to causal inference, students must identify the treatment, outcome, and control variables in each paper. This activity allows students to display their command of and to interpret existing knowledge as Hansen's higher-order proficiencies.

During the last three weeks of class, students combine their interest and understanding of research in environmental economics to propose new research questions. Students compile annotated bibliographies to justify their questions' novelty and identify data that indicates the questions' feasibility. These activities allow students to access and display their command of existing knowledge. Next, they begin applying and creating new knowledge via writing a research proposal, achieving five of Hansen's higher-order proficiencies. After the semester, the Faculty Leader chooses two to three research questions that will be worked on in FIRE Semester 3.

Table 1 identifies which course activities allow each student to achieve each of Hansen's proficiencies. The sequencing of course activities in Table 1 illustrates how learning is scaffolded in this course. Table 2 lists which course activities enable each student to achieve the course's learning outcomes. A list of FIRE Semester 2 assignments in 2023 can be found in the 2023 FIRE198 Syllabus provided in the Supplementary Materials.

2.3 Summer Research Internship

Since its inception, FIRE has placed a high value on providing an accelerated research experience and enhancing career readiness through an optional summer program. The nature of the summer program offered by FIRE has evolved over the years. From 2015 to 2021, FIRE Sustainability Analytics selected Summer Fellows from among FIRE Semester 2 students through a competitive application process. Once selected, these fellows worked alongside the Faculty Leader for twenty hours per week over eight weeks and received a modest stipend.

In the summers of 2020 and 2021, FIRE Sustainability Analytics collaborated with the U.S. Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS). USDA APHIS suggested research questions that could inform their agency, provided information from their staff, and funded the Summer Fellows program.

During the COVID-19 pandemic in 2020 and 2021, FIRE introduced a noncompetitive Summer Scholars program. This program aimed to advance knowledge and offer a sense of community to all FIRE Semester 2 students who were interested. FIRE Sustainability Analytics Summer Scholars dedicated four hours a week for four weeks to learning how to critique causal conclusions in empirical health research. Because the program focused on community building and the required time commitment was low, Summer Scholars did not receive a stipend nor course credit.

Post-COVID-19, FIRE strives to establish a financially sustainable summer program that does not rely on university funding or external institutions to provide student stipends. Building on the positive experiences students had while working with USDA APHIS, FIRE created a Summer Research Internship program that emulates an industry or institution-based internship experience. Unlike the past Summer Fellows program, where students competitively applied and received a stipend, FIRE Semester 2 students can enroll in a three-credit course to become FIRE Summer Interns. The students spend fifteen

Table 1: FIRE Sustainability Analytics Activities that Achieve Hansen's Proficiencies

Course	Proficiency Activity	Access existing knowledge	Display command of existing knowledge	Interpret existing knowledge	Interpret and manipulate economic data	Apply existing knowledge	Create new knowledge
FIRE Semester 2	Replicating a published paper		x	x	x		
	Working paper presentation		x	x			
	Proposal writing	x	x	x		x	x
FIRE Summer Research Internship	Querying, cleaning, and combining numeric and spatial data	x			x		
	Presenting the research project		x			x	x
FIRE Semester 3	Literature review writing	x	x	x			
	Data collecting	x					
	Data cleaning and combining				x		x
	Creating tables and plots				x	x	x
	Testing hypotheses				x	x	x
	Forming conclusions					x	x

hours a week for eight weeks collaborating with the Faculty Leader and addressing faculty-led research questions.

FIRE Summer Research Interns, both FIRE Semester 2 students and other undergraduates not previously affiliated with FIRE, gain valuable experience by querying, cleaning, and combining new data sets to address research questions directed by the Faculty Leader. They also acquire spatial analysis skills, which they apply to their projects. At the conclusion of the program, students present their research background and findings in slide presentations to students from other research streams. Preparing for these presentations allows students to showcase their command of economic knowledge,

Table 2: FIRE Sustainability Analytics Activities that Fulfill Course Learning Outcomes

Course	Learning Outcomes Activity	Develop proficiency in R	Understand enviro. problems and policies	Build collaborative relationships	Differentiate between prediction and inference models	Develop resilience to revise projects	Present research outcomes
FIRE Semester 2	Replicating a published paper	x		x			
	Working paper presentation		x	x			
	Proposal writing		x	x			
FIRE Semester 3	Literature review writing		x	x			
	Data collecting, cleaning, and combining	x		x			
	Visualizing data	x		x			
	Testing hypotheses	x		x	x	x	
	Forming conclusions		x	x	x	x	
	Presenting the research project		x				x

apply existing knowledge, and generate new insights as Hansen's advanced proficiencies. Summer Research Interns become extremely proficient FIRE Semester 3 students and team leaders, who are able to help train their peers and accelerate team progress when students return in the fall.

Table 1 in section 2.4 identifies which course activities allow each student to achieve each of Hansen's (1986, 2001) proficiencies. For a list of FIRE Summer Research Internship assignments in 2023, please refer to the Supplementary Materials provided in the 2023 FIRE199 Syllabus.

2.4 FIRE Semester 3

FIRE Sustainability Analytics Semester 3 has six learning outcomes. The first three continue the learning outcomes from FIRE Semester 2:

1. Develop proficiency in R programming to clean and combine data, create tables and visualizations, and test hypotheses.
2. Gain an understanding of the environmental science problems and public policies examined in the environmental economics literature.

3. Build collaborative relationships with others who represent diverse cultures, races, ages, genders, religions, lifestyles, and viewpoints.

The three new learning outcomes introduced in this course are that students will be able to:

4. Develop the ability to differentiate between prediction and inference models used in applied economics.
5. Develop the resilience to revise and refine research projects by incorporating peer and instructor feedback.
6. Present research outcomes to audiences with varying technical backgrounds using various modes of communication.

Approximately 80 percent of students typically continue through the third semester. At the beginning of the fall semester of their second year, these students form teams of three to five students with similar schedules that meet weekly in the FIRE Sustainability Analytics lab. Each team selects an ongoing research project initiated in past years or a new one proposed by their cohort in the spring semester and chosen by the Faculty Leader as described in section 2.2. Each research project must fulfill the four criteria of "new knowledge" as defined by Henderson (2018):

1. Be of interest beyond the classroom.
2. Be addressed by a scientific method.
3. Be questions that do not have a definitive answer in the literature.
4. Produce findings that are disseminated.

The course utilizes two learning environments weekly: a classroom session where the Faculty Leader teaches additional research skills for fifty minutes and mentoring or collaborative work in the FIRE Sustainability Analytics lab for one to four hours. Students take ownership of their chosen research question and engage in an authentic research experience from start to finish in the FIRE Sustainability Analytics lab under close supervision of the Faculty Leader and PRMs. Their research workflow includes writing a literature review, collecting data, creating a summative data set, interpreting the data in the form of plots and maps, testing hypotheses, and forming conclusions, which fulfills all of Hansen's higher-order economic proficiencies as shown in Table 1. The process of collecting, cleaning, analyzing, and interpreting data guides students through an authentic data experience as recommended by guidelines of the American Statistical Association (2014) and as described by Grimshaw (2015). In addition, students develop resilience by submitting a draft of an output or a revised version each week.

Toward the end of the semester, students present their ongoing work at the annual FIRE Summit. At this scientific poster session, students develop their presentation skills and communicate their findings to FIRE Semester 1 students who have not joined a research group. At the end of the semester, students create a scientific research poster and present their findings to Faculty Collaborators who can provide technical feedback on the projects. Students who completed both FIRE Semester 2 and FIRE Semester 3 receive a FIRE Researcher micro-credential that can be displayed on places like LinkedIn and Portfolium. Course credits from FIRE Semester 1 and Semester 3 also count toward UMD's Scholarship in Practice general education credit requirement.

Table 2 lists which course activities enable each student to achieve the course's learning outcomes. A list of FIRE Semester 3 assignments in 2023 can be found in Supplementary Materials in the 2023 FIRE298 Syllabus.

2.5 Peer Research Mentorship

Toward the end of FIRE Semester 3, interested students can apply to become a PRM, and up to eight

students are selected each year. The primary roles of PRMs are to mentor new students and continue contributing to ongoing research projects. Like all FIRE Sustainability Analytics students, they receive credit by enrolling in a course. However, PRMs have the flexibility to adjust their commitment levels based on their chosen credit load. One-credit PRMs spend at least five hours in the FIRE Sustainability Analytics lab each week while two-credit PRMs spend at least eight hours in the lab each week.

PRMs play an essential role in the training process as they are more approachable to their fellow students, making it easier for students to ask for help. Since they have gone through the course sequence, they can address common difficulties. Moreover, they receive basic training to foster inclusivity,[5] teamwork, and camaraderie within the research group. Additionally, they serve as role models, illustrating how research experiences can be leveraged to secure fellowships and internships.

PRMs also continue to work on projects they contributed to when they were in FIRE Semester 3. If other current FIRE Semester 3 students are interested in working on the same project, the PRMs will become the team leader. Every spring semester, PRMs are responsible for creating posters for these projects and presenting them at UMD's Undergraduate Research Day. This event welcomes any undergraduate student with a supporting faculty member to present their research projects. PRMs are also encouraged to create research products that can be submitted and presented at other university-level and national conferences throughout the year, such as UMD's College of Agriculture and Natural Resources (AGNR) Cornerstone Event, the Annual American Fisheries Society Conference, the American Geophysical Union's Annual Meeting, Posters on the Hill, or the EPA Social Justice Data Challenge.

By continually contributing to research projects and disseminating them to different audiences, PRMs strengthen all of their higher-order economic proficiencies. The Faculty Leader provides regular ongoing feedback on each PRM's interaction with new students, which develops and improves their leadership skills. Due to their close relationship with the Faculty Leader, PRMs receive personalized letters of recommendation that allow them to secure competitive post-FIRE opportunities.

3 Institutional Support

Four factors contribute to making FIRE Sustainability Analytics an authentic undergraduate experience that enhances career readiness: a Faculty Leader, Faculty Collaborators, FIRE Administrators, and a collaborative learning space. This section describes the institutional support that FIRE Sustainability Analytics receives.

3.1 A Faculty Leader

The demand for faculty time is one of the main obstacles to engaging undergraduate students in research (Hoyt and McGoldrick 2017). To overcome this problem, the FIRE program appoints a dedicated Faculty Leader for each research stream. The Faculty Leader for FIRE Sustainability Analytics[6] teaches one section of FIRE Semester 1, FIRE Semester 2, and FIRE Semester 3 a year and is present in the FIRE Sustainability Analytics lab for at least sixteen hours a week throughout the semesters. Besides ensuring research, educational, and mentorship excellence within FIRE Sustainability Analytics, the Faculty Leader serves in two administrative committees within the FIRE program. The Faculty Leader is not in a tenure-track position, so Dr. Ruangmas does not have to prioritize publications over mentoring undergraduate students. However, the Faculty Leader can advance in UMD's Clinical Professor Track, which emphasizes teaching ability, scholarly, and administrative accomplishments.

The Faculty Leader determines which research questions are pursued, allowing students to work on novel research questions in environmental economics, but she does not have to supervise student-led

[5] Each semester, PRMs must read at least two assigned articles and write their reflections. In the Fall 2023 semester, they read articles by Kennedy, Fry, and Funk (2021) and Vera (2021).

[6] The Faculty Leader for Sustainability Analytics is appointed by the FIRE program. However, the Faculty Leader's office and the FIRE Sustainability Analytics lab are provided by the Department of Agricultural and Resource Economics.

research projects that extend beyond her expertise as can happen in other economics capstone courses (Klein 2013).

3.2 Faculty Collaborators

The key to a Faculty Leader's success depends on research excellence, educational excellence, and mentorship excellence (Light, Fegley, and Stamp 2019). Tenured Faculty Collaborators in the Department of Agricultural and Resource Economics support the Faculty Leader's research excellence. Each year, the Faculty Collaborators review research questions that will be undertaken and provide feedback to research progress presentations at the end of the semester. Current Faculty Collaborators are Dr. Lars Olson and Dr. Jorge Holzer. Dr. Olson is the founding faculty. Prior Faculty Collaborators are Dr. Anna Alberini and Dr. Sebastien Houde. With the backing of the Department of Agricultural and Resource Economics, the Faculty Leader consistently seeks advice from other professors and guest speakers within the department.

3.3 FIRE Administrators

The FIRE Administration team consists of a Director, two Assistant Directors who are also Faculty Leaders, and two staff Assistant Program Directors. They oversee recruitment and program-wide administration to support all 16 FIRE research groups and play a crucial role in providing the foundation for FIRE Sustainability Analytics educational and mentoring excellence. FIRE trains students in a CURE where active collaboration, iteration, and problem-solving without a solutions manual are essential. This process differs greatly from teaching a traditional course (Stamp 2017). At the start of each semester, the FIRE Administration assists Faculty Leaders in "backward designing" the curriculum, where learning outcomes are prioritized and course activities are later designed to meet the intended outcomes (Bean 2011, ch. 12). Throughout the semester, the FIRE Administration facilitates community of practice discussions on various topics, including tracking students' progress, enhancing their professional skills, and supporting their career goals—similar to the program described in Light, Fegley, and Stamp (2019). Furthermore, the FIRE Administration aids in building a community among Faculty Leaders across diverse research groups, fostering interdisciplinary research collaborations. The FIRE Administration organizes the annual FIRE Summit, providing all FIRE students the opportunity to showcase their ongoing research projects.

3.4 A Collaborative Learning Space

A learning environment such as a collaborative workspace facilitates student learning through interaction with the environment (Dewey 1986). The FIRE Sustainability Analytics lab, referred to as "the lab," was created from a shared office space that was remodeled and equipped as a modern collaborative learning center incorporating design practices of the SCALE-UP initiative (Beichner 2006) and the Learning Spaces Collaboratory (Narum 2013). The Faculty Leader's office is adjacent to the lab with a connecting door between. The lab itself comprises three large-screen monitors, three desktop computers, meeting tables, a small library, code cheat sheets, and research posters produced by the group. Images of the lab are featured in Figure 2. The Faculty Leader is available in the lab for a minimum of sixteen hours each week, while students are required to spend at least four hours per week working in the lab as part of the FIRE Sustainability Analytics course sequence. At the beginning of each semester, students indicate their availability in a survey form, and the Faculty Leader then groups students with similar schedules together. Students within the same group are required to come into the lab during the same time. Since research is an ongoing endeavor, mandatory lab hours assist students in establishing routines and effectively managing their time.

The large-screen monitors in the lab enable students to share their laptop screens with others. This functionality encourages collaborative work on programming scripts and research outputs.

Figure 2: The FIRE Sustainability Analytics Lab

Students can also seek guidance and feedback from PRMs. Being in a collaborative environment allows students to enrich their learning process through discussions with their peers (Yamarik 2017), and it develops professional skills such as teamwork, effective communication, and time management. Prior research has shown that these skills are both highly valued by employers and associated with success in life (National Research Council 2012; Heckman and Kautz 2012).

Once a collaborative learning space has been set up and the Faculty Leader has been appointed, the annual costs of running FIRE Sustainability Analytics are modest. Operational costs include a Posit Cloud subscription to ensure students have equal access to computing resources and poster printing to showcase students' work at various events. Other costs are institution-specific. At Maryland, the FIRE program provides Faculty Collaborators a small overload stipend to compensate for their commitment, which is in addition to their normal teaching load.

4 Research Projects and Outcomes

Since its inception in 2015, FIRE Sustainability Analytics has continued to produce and disseminate high-quality research projects. Table 3 shows a timeline of the eleven research projects that the group has worked on and presented at university and national conferences. The rest of this section briefly summarizes each research project.

Table 3: Research Project Timeline

	2015	2016	2017	2018	2019	2020	2021	2022	2023
1. Household Energy Use	a, b								
2. Fisheries Mgmt and Conservation Status	a	a	c						
3. Groundwater Use			d						
4. El Niño and Fisheries					a	e			
5. Grey Markets						f			
6. NBP and Social Justice									
7. Citrus Canker							a, e		
8. Forest Protection and Leakage							a		
9. Air Pollution and Crime							a, e		
10. COVID-19 and Water Pollution							a, g		
11. Light Rails and Air Pollution								e	a

Legend
- Project has ended
- Still in development

Note: The following letters designate where each research project was presented:
- a: Poster presented at UMD's Undergraduate Research Day
- b: Poster presented at Posters on the Hill
- c. Presentation at 2017 Annual American Fisheries Society Conference, Tampa, FL
- d: Multiple posters presented at American Geophysical Union's Annual Meeting
- e: Poster presented at UMD AGNR Cornerstone Event
- f: Results presented to USDA APHIS
- g: Video created for EPA Social Justice Data Challenge

4.1. Project Summaries

1. Household Energy Use
   Faculty Leader: Ian Page
   Faculty Collaborators: Anna Alberini and Sebastien Houde
   Project Description: Three projects concerning household energy use were conducted. One project examined how presentation of energy efficiency information online influences consumer purchase decisions. Another project analyzed the impact of fuel efficiency on household driving patterns in Italy and the United Kingdom. The third project studied households' energy audit choices and their differences in energy consumption patterns using data from greeNEWit, a local energy auditing company.
   Project Outcome: The third project was chosen to represent the state of Maryland at the 2016 Posters of the Hill conference.

2. Fisheries Management and Conservation Status
   Faculty Leader: Ian Page
   Faculty Collaborator: Lars Olson
   Project Description: To study how trade and species characteristics impact conservation status, students combined data from the Food and Agriculture Organization (FAO) with data from the International Union for Conservation of Nature and Natural Resources (IUCN). Project Outcome: This project resulted in a presentation "Synthesizing Trade Data and Fishery Conservation Status" in a session of the 147th Annual Meeting of the American Fisheries Society.

3. Groundwater Use
   Faculty Leader: Ian Page
   Faculty Collaborator: Lars Olson
   Project Description: The project analyzed which factors influence the farmers' decisions with respect to irrigation technology, crop choice, and groundwater extraction rates in the High Plains aquifer.
   Project Outcome: Two posters titled "Predicting Groundwater Usage with Machine Learning Methods and Traditional Statistical Techniques: An Application to the Ogallala Aquifer" and "Modeling the Determinants of Agricultural Groundwater Extraction in the Ogallala Aquifer" were presented at the American Geophysical Union's 2018 Annual Meeting.

4. El Nino and Fisheries
   Faculty Leader: Thanicha Ruangmas
   Faculty Collaborators: Lars Olson and Jorge Holzer
   Project Description: To study what fisheries have been affected by the 2015 El Niño, thirteen groups of students chose specific species to study and created data sets summarizing daily sea surface temperature and average latitude and longitude of each fishing vessel targeting those species.
   Project Outcome: Students presented a research poster at two of UMD's research events. The project did not continue due to inadequate data about each fishing trip.

5. Grey Markets
   Faculty Leader: Thanicha Ruangmas
   Faculty Collaborator: Lars Olson
   Project Description: With funding from the USDA APHIS, the project identified farms selling live poultry and eggs in Delaware, Maryland, and Virginia using publicly available online data from federal and state registries, online directories, and Google Places. Results from the project can provide information to support USDA APHIS's mission to safeguard U.S. agriculture and to enhance their capability to disseminate information during a poultry disease outbreak.
   Project Outcome: The Summer Fellows gave a presentation to 125 professionals from USDA APHIS and submitted a final report and programming codes used in the project to USDA APHIS.

6. NBP and Social Justice
   Faculty Leader: Thanicha Ruangmas
   Faculty Collaborator: Lars Olson and Jorge Holzer
   Project Description: Deschênes, Greenstone, and Shapiro (2017) found that the NOx Budget Program (NBP) decreased summertime NOx emissions from regulated counties by 330 to 440 tons but did not conclude if it evenly benefits all demographic groups. Eight groups of students re-examined the NBP's effect on reducing NOx from power plants in different North American Electric Reliability Corporation Regions. Each group then used an air pollution dispersion model to identify impacted communities and found different results.
   Project Outcome: The students were unable to clearly identify the winners and losers from the regulation due to a weak counterfactual. Code developed from the project is now being used as training materials for current students.

7. Citrus Canker
   Faculty Leader: Thanicha Ruangmas
   Faculty Collaborator: Lars Olson
   Project Description: With funding from USDA APHIS, the research project examines a stylized model of the optimal management of citrus canker. Optimal intertemporal policies for citrus canker control are being examined in two cases; first, in a single homogenous landscape and second, in a multiple heterogeneous landscape where the infestation can disperse from one orchard to another.
   Project Outcome: A manuscript which involves a theoretical analysis and a numerical case study in a homogenous landscape setting is being developed.

8. Forest Protection and Leakage
   Faculty Leader: Thanicha Ruangmas
   Faculty Collaborator: Lars Olson and Jorge Holzer
   Project Description: Sierra Leone and Liberia had high deforestation rates before establishing national parks to protect the Gola rainforest region on either side of the border. The project examined the change in deforestation rates after specific areas were protected.
   Project Outcome: The project found that protected areas reduced deforestation rates inside them. However, deforestation rates significantly increased in the 10 km buffer areas outside the park in Sierra Leone. The project did not continue as there were limited qualitative data sources and people willing to give interviews.

9. Air Pollution and Crime
   Faculty Leader: Thanicha Ruangmas
   Faculty Collaborators: Lars Olson and Jorge Holzer
   Project Description: According to Herrnstadt et al. (2021), air pollution can alter people's cognition and lead to higher violent crime rates. As Baltimore City has one of the highest crime rates in the United States, the project examines whether the same conclusion can be established.
   Project Outcome: Results showing correlations between pollution and crime were selected to represent the state of Maryland at the 2022 Posters on the Hill event. Since then, the relationship between crime rates and air pollution is being examined at the city and neighborhood level.

10. COVID-19 and Water Pollution
    Faculty Leader: Thanicha Ruangmas
    Faculty Collaborators: Lars Olson and Jorge Holzer
    Project Description: The impact of COVID-19 lockdowns on water quality changes in different areas of the Chesapeake Bay is being analyzed. Improved water quality has been identified in some areas.
    Project Outcome: Three students identified vulnerable communities with high pollution increases and made a video highlighting this result. The team of students received an "Honorable Mentions" award for the EPA's Environmental Justice Video Challenge for Students. The project is still in progress.

11. Light Rails and Air Pollution
    Faculty Leader: Thanicha Ruangmas
    Faculty Collaborators: Lars Olson and Jorge Holzer
    Project Description: Numerous studies have looked at the pollution reduction effect of subway openings, most notably Gendron-Carrier et al. (2022), but few have looked at light rails. This project is examining the impact of light rail openings on air pollution.
    Project Outcome: The project found that the only city that improved air quality after light rail opening is Charlotte, North Carolina. A credible counterfactual is being developed to establish whether the opening of light rails causes this.

5 Lessons Learned

5.1 FIRE Sustainability Analytics can fulfill a call for an equitable research opportunity for undergraduate students.

It is widely accepted that research skills are integral to achieving career readiness, whether in the job market or for graduate school (Hoyt and McGoldrick 2017). A high-impact practice that greatly contributes to this preparedness involves immersing students in research experiences (Kuh 2008). An equitable undergraduate research experience can increase participation from underrepresented minorities making scientific research more inclusive (Bangera and Brownell 2014). Despite the demand for undergraduate research experiences, the economics curriculum is still falling behind (Henderson 2018). FIRE Sustainability Analytics provides a solution to this conundrum by engaging large numbers of undergraduate students in research, regardless of their background or academic performance. From 2017 to 2021, the fraction of first-generation students in FIRE exceeds that of Carillon Communities[7] by 68 percent, surpasses College Park Scholars[8] by 36 percent, and more than doubles that of the Honors College.[9] FIRE and the UMD Office of Institutional Research Planning and Assessment used propensity score matching between FIRE students and demographically and academically matched students who did not participate in FIRE or any other living-learning program to examine the impact of FIRE participation on three-year retention rates. In every cohort from 2014 to 2019, FIRE participation increased three-year retention with an average increase in three-year retention rates of 5.6 percent.

[7] Carillon Communities is a one-year living-learning program where first-year students work with faculty to ask *big questions* that matter to our world and learn to use teamwork and creative problem-solving approaches ("About," University of Maryland Carillon Communities, 2024).
[8] College Park Scholars is a two-year living-learning program for academically talented students ("About," University of Maryland College Park Scholars, 2024).
[9] The Honors College is a highly acclaimed living-learning program for students with exceptional academic talents. It creates a close-knit community faculty and undergraduates committed to acquiring a broad and balanced education ("About Us," University of Maryland Honors College, 2024).

5.2 FIRE Sustainability Analytics can introduce students to environmental economics research and foster an appreciation of data analytics.

In every cohort, only a few students are familiar with environmental economics before joining FIRE Sustainability Analytics. Our observation indicates that exposure to the field's research during FIRE Semester 2 often sparks increased interest and appreciation for environmental economics among many students. In a class survey conducted at the end of FIRE Semester 2 in 2023, we inquired about the extent to which class activities enhanced their appreciation of research in FIRE Sustainability Analytics. Students were given the options of responding with "To a great extent," "Somewhat," "Very little," or "Not at all." The survey results, illustrated in Figure 3, clearly demonstrate that active involvement in preparing a literature review presentation, which involves delving into cutting-edge research papers, and participating in PRM sessions, where they discuss the data analysis methods employed in published research papers, contributed significantly to increasing their appreciation. In contrast, more passive activities such as listening to podcasts or lectures did not generate as much interest.

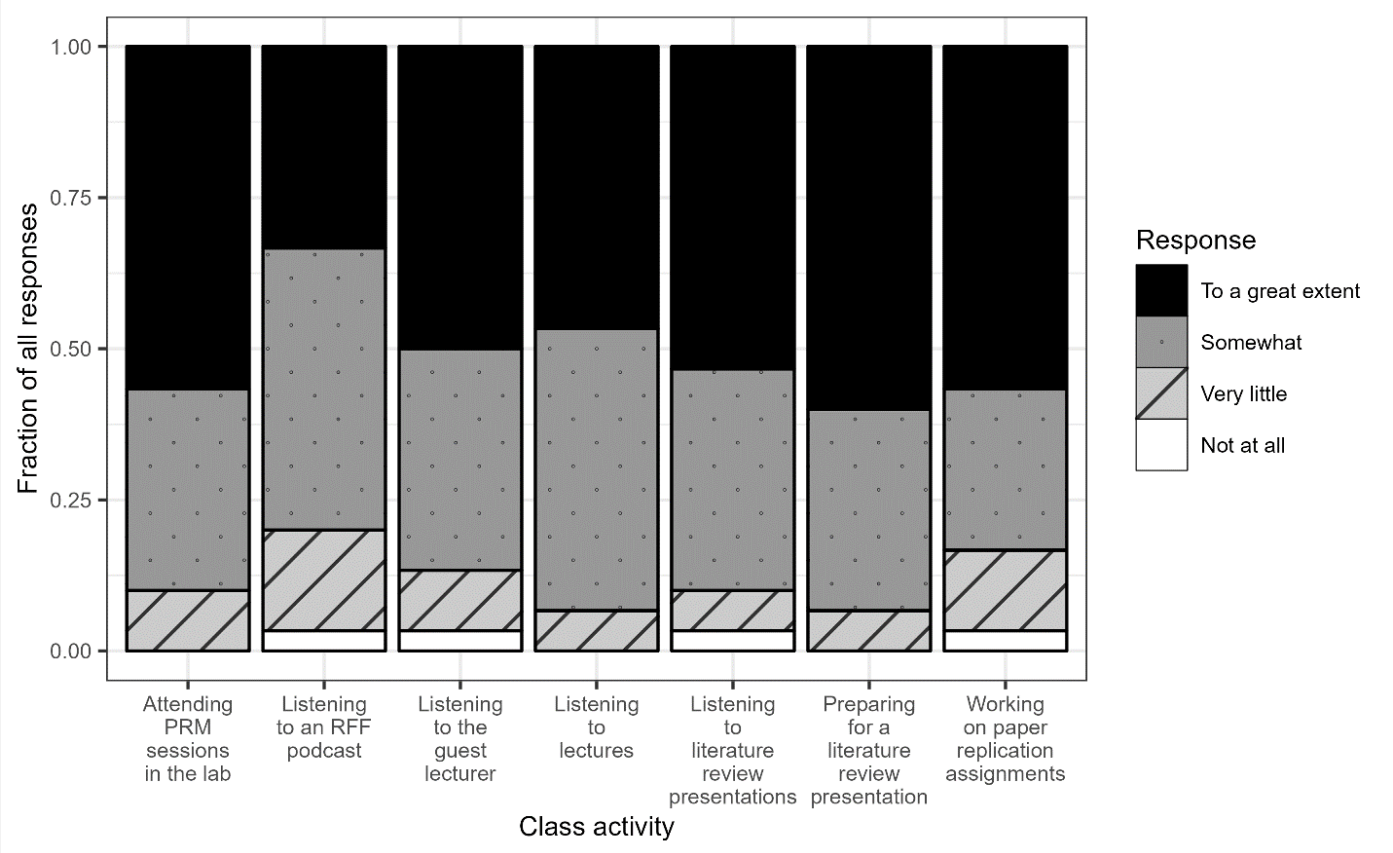

Figure 3: Class Activities That Increased Their Appreciation of FIRE Sustainability Analytics

Our experience aligns with the findings of Russell, Hancock, and McCullough (2007), indicating that an undergraduate research experience can result in increased interest in STEM careers. Over the years, several students initially majoring in environmental studies have opted to include a minor in geographical information systems. Economics students have developed an interest in applied microeconomic topics. Other students have shifted their focus from a Bachelor of Arts to a Bachelor of Science to specialize in data analytics.

5.3 An undergraduate experience can help develop Hansen's higher-order proficiencies in economics.

We affirm Henderson's (2018) findings that a well-designed undergraduate research experience can facilitate the development of Hansen's higher-order proficiencies. In addition to the previously presented Table 1 in section 2.4, which establishes the connection between class activities and Hansen's higher-order proficiencies, we further provide insight into students' perceptions of their proficiencies and learning outcomes through a class survey at the conclusion of FIRE Semester 3 in 2023, as depicted in Figure 4. This figure comprises four panels, each representing one of Hansen's higher-order proficiencies. Each bar in the figure illustrates the fraction of students' responses to the question "In your opinion, what learning outcomes have you achieved in the two semesters of FIRE Sustainability Analytics?" for specific learning outcomes of the courses. Students could choose "To a great extent," "Somewhat," "Very little," or "Not at all" for each learning outcome. We then link the learning outcomes to four of Hansen's six higher-order proficiencies as shown in four panels of the figure, where each panel represents one of Hansen's higher-order proficiencies. Two proficiencies are not represented because the survey was initially designed to improve the course in the future.

Figure 4 reveals that the majority of students perceive they can demonstrate a command of existing knowledge and interpret and manipulate economic data. Not surprisingly, as proficiencies become more advanced, the proportion of students who self-assess as proficient declines. Only about half of the students feel that they can interpret existing knowledge and apply it to a great extent. In part, these perceptions may stem from the addition of basic machine learning or modeling for prediction to the course content in 2023 and a resulting compression of material during the last part of the course. Assessing these learning outcomes is a useful part of the ongoing process to improve the program.

Furthermore, Figure 4 highlights that the benefits derived from the experience are not distributed equally, with students who invest more effort into their projects reporting greater benefits. Top-performing students have indicated that their work in FIRE Sustainability Analytics played a significant role in securing prestigious opportunities, such as the Ernest F. Hollings Undergraduate Scholarships, becoming Merrill Presidential Scholars, securing internships at the Federal Reserve, and working for esteemed organizations like the consulting firm Guidehouse and the International Monetary Fund.

5.4 Faculty-led projects can alleviate expertise and time constraints.

While one third of economic programs already offer research experience through student-led projects (Hoyt and McGoldrick 2017), there are challenges associated with establishing a successful undergraduate research program. First, faculty members are tasked with supervising research projects across diverse fields in economics, often extending beyond their expertise (Klein 2013). Second, the research projects stop after the semester ends and do not get disseminated. Third, both faculty and undergraduate students face difficulty navigating time constraints as developing a rigorous research project that contributes novel insights requires several years of work (Fenn et al. 2010).

FIRE Sustainability Analytics provides a potential solution to these challenges by involving undergraduate students in faculty-led research projects. The FIRE Sustainability Analytics's approach to project management has evolved over time in response to faculty and student experiences. When FIRE Sustainability Analytics was launched, the stream's research agenda was largely determined by a few tenure-track Faculty Collaborators in the Department of Agricultural and Resource Economics. The FIRE program recruited a Faculty Leader to direct the program's day-to-day activities, oversee student mentoring, and coordinate multiple projects with the faculty collaborators. Students were matched with

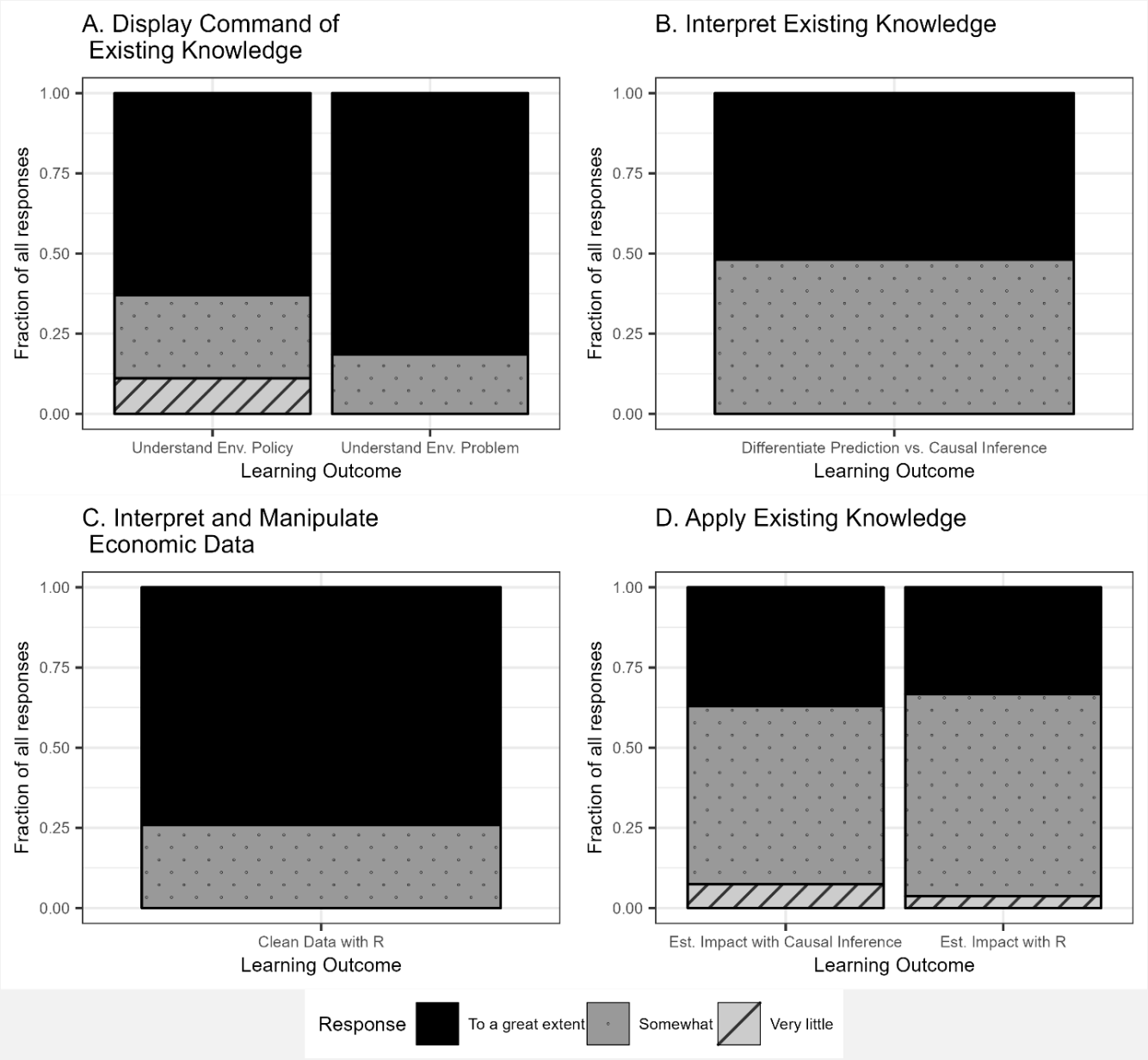

Figure 4: Student's Perceptions of Their Learning Outcomes and Proficiencies

projects and trained in research techniques appropriate for their project. The challenges of managing up to four research projects, not all within the expertise of the Faculty Leader, while simultaneously training students, made this mode of operation difficult to sustain.

In 2019, the initial Faculty Leader advanced professionally, and FIRE Sustainability Analytics welcomed a new Faculty Leader, Dr. Ruangmas, who led her own research project with the support of Faculty Collaborators. During her first two years, it was decided to streamline project management and the entire class worked on answering one faculty-led research question, with the class divided into groups focused on answering the same question in different geographic areas. However, this approach resulted in reduced student engagement and lower student retention. Through conversations with students, Dr. Ruangmas learned that some students, especially those majoring in environmental science or environmental studies, were extremely well-versed in highly interesting research topics. As a result,

Dr. Ruangmas allowed students to brainstorm research questions at the end of FIRE Semester 2, and she chose specific topics for the class to work on in FIRE Semester 3.

Pursuing faculty-led projects that are selected from a pool of student ideas allows the Faculty Leader to supervise projects aligned with her specialization. Faculty-led research by student teams also addresses the challenge of time constraints, as each student within a team contributes to a specific aspect of a larger project (Gitter 2021). Faculty oversight and the overlap between new cohorts and peer mentors enables projects to span multiple years, so a deeper understanding of research questions can be developed, and findings can be presented at various venues. PRMs who have already worked on the topics can quickly onboard new students. This approach not only overcomes time limitations but also offers students authentic research experience and professional development within a collaborative setting. While we have generated new knowledge in undergraduate projects, as defined by Henderson (2018), our aspiration is to publish our findings in the future.

6 Conclusion

A well-designed undergraduate research program, such as FIRE Sustainability Analytics, can offer significant benefits to students provided it receives the necessary institutional support and faculty commitment. Still, we believe that a smaller program implemented at the department-level can achieve the same benefits. Instead of a three-course sequence, a similar research program in applied economics can be condensed to two courses: a research methods and data analytics course, followed by a research-intensive course experience. These could be offered as a two-course sequence where the first benefits all students, with the second engaging interested students in an in-depth, authentic research experience.

In conclusion, we hope that this paper provides an outline for implementation of a course-based undergraduate research experience and an overview of the student success outcomes it can achieve.

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Teaching and Educational Methods

Integrating Mixed Methods and Service-Learning in Undergraduate Education in Applied Research Methods: A Course Preparing Students to Address Complex Social Issues

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JEL Codes: A22
Keywords: Mixed methods, service-learning, transdisciplinary, Vermont, wicked problems

Abstract
This paper discusses the methods and outcomes of an undergraduate social science research methods class in the Department of Community Development and Applied Economics (CDAE) at the University of Vermont (UVM). The course is required for all (approximately) 500 majors in this department. The paper reviews literature on experiential, service-learning (S-L) education, co-creation of knowledge, and mixed-methods research, arguing that the approaches prepare students to address wicked (complex social) problems. It then outlines the methods of the class and how these approaches are incorporated into class via a class research project with a community partner (CP). It presents the class's publications, awards, and impacts. The Conclusions section focuses on strengths and limitations.

1 Introduction

Research and education from institutions of higher learning have vital roles to play in addressing the most vexing issues of our day, including the sustainability of food systems, climate resilience, and community development. Almost two decades ago, Batie (2008) called for applied economists to develop the tools and knowledge to address so-called wicked problems (WPs), problems of high social complexity. Another applied economist, Peterson (2009) emphasizes the need for co-created knowledge as an essential tool to attend to WPs. Since then, scholars from across disciplines have documented educational approaches to address WPs. Kłeczek, Hajdas, and Wrona (2020) call for project-based learning to address WPs. Harker Steele and Bergstrom (2018) emphasize the need for a participatory, student-centered approach to tackle WPs. Dekker et al. (2020) note the need for transdisciplinary[1] approaches to solve WPs, a view echoed by Conner (2022).

Service-learning (S-L) has many elements to address WPs: project-based, student-centered, and participatory approaches. S-L is defined as "experiential education in which students engage in activities that address human and community needs together with structured opportunities intentionally designed to promote student learning and development" (Jacoby 1996). For example, Van Meter (2012) discusses the role of S-L in creating sustainable citizens able to confront WPs. McGowan and Branche (2020) discuss the use of S-L to help students develop higher-order thinking skills, synthesize information, and draw conclusions on highly complex topics.

This paper discusses the methods and outcomes of an undergraduate social science research methods class in the Department of Community Development and Applied Economics (CDAE) at the University of Vermont (UVM). The objectives include: (i) highlight the merits of S-L instruction and a mixed-methods course to address WPs; (ii) provide an example of a class with these features in an

[1] In this paper, I operationally define "transdisciplinary" research as having submersed disciplinary frames, adaptive and iterative methods, and the aim to address gaps that exist between disciplines (Baker et al. 2009).

applied economic department; and (iii) contribute to discourse on incorporating these features in future classes.

CDAE was a pioneer in bringing a transdisciplinary approach to applied economics at land-grant universities (Baker et al. 2009). The course, previously CDAE 250, recently renumbered as CDAE 3500, Applied Research Methods, is required for all (approximately) 500 majors in this department. This section is taught every Fall semester by Professor David Conner and has an enrollment of approximately 55 students. The class utilizes a S-L approach. The official goals of the class are to:

1. Develop necessary methodological and analytical abilities to evaluate and critique research arguments, involving both qualitative and quantitative information;
2. Be equipped with skills and techniques needed for successfully completing an independent capstone senior project and lifelong research needs; and
3. Apply class concepts to conduct research to benefit a community partner (CP) in an S-L format.

The unofficial goals are for students to become better consumers and producers of research; by producing research, they become more discerning consumers of it as well. The unofficial goals are stated to emphasize the key intended outcomes in layperson terms. The class has been taught once a year by this instructor since 2011. Other sections have been taught by other instructors in different formats.

Each year, a CP (usually one based at the university) brings to the class a research problem, to understand student awareness, beliefs, experiences, and behaviors germane to the organizations' mission. Past partners (and topics) have included UVM Dining (The Real Food Challenge and demand for sustainably raised livestock products), Office of Sustainability (reducing plastic bottle waste, climate change, and sustainable transportation), Center for Teaching and Learning (CTL; online learning, "belonging" in the classroom, and student use of Artificial Intelligence), and UVM Career Center (overall efficacy).

The class engages CPs in or close to the university, so that the research subjects are university students. The intent of this practice is to make the topics more relatable and research subjects more accessible.

The research topics addressed by the class generally have elements of WPs: complex, ill-structured social problems influenced by social and political factors as well as biophysical complexity (Batie 2008). These topics involve multiple stakeholders and require nuance and understanding of tradeoffs in addressing them.

2 Literature Review

The following section will review literature in S-L, co-creation of knowledge, and mixed-methods research. Following that, the methods of the course will be discussed, along with an overview of outputs and evaluations. It will conclude with a discussion section, featuring reflections and future plans.

2.1 Service-Learning

Jacoby (1996) defines S-L as "experiential education in which students engage in activities that address human and community needs together with structured opportunities intentionally designed to promote student learning and development" (Jacoby 1996). S-L brings many student benefits, including increased knowledge retention, civic engagement, and professional skill development (Eyler and Giles 1999; Eyler et al. 2001). CPs gain from improved networks and greater university ties as well as the tangible outputs or deliverables of the class projects (Eyler et al. 2001).

Celio, Durlak, and Dymnicki (2011) identify key practices that improve beneficial outcomes to students. First, the S-L component should be aligned with curricula and include clear goals and articulation of the relationship between learning and service outcomes. Second, the class should allow for student voice in input on design of the project. Third, a strong connection to the CP improves

multiple outcomes. The partner should also have a voice in the service component subject and design. The benefit to both students and partners should be clearly articulated, and opportunities should be made to forge positive relationships between both faculty and students and the partner. Finally, reflections help to link the service project to course learning outcomes, as well as providing students with greater confidence, self-efficacy, and caring relationships.

2.2 Co-Creation of Knowledge

Another pedagogic goal of the class is to foster co-created knowledge, as well as transferring explicit (written or spoken) knowledge and facilitating tacit (how-to) knowledge. Peterson (2009) emphasized the unique role of co-created knowledge in addressing complex issues and its high strategic value when created and used. Conner et al. (2014) argue that explicit, tacit, and co-created knowledge are all needed in food and agricultural entrepreneurship curricula; further work corroborates the role and value of co-created knowledge in food businesses in Vermont (Conner 2020).

2.3 Mixed Methods

Another theme emphasized throughout the class is the value of mixed-methods research; using a combination of idiographic, qualitative, and nomothetic, quantitative data brings depth and breadth of perspective, accuracy, and precision, respectively, with each type of data, shoring up the weakness of the other (Babbie 2010). Mixed-methods approaches are increasingly seen as necessary to address complex social issues (Bigler et al. 2019; Strijker, Bosworth, and Bouter 2020). A goal of social science research is to deeply understand the subjects' experience of a given phenomenon; this class takes a positive approach, rather than the normative (assuming a single correct rational action subjects should take) approach used in many economics studies.

3 Methods

As discussed above, this is a S-L class taught in Fall semester. Over the summer, before the class begins, the CP is finalized. Thus far, the CP has been an on-campus entity. The instructor and CP discuss and delineate the details of the research project the CP would like to undertake. A few key features are: (i) they are able to articulate how the results will be used, and (ii) the target research subjects are mostly or entirely composed of UVM students. The latter provision is intended to reduce time and effort finding subjects, and to make for an emotionally and possibly physically safer process. Generally, the goal of the research is to understand student beliefs, perceptions, knowledge, and behaviors around some issue the CP's organization is facing.

The CP attends class four times. The first meeting is to introduce the partners and the research topic and questions. The CP explains why the results are important and how they will be used; demonstrating that the results will not just sit on a shelf but be put into action engages and motivates students. The second meeting takes place after the literature review and observation assignments are complete (see below for more detail on each assignment). The class discusses key themes and results from these activities and then brainstorms interview questions. In the third meeting, the class discusses results from the interviews and brainstorms survey questions. In the final meeting, near the end of the semester, the class discusses survey results and overall results, implications, and recommendations.

The students engage in four research activities: a literature review, an observation, a series of interviews, and a survey, each with an accompanying homework. They also compose a final report, compiling, refining, and summarizing the previous results. Homework assignments are done both as individuals and in groups of four (with the occasional groups of three or five depending on class size). The literature review has two parts: after a session led by the department's refence librarian liaison, each student finds and cites five relevant articles, and puts them in a wiki so that all other students can

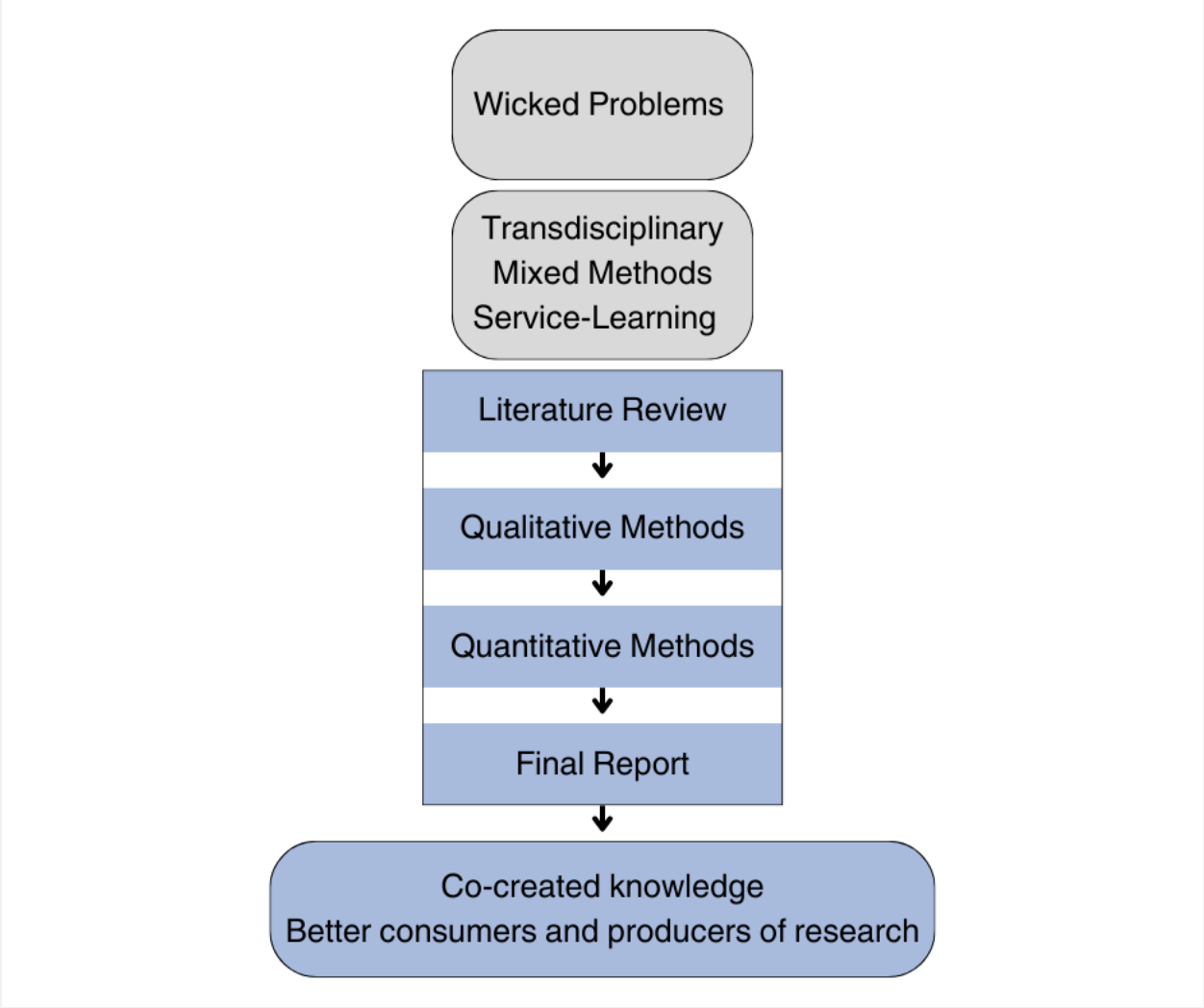

Figure 1. Overview of Course Activities

see and use them. In part two, each group writes a (approximately) ten-page literature review, ending with an identified gap in the literature. Students are presented with a number of options on how to organize a literature review (chronological, pro and con, by dimension and by stakeholder type). The instructor holds a workshop about a week before the due date of the literature review, reviewing outlines and drafts of progress so far. The instructor also provides examples of assignments from previous years that earned all or nearly all possible points.

Next, each individual conducts a participant observation. This has been the assignment most varied and challenging to design. The goal is for the students to experience a phenomenon first-hand—to get a sense of the "vibe"—before collecting data from others. This assignment is designed in conjunction with the CP. Part examples include: visiting online class pages; visiting a dining hall to see how food is presented and marketed; attending a climate justice rally; and using a type of sustainable transportation (e.g., bus, bike) they do not normally use. Students fill out a document with a number of prompts (date and time; expectations before beginning; reflections on their experience—emotions and impressions, descriptions of other people, and their behaviors; and sensory prompts—sights, smells, and sounds). It concludes with reflections on what they learned (what was new, unexpected) and ideas for questions on interviews.

For the third homework, students conduct and analyze data from five interviews. Ideas for questions are brainstormed in the second CP meeting (and a fast-typing student records the various ideas on the classroom computer and displays on the screen). Students are reminded that interview questions should be ordered by three principles: general to specific, most to least important, and least to most risky. The instructor takes the list of brainstormed questions, identifies common and important themes, and composes a draft interview guide, which is shared with and edited as needed by the CP until all agree on a final version. When the interview homework is assigned, the class brainstorms dimensions of variability in the subject population (major, year of study, on- or off-campus; as well as gender, race, ethnicity, age, and place of origin). The class discusses strategies and the importance of a diverse sample, and outlines strategies on how to gain one. Each student interviews five subjects.

In addition to a class session on qualitative data collection (key informant interviews and focus groups), there are two sessions on qualitative data analysis. Students are taught the basics of coding in one class; then in the next class, they are given part of a transcript from a previous unrelated study and asked to list open, axial, and selective codes. They code the data in these three steps alone, then compare them with a partner, and then the whole class attempts to reach consensus. For the homework assignments, the groups of four write a report on the methods, results, and implications of the interviews. In the results section, they present the (approximately five to eight) axial codes and (one or two) selective codes (Babbie 2010) that emerged from the interviews, creating a heading and description of that theme, describing the range and relative frequencies, and giving at least one quotation that captures each. Implications focus on key findings to date, how they may be used, and ideas for survey questions.

For the fourth homework, students help design an online survey, solicit responses, and analyze the data. Similar to the interview, the survey questions are brainstormed by the class (during the third CP meeting). Key demographic variables to the study are also discussed ("do we believe different demographic groups' views should be recorded? Would different demographic groups answer questions differently and why?"). The question ideas are recorded, then the instructor creates a draft and shares it with the CP, who edits it. When complete, the instructor uploads it into the Qualtrics platform. Students are directed to obtain ten responses (and get one homework point for each response up to ten): the first question of the survey asks the name of the student to be credited by the response. Questions generally focus on attitudes, beliefs, awareness, and behaviors around the research topic (often using Likert-type scales) along with demographic variables. The instructor converts the data in an SPSS file. In groups, the students compose a report on the survey portion; they outline the methods and choose eight to ten variables of interest to provide descriptive statistics or frequencies. They also conduct two bivariate analyses, and test and report on statistically significant differences in response among various groups (e.g., testing a null hypothesis that different genders or majors had no difference in responses to a question of perception or behavior). Prior to the survey design and data collection and analysis, class sessions cover survey strategies (length, sections, and question order) and variable types (nominal, ordinal, interval, and ratio). Subsequent sessions cover statistical inference, and the appropriate bivariate and regression analyses for different variable types. Throughout the semester, the students have a weekly computer lab taught by a graduate assistant, where they learn to use SPSS.

Finally, each group composes and submits a final report. They integrate and adapt the prior four assignments (literature review, observation, interviews, and surveys) and develop implications and recommendations for the CP based on the results. It is emphasized that simply cutting and pasting is insufficient; research is an iterative process where new results should cause you to reflect upon and re-evaluate prior framing, assumptions, and results, and revise accordingly. The students must revise the literature review and curate results to make a cogent argument in order to earn full points on this report. The intentions of the final report are to: (i) give experience and test the ability to form an argument based on data; (ii) provide results and recommendations for the CP; and (iii) provide a tangible output, evidence of having completed a research project, for the student' portfolios.

In addition to the homework assignments, the class also has a midterm and final exam (which tests the students' ability to conduct research on topics other than the S-L project and use methods such as experiments and different sampling techniques), a lab grade, and participation points. The class uses a flipped classroom where the students watch pre-recorded video lectures on each topic prior to class, then use class time to answer questions and discuss why, when, and how the method is used. Each video lecture has a small assessment, due before class, to motivate the student to watch the video. There are two class sessions on how to evaluate the veracity of research claims and outputs, one each near the beginning and end of the class, to enable the goal of being better research consumers. Finally, the qualitative research component includes a discussion on how to demonstrate rigor in qualitative work.

The class also has frequent informal check-ins and two (mid and end of semester) exercises where the professor makes columns titled start, stop, and keep, and invites the students to write what the professor should start doing, stop doing because they do not work, and keep doing because they are effective. The professor leaves the room and asks students to fill the column and put check marks next to things they agree with. When complete, the professor returns and discusses them with the class.

4 Results

Students gained experience and skill in research ethics, conceptualization, research design, literature review, and qualitative and quantitative data collection and analysis. Other topics covered in class, but not directly used in the research project, include experiments and epistemological social and economic paradigms.

4.1 Publications

In two cases, the instructor selected a group of outstanding students and composed and published peer-reviewed articles on the data from the class project; the topics were campus sustainability perceptions, working with UVM's Office of Sustainability (Conner et al. 2018), and demand for humanely raised animal products, working with UVM Dining (Robinson et al. 2021). A Food Systems MS student used the data in her thesis and published an article on students' experiences of UVM Dining's Real Food Challenge program (Porter et al. 2017). A Natural Resources MS student used class data on students' emotional responses to climate change in her final project paper (McCamp 2020).

4.2 Awards

This class has led to a number of teaching awards. The instructor won the North American Colleges and Teachers of Agriculture's Excellence in Teaching Award in 2014 and the UVM College of Agriculture and Life Science's Carrigan Award for Excellence in Teaching and Undergraduate Education in 2021. The CP for the Fall 2021 class, Sarah Heath of the UVM Career Center, was recognized by UVM's Office of Community-Engaged Learning in April 2022.[2]

4.3 Impacts

A few policy and practice changes were guided by the class's research. In an effort to decrease single use water bottle use, a number of water fountains were fitted with bottle fillers; the locations were based on suggestions from the interviews and surveys. The UVM Dining changed labelling practices to promote the Real Food Challenge and started serving more items made entirely to qualify as "real" foods (sustainable, local, humane, and fair).[3]

[2] https://site.uvm.edu/cals-news/cdae-community-partners-recognized-for-commitment-to-students/
[3] https://www.uvm.edu/sites/default/files/RFWGMinutes2013.05.21.pdf

4.4 Testimonials

Testimonial 1
Working with Professor Conner's CDAE class in Fall 2021 was of real benefit to the UVM Career Center. Though the audience surveyed was not necessarily representative of the whole student body (given the CDAE slant), it was nevertheless a treasure-trove of information from nearly 500 students. Not only did it confirm our suspicions (that we already offer most of what students want, they just don't know it)—which was tremendously helpful in informing our marketing and outreach efforts—but it also allowed us to point to a data set backing our new strategies when sharing them with university leadership. The attached card—given out to academic advisors—is an example of a direct result from this research, and so was the creation of our BuzzFeed-esque quizzes that guide students' career preparation. Of course, we still have to get students to use the quizzes, but that is a question of culture shift that will take time. It was great working with David and his students, and the research has proven so useful, we still reference it regularly.

Testimonial 2
The Office of Sustainability has worked with David's class multiple times since 2011, and we have benefitted from the qualitative and quantitative data collection and analysis provided. We often use the surveying the class does as a pilot for future surveying efforts, and methodological support from David has helped us answer meaningful questions (about everything from food/beverage systems and campus sustainability efforts to transportation and climate anxiety) with confidence. The interviews students conduct are especially valuable in giving us insight into the beliefs, values, and attitudes of the student body that our staff would not have the capacity to conduct at such scale. The peer-to-peer nature of these interviews creates a uniquely relaxed, trusting, and open environment that results in more honest and candid responses than our staff could facilitate. Working with the class also gives us an opportunity to engage with the students and tell them more about the work of our office. We appreciate David's commitment to providing the student with real-world projects that benefit the campus and community.

Testimonial 3
In Fall 2020, the CTL partnered with Dr. Conner and students enrolled in CDAE 250, Applied Research Methods, to explore the relationship between teaching practices grounded in pedagogy of care, inclusivity, and belongingness and student engagement. At a time when both students and faculty were feeling disconnected, this collaboration was timely and valuable. During the COVID-19 pandemic, students and faculty needed to quickly adapt to online learning, video conferencing, and socially distanced classrooms. Dr. Conner and his students designed a study to help CTL better understand what teaching behaviors were helpful, supported student learning, and caused students to feel more connected in uncertain times. The results helped to inform CTL's programming for faculty. The data provided validation for the center's continued emphasis on creating a supportive social presence, course design that was both flexible and structured, and adjusting expectations given the state of the world. The opportunity to "ground-truth" our programmatic themes using UVM faculty and students data strengthened our resolve to move forward with our work.

5 Conclusion
This paper highlights the objectives, methods, and outcomes of an applied social science research methods class at UVM. The intent of the class is to instruct the use of mixed-methods research in a S-L format, creating better producers and consumers of research to be able to confront WPs, the most important and complex issues of today. The class instructs in mixed methods because this approach is

well-suited to holistically address complex problems (Bigler et al. 2019; Strijker et al. 2020). Especially, this class uses qualitative (observation, interviews, and inductive coding) and quantitative (surveys and statistics) methods to provide both breadth and depth to the topic as well as give students more research tools for future use (Babbie 2010).

The class intends to incorporate S-L best practices as posited by Celio et al. (2011), succeeding in certain ways better than others. The research project explicitly uses methods learned in class to address the CP's research objectives. Student input is incorporated throughout, especially in the interview and survey instrument design, although the topic is set before the course begins. Four CP meetings permit some relationship building between students and the CP, although large class size and short class time (50 minutes) limits this. Students mainly reflect via the start-stop-keep exercise and anonymous course evaluations. Common critiques include a wish for each student to pick an individual research project (which would be logistically difficult if not impossible in a class this size) and the occasional grumble that students are doing unpaid work for the university.

As discussed above, the stated goals of the class are to make the students better consumers and producers of research. Students generate co-created knowledge (Peterson 2009; Conner et al. 2014) alongside the professor and the CP, developing recommendations for the specific context of the project. Finally, student final reports contribute to their portfolios, providing tangible evidence of their research ability and experience for future education and employment opportunities.

The research topics covered in the classes have elements of WPs. By tackling complex topics such as artificial intelligence, climate change, and food systems sustainability, students use results to make recommendations for multiple stakeholders with different viewpoints and which must balance biophysical, social, and political factors with inherent tradeoffs.

The major challenges of this class have been finding and selecting CPs and addressing student feedback that they are being used as unpaid labor, doing research the university should pay for itself. The first challenge is addressed by being proactive, developing a course outline and partner expectations, and beginning inquiries in April for the following Fall semester.

The strengths of this class are its experiential, hands-on nature, producing benefit to both students and CPs, and its emphasis on mixed-methods research, all of which prepare students to confront complex problems. The major weakness is the lack of time devoted to each method, necessitating further education to gain depth in one or more of the methods covered. One limitation is the exclusive use thus far of internal partners; external partners may bring different perspectives and objectives. Pre- and post-tests could be used to measure course impacts more precisely, as would student testimonials.

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Note: According to the policy defining activities, which constitute research at the University of Vermont/University of Vermont Health Network, this work met criteria for a project that does not require IRB review.

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AAEA Agricultural & Applied Economics Association

Teaching and Educational Methods

Creating and Implementing Undergraduate Research Experiences: An Example for Analyzing the Size, Structure, and Performance of U.S. Food Manufacturing Industries

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Abstract
The article explains how to create and implement undergraduate research experiences using an example for analyzing the size, structure, and performance of U.S. food manufacturing industries. The research projects discussed in the article utilize publicly available data reported by the U.S. Census Bureau. The food manufacturing industries can be analyzed at the U.S., regional, and state level. In addition to gaining valuable data collection and analytical research skills, students acquire knowledge on economic and business aspects of food manufacturing industries that can be useful in their future careers. The research example presented in the article can be easily modified to fit the course, the level of undergraduate students, and the audiences.

1 Introduction

This article provides an example of how to create and implement a research experience for undergraduate students. This example demonstrates that an instructor can provide a clearly defined research topic area, guidance on how to access publicly available secondary data, and instruction on specific methods for analyzing these data that are well within the skill sets and academic development of a typical undergraduate student.

The research example is an analysis of the size, structure, and performance of food manufacturing industries in the United States. The research projects developed using this example would utilize publicly available data reported by the U.S. Census Bureau (U.S. Census Bureau 2024a). The food manufacturing industries can be analyzed at the U.S., regional, or state level. In addition to gaining valuable data collection and analytical research skills, students acquire knowledge on economic and business aspects of food manufacturing industries that can be useful in their future careers.

The student learning objectives are:

1. Locate economic data in the U.S. Census Bureau publicly available databases and use these economic data to characterize the size, structure, and performance of the U.S. food manufacturing industries.

2. Assess the revenue structure, profitability, and economic effectiveness of food manufacturing industries by using revenue-related indicators (e.g., value of shipments and value added), cost-related indicators (e.g., annual payroll, cost of materials, and capital expenditures), and number-related indicators (e.g., number of companies, number of establishments, and number of production workers).

3. Conduct benchmarking analysis of state and regional industry performance.

The article is organized as follows. Section 2 discusses the place in the curriculum of the undergraduate research projects discussed in the article. Section 3 explains the classification of food manufacturing industries and data sources. Section 4 discusses economic indicators that are suitable to be used in undergraduate research. Section 5 explains alternative methodologies that can be used to analyze the size, structure, and performance of food manufacturing industries. Section 6 outlines

alternative designs for undergraduate research projects. Section 7 discusses potential audiences for students' research outputs. Section 8 is the conclusion and recommendations. The teaching note Excel file includes yearly data for the U.S. food manufacturing industries for the period of 2018 to 2021 reported in the U.S. Census Bureau Annual Surveys of Manufactures that can be used in undergraduate research projects.

2 Place in the Curriculum

The research projects developed using the example presented in this article can be incorporated in a variety of undergraduate courses in several ways. First, these research projects can be used in stand-alone undergraduate research courses as explained in this section. Second, these research projects can be incorporated in capstone courses, for example in an "Agribusiness Management" course typically offered as a capstone course in undergraduate agribusiness programs. Third, these research projects can be assigned in senior-level courses where research projects are required. The course examples include "Analysis of Food Markets," "Agribusiness Management and/or Strategy," "Agricultural and Food Marketing," "Food System Organization and Policy," "Regional Economics and Policy," and "Agricultural and Food Policy."

The research projects discussed in the article were offered to first-year undergraduate Honors Program students, who took HON 290H "Undergraduate Honors Students Research" course taught at Iowa State University and administered by the Honors Program. During the fall semester, instructors teaching this course upload descriptions of their research projects to be available to first-year Honors Program students on the Honors Program webpage. In addition to the research project descriptions, instructors specify skills that students selecting the projects should possess and their responsibilities. The description of the research project discussed in this article is included Appendix I. During the fall semester, first-year Honors Program students select research projects that they are interested in working on during the following spring semester.

Two first-year undergraduate Honors Program students were enrolled in this course in Spring 2023. One student is an Economics major student. This student conducted a comparative analysis of the size, structure, and economic effectiveness of food manufacturing industries in three states with a similar agriculture and food manufacturing profile located in the U.S. Midwest region (Iowa, Illinois, and Missouri). The other student is a Global Resource Systems major student. This student evaluated the revenue structure and profitability of food manufacturing industries located in Iowa.

The class met in-person approximately two times a month during Spring 2023. Canvas was used to upload class materials: literature, web-links to data sources, sample data sets, etc. During the first three to four meetings, the instructor explained the main economic indicators, data sources and data collection procedure, and alternative methodologies that could be used to analyze these data. Each student made an individual decision on the methodology to use and geographic scope of their analysis. The Honors Program at Iowa State University requires students registered for this course to present their research during either the Spring Undergraduate Honors Research Symposium or in small discussion groups. By the end of March, both students completed data analysis in Excel and prepared PowerPoint presentations.

3 Food Manufacturing Industries

To classify all industries, the U.S. Census Bureau uses the North American Industry Classification System (NAICS), which was adopted in the United States, Canada, and Mexico in 1997 (U.S. Census Bureau 2024a). NAICS replaced the Standard Industrial Classification (SIC) system that had been used in the United States prior to 1997. According to NAICS, the food manufacturing industry group (311)[1] includes

[1] The NAICS code is in the parentheses.

nine groups of individual industries: animal food manufacturing (3111), grain and oilseed milling (3112), sugar and confectionary product manufacturing (3113), fruit and vegetable preserving and specialty food manufacturing (3114), dairy product manufacturing (3115), animal slaughtering and processing (3116), seafood product preparation and packaging (3117), bakeries and tortilla manufacturing (3118), and other food manufacturing (3119).

This classification is referred to as a four-digit classification level. Each of these groups of industries includes a number of sub-groups or product classes, up to a six-digit classification level. For example, dairy product manufacturing includes dairy product (except frozen) manufacturing (31151) and ice cream and frozen dessert manufacturing (31152). Dairy product (except frozen) manufacturing (31151) includes fluid milk manufacturing (311511) and cheese manufacturing (311513), among other product classes.

The following two U.S. Census Bureau surveys are the main sources of data (economic indicators) that can be used to analyze the size, structure, and performance of food manufacturing industries in the United States. The first one is the U.S. Economic Census surveys that are conducted every five years (U.S. Economic Census 2024). The second one is the Annual Survey of Manufactures (U.S. Census Bureau 2024b). Most of the economic indicators that can be used to analyze the size, structure, and performance of food manufacturing industries in undergraduate research are available in both surveys. The data reported by the U.S. Economic Census and Annual Survey of Manufactures are widely used by various government agencies, individual business entities, and trade organizations.

The U.S. Census Bureau surveys are conducted on an establishment basis. All economic indicators are reported per establishment and then aggregated over all establishments comprising a particular product class and industry. An establishment is a single physical location at which business is conducted (i.e., plant, warehouse, or shop). It may or may not be identical with a company (i.e., firm or enterprise). A firm can have only one establishment; in this case the establishment and the firm are identical. However, in many cases, the same firm has more than one establishment. For example, many food manufacturing companies operate more than one plant often located in different geographic areas. Each establishment is included in a separate industry classification conditional on its main activity, which may be different from its company's main activity.

4 Economic Indicators

The main economic indicators that can be used to analyze the size, structure, and performance of food manufacturing industries in undergraduate research can be generally combined into three categories. ***The number-related indicators*** include number of companies, number of establishments, number of employees, number of production workers, number of production workers hours, etc. ***The cost-related indicators*** include annual payroll, cost of materials, capital expenditures, etc. ***The revenue-related indicators*** include the value of shipments, value added, etc.

The economic indicators are reported for each industry (at all available digit-classification levels) for a particular calendar year. In the case of the Annual Survey of Manufactures, economic indicators that can be used in undergraduate research are reported for each calendar year (except for number of companies and number of establishments). In the case of U.S. Economic Census, economic indicators are reported for years ending in "2" and "7." If an industry has a small number of companies, selected economic indicators (e.g., number of companies and/or number of establishments) may not be disclosed due to data confidentiality issues. The economic indicators are reported for the United States and for all individual states. The web links to data sources are provided in Appendix II.

The number of companies includes all companies operating in the industry.[2] ***The number of establishments*** includes all establishments associated with the industry. The number of establishments may or may not be identical with the number of companies, as it was explained in the previous section. ***The number of employees*** includes all full-time and part-time employees on the payrolls. ***The number of production workers*** includes workers engaged in fabricating, processing, assembling, inspecting, receiving, storing, handling, packing, warehousing, shipping, maintenance, repair, recordkeeping, and other services closely associated with the production operations. ***The number of production workers hours*** includes all hours worked or paid for at the manufacturing plant.

Annual payroll includes the gross earnings of all employees on the payroll paid in the calendar year. ***Cost of materials*** refers to direct charges actually paid or payable for items consumed or put into production during the year; in particular, it includes the cost of materials or fuel consumed. In the case of food manufacturing industries, the cost of materials typically includes the cost of agricultural materials, semi-processed foodstuffs, other ingredients, packaging and containers, fuels and energy, and contract work. ***Capital expenditures*** represent the total new and used capital expenditures reported by establishments in operation; these are the expenditures related to new and used machinery and equipment as well as permanent additions and major alterations to manufacturing establishments.

Value of shipments (revenue or sales) includes the received or receivable net selling values, "Free on Board" (FOB) plant (exclusive of freight and taxes), of all products shipped as well as all miscellaneous receipts. ***Value added*** is the difference between value of shipments and cost of materials, supplies, containers, fuel, plastic, purchased electricity, and contract work. The value-added indicator avoids duplication resulting from the use of products of some establishments as materials by others. For example, in the case of food manufacturing industries, the cost of raw agricultural materials, containers, packaging, and fuel is included in the value of shipments; however, it is not included in the value added generated by these industries. In other words, the value added includes the value of recourses added to raw agricultural materials to produce the final product and also the value that consumers attribute to a particular product, which is reflected in the level of price and profit. Therefore, the value added in food manufacturing typically includes wages paid to employees, depreciation of fixed assets (i.e., capital expenditures), advertising and promotion expenditures, and profit.

While both the value of shipments and value added can be used to evaluate the size, structure, and performance of food manufacturing industries, the value added is considered to be superior to the value of shipments as it avoids double-counting of certain resources, which is inherent to the value of shipments. Therefore, the value added is a preferred measure to assess the performance of food manufacturing industries (Connor et al. 1985; Connor 1988). According to the U.S. Census Bureau, "value added is considered to be the best value measure available for comparing the relative economic importance of manufacturing among industries and geographic areas" (U.S. Census Bureau 2024c).

5 Data Analysis: Methodologies

To analyze the size, structure, and performance of food manufacturing industries in undergraduate research, a variety of economic indicators reported by the U.S. Census Bureau and economic ratios (shares) constructed using these indicators are used. Selected economic indicators and economic ratios (shares) are discussed in two books focusing on the structure, conduct, and performance of food manufacturing industries in the United States (Connor et al. 1985; Connor 1988), U.S. Department of Agriculture, Economic Research Service reports (Huang 2003; U.S. Department of Agriculture, Economic Research Service 2023), and several academic articles (Asiseh et al. 2009, 2010; Bolotova 2008, 2016;

[2] The economic indicator definitions are provided on the Glossary webpage of the U.S. Census Bureau (U.S. Census Bureau 2024c). These definitions are also summarized in PDF reports organizing U.S. Economic Census survey data (for example, see U.S. Economic Census 2004, Appendix A. Explanation of Terms).

Bolotova and Asiseh 2009; Capps, Fuller, and Nichols 1988; Christy and Connor 1989; Henderson and McNamara 1997, 2000; Rogers 2001; Salin, Atkins, and Salame 2002).

5.1 Analyzing the Size and Structure of Food Manufacturing Industries

The size of the food manufacturing industry group (at a three-digit classification level) and/or the size of individual food manufacturing industries (at a four-digit or higher classification level) can be analyzed by using economic indicators relevant to a particular research project objective. The economic indicators themselves (without any transformation) for the analyzed industry in a particular year generally can be used to characterize this industry's size. Typically, the industry revenue (value of shipments or sales) is used to evaluate the industry size. The cost of materials (raw agricultural commodities) purchased to produce food products can also be used to evaluate the industry size on the input side. Also, the number of employees employed by the industry may be used as an indicator of the industry size.

To analyze the structure of the food manufacturing industry group (at a three-digit classification level), the share of each individual food manufacturing industry (at a four-digit classification level) is calculated in the total value of selected economic indicator. For example, the following economic indicators can be used to analyze the industry structure: revenue (value of shipments or sales), value added, cost of materials, number of employees, etc. Figure 1 depicts the selected results generated by a student who analyzed the food manufacturing industry structure in Iowa.[3]

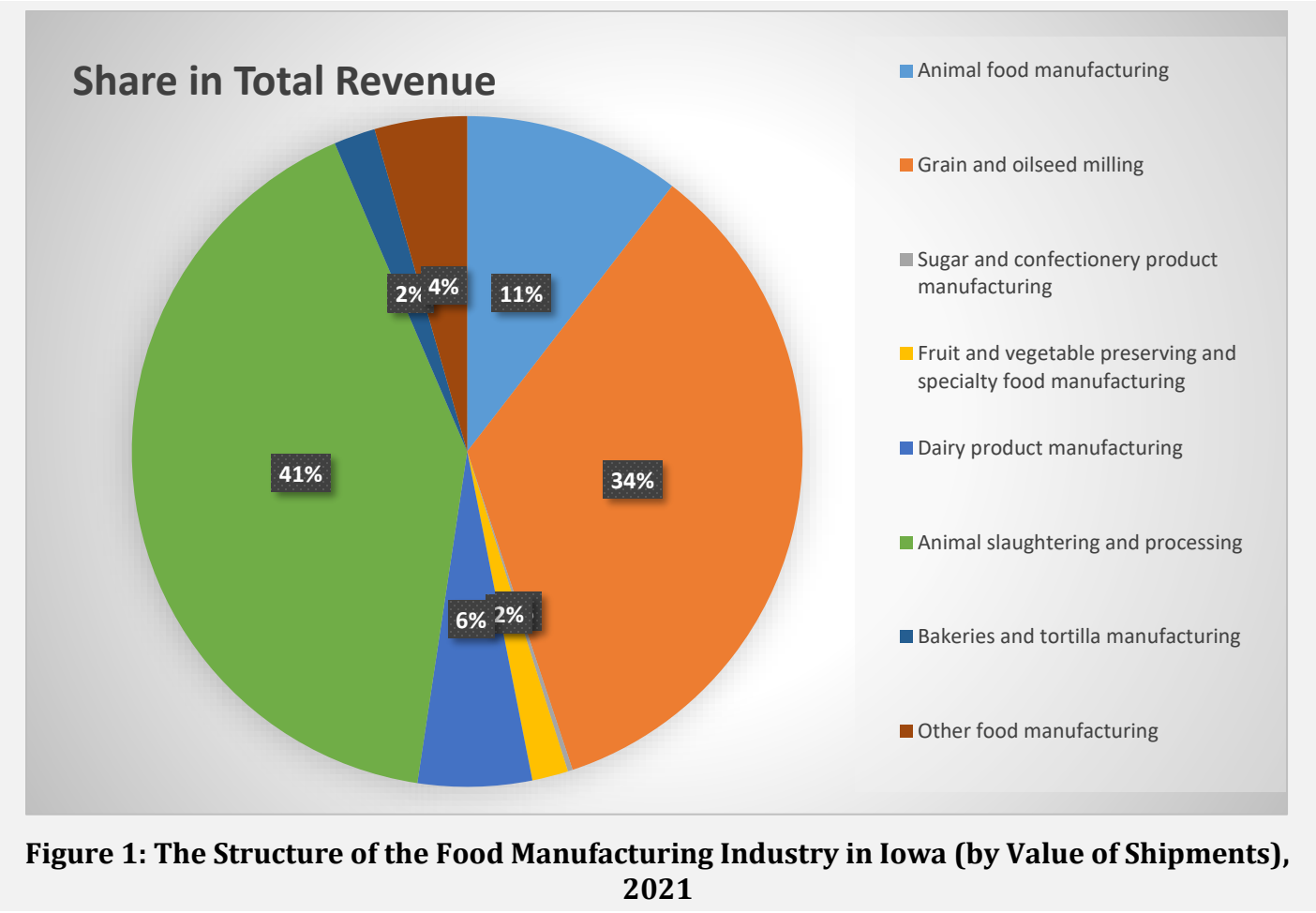

Figure 1: The Structure of the Food Manufacturing Industry in Iowa (by Value of Shipments), 2021

[3] Similar charts were developed by using the number of establishments and the number of employees.

Table 1: The Industry Revenue Structure and Profitability: Framework		
	Measure ($)	**Revenue structure**
[1]	**Revenue**	**100 percent**
[2]	**Costs = [2.1] + [2.2] + [2.3]**	**[Costs/Revenue]*100**
[2.1]	Costs of Materials	[Cost of Materials/Revenue]*100
[2.2]	Annual Payroll	[Annual Payroll/Revenue]*100
[2.3]	Capital Expenditures	[Capital Expenditures/Revenue]*100
[3]	**Profit = [1] – [2]**	**[Profit/Revenue]*100**

5.2 Analyzing the Performance of Food Manufacturing Industries

5.2.1 Revenue Structure and Profitability Analysis

The cost and revenue-related economic indicators can be used to analyze the revenue structure and profitability of food manufacturing industries. This analysis can focus on the food manufacturing industry group (at a three-digit classification level) and on individual food manufacturing industries (at a four-digit or higher classification level).

The economic indicators to be used in this analysis are: revenue (value of shipments) and cost-related indicators that include cost of materials, annual payroll, and capital expenditures. The profit proxy[4] is calculated as the difference between the revenue and total costs (all cost-related indicators combined). The profit proxy is calculated in $ and as a percentage of the revenue. To evaluate the revenue structure, the share of each cost-related indicator and profit proxy in the total industry revenue is calculated. Table 1 presents the methodology of revenue structure and profitability analysis. Tables A3.1–A3.2 and Figure A3.1 included in Appendix III summarize the selected results generated by a student who used this methodology to analyze the revenue structure and profitability of food manufacturing industries in the United States and Iowa.

5.2.2 Economic Effectiveness Analysis

The number, cost, and revenue-related economic indicators can be used to analyze economic effectiveness of food manufacturing industries. These economic indicators can be combined in different ways to construct ratios of economic effectiveness. This analysis can focus on the food manufacturing industry group (at a three-digit classification level) and on individual food manufacturing industries (at a four-digit or higher classification level).

For example, one approach is to combine cost-related indicators with revenue-related indicators to construct ratios reflecting how effectively different types of resources are used (materials, labor, and capital). This analysis would also provide evidence on productivity of food manufacturing industries. Another approach is to combine selected revenue and/or cost-related indicators with number-related indicators to evaluate economic effectiveness. The examples of the ratios would include the number of production workers per establishment, the number of employees per establishment, the value added per one production worker, the value added to cost of materials, the value of shipments per one production worker, and the value of shipments per one production worker hour. Table 2 summarizes selected ratios of economic effectiveness. Tables A4.1–A4.5 included in Appendix IV summarize the selected results generated by a student who used this methodology to analyze economic effectiveness of food manufacturing industries in Iowa, Illinois, and Missouri.

[4] The profit measure is referred to as "profit proxy" because there are other cost-related indicators that are not collected and are not used in this analysis. The share of these "other costs" is relatively small, compared to the three major cost components: annual payroll, cost of materials, and capital expenditures that are used in this analysis.

Table 2: Ratios of Economic Effectiveness

Ratios
Ratio characterizing the overall effectiveness of production and marketing processes
$$\frac{Value\ added}{Value\ of\ shipments} * 100\%$$
Ratios characterizing the effectiveness of production workers use
$$\frac{Number\ of\ production\ workers}{Number\ of\ employees} * 100\%$$
$$\frac{Value\ Added}{Number\ of\ production\ workers\ hours}\ [\$\ per\ hour]$$
Ratios characterizing the effectiveness of capital and material resources use
$$\frac{Value\ added}{Capital\ expenditures}$$
$$\frac{Value\ added}{Cost\ of\ materials}$$

6 Research Projects: Alternative Designs

There are several alternative research designs for undergraduate research projects focusing on the size, structure, and performance of food manufacturing industries.

1. Analyzing data for a particular year for an individual state.
2. Analyzing data for a particular year across a number of states located in the same geographic region. The analyzed states should have a similar agriculture and food manufacturing profile.
3. Analyzing data over time for an individual state or a group of states located in the same geographic region. In addition to analyzing changes in the size, structure, and performance of food manufacturing industries, this analysis would allow to identify economic development trends over time. The economic indicators expressed in $ should be adjusted using producer-price indices to make these indicators comparable over time (U.S. Bureau of Labor Statistics 2024).
4. Analyzing data for a particular year or overtime for an individual state and the United States. In the case of the performance analysis, the U.S. level indicators may be used as "average" performance indicators. An individual state performance can be compared to the U.S average performance (benchmarking analysis). Tables A3.1 and A3.2 included in Appendix III summarize selected results generated by a student who benchmarked the profitability of food manufacturing industries in Iowa relative to the average profitability characterizing food manufacturing industries in the United States.
5. Analyzing data for food manufacturing industries at different aggregation (NAICS digit-classification) levels and focusing on industries that are most relevant to the analyzed state.

7 Potential Audiences for Students' Research Outputs

The results of research projects evaluating the size, structure, and performance of food manufacturing industries could be used by Extension and outreach personnel, agribusiness decision-makers, financial institutions, and government agencies in several ways.

- The research projects can be tailored to contribute to Extension (outreach) programs directed toward food processing businesses. The research outputs can be used to develop information sheets for food processing businesses and local and state government authorities, as well as presentations to Extension and outreach communities.
- The research projects can be designed as business consulting projects for a particular food manufacturing business, or a cooperative involved in food manufacturing. The economic performance of an individual establishment or a group of establishments belonging to the same company can be compared to the average economic performance characterizing a particular industry in a particular state. Consequently, if needed, the company's production, input procurement, and/or marketing strategies may be modified to improve economic performance of the analyzed establishment(s) and the company.
- The research results may be used by agribusiness decision-makers when they make decisions on whether to expand the existing food manufacturing operations. The expansion may be within the same and/or a different state. The research results may also be useful for agribusiness decision-makers who consider getting involved in food manufacturing businesses.
- Financial institutions working in the region could utilize the results in their relations with agricultural and food businesses when decisions on financial assistance are made. For example, economic development trends characterizing a particular food manufacturing industry may affect decisions of the financial institutions on the amount of financial assistance to be provided for business entities operating in this industry.
- Government agencies may use the research results in their decision-making process; for example, when various agricultural and food promotion programs are developed, as well as when different types of grants are awarded to agricultural and food businesses.

8 Conclusions and Recommendations

This article provides an example of how to create and implement a research experience for undergraduate students. This research experience will improve career opportunities for undergraduate students and will provide information relevant for agribusiness and policy decision-makers. The research example presented in the article can be easily modified to fit the course, the level of undergraduate students, and the audiences.

- The research project focus can be readily refined to an appropriate scale and scope for undergraduate students. Research questions can be specified as not being too narrow nor too broad.
- The research area can be tailored to any geographic area of the United States, so location is not a constraint, making this example easily adapted and adopted by instructors at any U.S. college or university.
- The research utilizes publicly available government data, which are periodically updated, so undergraduate students do not have to collect primary data, and instructors, over time, could even recycle specific research questions with successive cohorts of students, given that new data might capture trends or shifts in industry dynamics.

The research projects developed using the example presented in this article can be incorporated in stand-alone undergraduate research courses, in capstone courses in undergraduate agribusiness programs, and in upper-level undergraduate courses taught in agribusiness and agricultural economics programs where research projects are a requirement.

A limitation is that students might need help of the instructor to locate and download data to be used in their research. The data search process might be confusing for some students. Appendix II explains the steps to follow to locate and download data on the U.S Census Bureau webpages (U.S. Economic Census surveys and Annual Surveys of Manufactures). In addition, the web links are provided to the PDF reports that conveniently visualize data and provide all definitions (U.S. Economic Census 2002).[5] Beginning in 2007, the U.S. Census Bureau discontinued publishing U.S. Economic Census data organized in PDF reports. However, these reports for earlier years may serve as a useful guide for understanding data and how these data are now organized in the U.S. Economic Census online database (U.S. Census Bureau 2024d). The teaching note Excel file includes yearly data for the U.S. food manufacturing industries reported in Annual Surveys of Manufactures for the period of 2018 to 2021 that can be used in undergraduate research projects.

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[5] The weblink is provided in the Reference section. The PDF reports for all food manufacturing industries surveyed in 2002 are available on this webpage.

Appendix I: Research Project Description

Spring 2023
Iowa State University HON 290H Section B3 "Undergraduate Honors Students Research"
Structure and Performance of Food Manufacturing Industries in Iowa

Iowa is the second largest agricultural production state in the country following California. A large volume of agricultural production in Iowa creates significant economic opportunities for food manufacturing industries located in Iowa and the Midwest region. The firms operating in food manufacturing industries purchase agricultural products from agricultural producers to process them into food products and animal feed products. Food manufacturing industries are important drivers of rural and economic development of the state and the region.

The objective of this research project is to analyze the structure and performance of food manufacturing industries in Iowa and in the Midwest. The main source of data is the U.S. Census Bureau: U.S. Economic Census Surveys and Annual Surveys of Manufactures. The U.S. Economic Census classifies food manufacturing industries into the following groups: animal food manufacturing; grain and oilseed milling; sugar and confectionary product manufacturing; fruit and vegetable preserving and specialty food manufacturing; dairy product manufacturing; meat product manufacturing; seafood product preparation and packaging; bakeries and tortilla manufacturing; and other food manufacturing.

The main economic indicators to be used in the analysis include the number of establishments, annual payroll, the number of production workers, costs of materials, capital expenditures, the value of shipments, and the value added. These economic indicators are reported for individual food manufacturing industries.

Our analysis will proceed in two directions. First, we will analyze the structure of food manufacturing industries by calculating each individual industry's share in the total value of the economic indicators associated with all food manufacturing industries as a group. Second, we will calculate and evaluate changes in the economic indicators over time. The changes in the economic indicators are to be analyzed for individual food manufacturing industries over the last two decades to determine their economic performance and economic development trends. In addition, using the same economic indicators, the performance of food manufacturing industries in Iowa will be compared to the performance of food manufacturing industries in other Midwestern states (Wisconsin, Minnesota, Missouri, and Illinois). The data analysis will be conducted in Excel.

To get a general idea about this type of research, students are encouraged to check the following articles:

Bolotova, Y. 2016. "Food Manufacturing Industry in South Carolina: An Analysis of the Size, Structure, and Performance." *Journal of Food Distribution Research* https://ageconsearch.umn.edu/record/232289?ln=en

Bolotova, Y., and F. Asiseh. 2009. "Evaluating Economic Performance of Food Manufacturing Industries: An Analysis of the U.S. Pacific Northwest States." *Journal of Food Distribution Research*. https://ageconsearch.umn.edu/record/99769?ln=en

Bolotova, Y. 2008. "The Economic Performance of Food-Manufacturing Industries in Idaho." *Journal of Food Distribution Research*. https://ageconsearch.umn.edu/record/55586?ln=en

Skills

1. Data analysis using Excel (organizing data; calculating changes in physical units and percentage changes; calculating shares; developing graphs).
2. Excellent writing skills.
3. Willingness to learn how to download data using the U.S. Economic Census database (the guidance will be provided).
4. Willingness to conduct a literature review relevant to the structure and performance of food manufacturing industries (the guidance will be provided).

Responsibilities

1. To compile a data set by downloading data from the U.S. Economic Census database.
2. To conduct data analysis using Excel (organizing data; calculating changes in physical units and percentage changes; calculating shares; developing graphs).
3. To write a report summarizing the results of data analysis and relevant literature reviews.

Appendix II: U.S. Census Bureau Data Sources

I. U.S. Economic Census (five-year surveys of industries)

1. Data webpage
https://www.census.gov/programs-surveys/economic-census.html
2. Data tables
https://www.census.gov/programs-surveys/economic-census/data/tables.html
3. Tables for Manufacturing Industries (we will need a four-digit industry classification level and FOOD manufacturing industries only)
https://www.census.gov/data/tables/2017/econ/economic-census/naics-sector-31-33.html
The insert from the webpage is below.
Manufacturing (NAICS Sector 31-33) 2017
Below are the data released in the 2017 Economic Census for Manufacturing. All data are available as formatted tables on data.census.gov and downloadable csv files on the census FTP site.
Geographic Area Statistics
As part of the ECNBASIC data set, Geographic Area Statistics provide summary statistics by geographic area for establishments and firms with paid employees. Data are shown on the 2017 North American Industry Classification System (NAICS) basis. State data will be released on a flow basis starting in January 2020; see the 2017 Release Schedules for more information.
Formatted Tables (links to data.census.gov)

- EC1700BASIC – All Sectors: Summary Statistics for the U.S., States, and Selected Geographies: 2017
- EC1731BASIC – Manufacturing: Summary Statistics for the U.S., States, and Selected Geographies: 2017

To see data for a specific state for this sector, use the drop-down below. Additional geographies can be selected under the geography menu within the table on data.census.gov.
Dataset(s) (links to FTP) ZIP FILES

- **EC1731BASIC** – Manufacturing: Summary Statistics for the U.S., States, and Selected Geographies: 2017

4. PDF Reports for 2002: Industry-Specific
https://www.census.gov/library/publications/2002/econ/census/manufacturing-reports.html

- PDF reports provide tables for 2002. Data for the following years are available only in the online database (U.S. Census Bureau 2024b).
- PDF reports provide detailed definitions of all economic indicators.
- U.S. reports and state-specific reports.

II. Annual Survey of Manufactures
1. Data webpage
https://www.census.gov/programs-surveys/asm.html
2. Tables
https://www.census.gov/data/tables/time-series/econ/asm/2018-2021-asm.html

Appendix III: The Revenue Structure and Profitability Analysis

Table A3.1: The Revenue Structure and Profitability of Food Manufacturing Industries in the United States, 2021

[NAICS code] Industry	Value of shipments	Annual payroll	Cost of materials	Capital expenditures	Total costs	Profit proxy
	$1,000,000					
[311] Food Manufacturing	***904,147.676 (100.0)***	***79,699.884 (8.8)****	***552,686.256 (61.1)***	***19,788.535 (2.2)***	***652,174.675 (72.1)***	***251,973.001 (27.9)***
[3111] Animal Food Manufacturing	65,897.742 (100.0)	3,543.899 (5.4)	41,248.482 (62.6)	960.945 (1.5)	45,753.326 (69.4)	20,144.416 (30.6)
[3112] Grain and Oilseed Milling	105,594.612 (100.0)	3,769.484 (3.6)	80,611.609 (76.3)	2,122.904 (2.0)	86,503.997 (81.9)	19,090.615 (18.1)
[3113] Sugar and Confectionery Product Manufacturing	40,174.294 (100.0)	4,339.513 (10.8)	22,608.194 (56.3)	1,201.228 (3.0)	28,148.935 (70.1)	12,025.359 (29.9)
[3114] Fruit and Vegetable Preserving and Specialty Food Manufacturing	77,745.532 (100.0)	8,550.269 (11.0)	42,110.786 (54.2)	1,972.569 (2.5)	52,633.624 (67.7)	25,111.908 (32.3)
[3115] Dairy Product Manufacturing	130,296.821 (100.0)	9,357.991 (7.2)	87,876.43 (67.4)	2,713.725 (2.1)	99,948.146 (76.7)	30,348.675 (23.3)
[3116] Animal Slaughtering and Processing	266,996.588 (100.0)	25,027.474 (9.4)	175,320.793 (65.7)	5,062.469 (1.9)	205,410.736 (76.9)	61,585.852 (23.1)
[3118] Bakeries and Tortilla Manufacturing	76,512.821 (100.0)	12,025.957 (15.7)	31,183.238 (40.8)	2,280.83 (3.0)	45,490.025 (59.5)	31,022.796 (40.5)
[3119] Other Food Manufacturing	126,586.386 (100.0)	11,545.469 (9.1)	62,595.814 (49.4)	3,125.939 (2.5)	77,267.222 (61.0)	49,319.164 (39.0)

Source: U.S. Census Bureau (2021)
*The shares of each cost indicator and profit proxy in the value of shipments are in parentheses.

Table A3.2: The Revenue Structure and Profitability of Food Manufacturing Industries in Iowa, with Comparison to the United States, 2021

[NAICS code] Industry	Value of shipments	Annual payroll	Cost of materials	Capital expenditures	Total costs	Profit proxy	Profitability: Iowa compared to the U.S.
				$1,000,000			
[311] Food Manufacturing	***45,375.98 (100.0)***	***3,041.778 (6.7)****	***31,800.829 (70.1)***	***962.985 (2.1)***	***35,805.592 (78.9)***	***9,570.392 (21.1)***	***Below Average***
[3111] Animal Food Manufacturing	4,750.27 (100.0)	265.615 (5.6)	2,897.532 (61.0)	87.843 (1.9)	3,250.99 (68.4)	1,499.275 (31.6)	Above Average
[3112] Grain and Oilseed Milling	15,628.72 (100.0)	472.47 (3.0)	12,463.428 (79.8)	224.637 (1.4)	13,160.535 (84.2)	2,468.183 (15.8)	Below Average
[3113] Sugar and Confectionery Product Manufacturing	106.463 (100.0)	15.969 (15.0)	56.772 (53.3)	0.198 (0.2)	72.939 (68.5)	33.524 (31.5)	Above Average
[3114] Fruit and Vegetable Preserving and Specialty Food Manufacturing	787.992 (100.0)	100.86 (12.8)	626.226 (79.5)	58.402 (7.4)	785.488 (99.7)	2.504 (0.3)	Below Average
[3115] Dairy Product Manufacturing	2,493.46 (100.0)	280.003 (11.2)	1,420.506 (57.0)	22.426 (0.9)	1,722.935 (69.1)	770.523 (30.9)	Above Average
[3116] Animal Slaughtering and Processing	18,676.82 (100.0)	1,648.407 (8.8)	12,806.11 (68.6)	358.068 (1.9)	14,812.585 (79.3)	3,864.236 (20.7)	Below Average
[3118] Bakeries and Tortilla Manufacturing	909.793 (100.0)	88.15 (9.7)	356.938 (39.2)	9.436 (1.0)	454.524 (50.0)	455.269 (50.0)	Above Average
[3119] Other Food Manufacturing	2,022.47 (100.0)	170.303 (8.4)	1,173.317 (58.0)	201.976 (10.0)	1,545.596 (76.4)	476.878 (23.6)	Below Average

Source: U.S. Census Bureau (2021)
*The shares of each cost indicator and profit proxy in the value of shipments are in parentheses.
"Above-average performance" is if Iowa's profit proxy is greater than the U.S. profit proxy (Table A3.1).
"Below-average performance" is if Iowa's profit proxy is smaller than the U.S. profit proxy (Table A3.1).

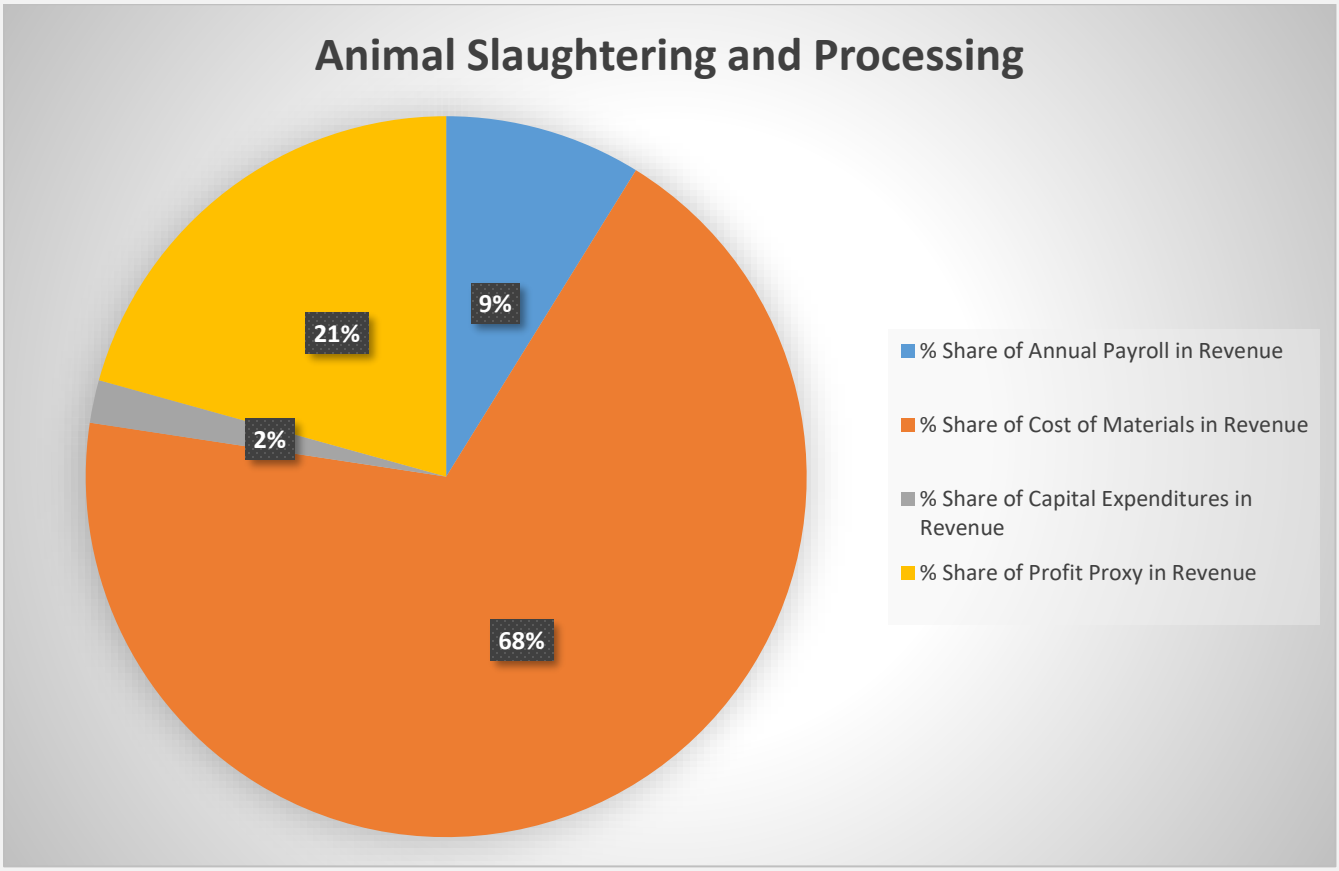

Figure A3.1: The Revenue Structure of Animal Slaughtering and Processing Industry in Iowa, 2021

Source: U.S. Census Bureau (2021)

Appendix IV: Economic Effectiveness Analysis

Table A.4.1: Share of the Value Added in the Value of Shipments, 2021

NAICS code	Industry	Iowa	Illinois	Missouri
311	***Food Manufacturing***	***30.2[l]***	***36.6[h]***	***34.5***
3111	Animal food manufacturing	39.4[l]	40.9	54.8[h]
3112	Grain and oilseed milling	20.7	20.9[h]	20.5[l]
3113	Sugar and confectionery product manufacturing	N/A	43.4	N/A
3114	Fruit and vegetable preserving and specialty food manufacturing	N/A	40.9[l]	42.8[h]
3115	Dairy product manufacturing	43[h]	33[l]	N/A
3116	Animal slaughtering and processing	31.6[l]	37.4[h]	34.2
3118	Bakeries and tortilla manufacturing	60.2[h]	50.7	44.9[l]
3119	Other food manufacturing	41.9[l]	52.5	53.7[h]

Source: U.S. Census Bureau (2021)
[h] Highest share among the three states. [l] Lowest share among the three states.
N/A means that either the industry is not present in the state, or data are not reported due to confidentiality reasons.

Table A4.2: Ratio of the Value Added to the Cost of Materials, 2021

NAICS code	Industry	Iowa	Illinois	Missouri
311	***Food Manufacturing***	***0.4[l]***	***0.6[h]***	***0.5***
3111	Animal food manufacturing	0.6[l]	0.7	1.2[h]
3112	Grain and oilseed milling	0.3	0.3	0.3
3113	Sugar and confectionery product manufacturing	N/A	0.8	N/A
3114	Fruit and vegetable preserving and specialty food manufacturing	N/A	0.7	0.7
3115	Dairy product manufacturing	0.8[h]	0.5[l]	N/A
3116	Animal slaughtering and processing	0.5[l]	0.6[h]	0.5[l]
3118	Bakeries and tortilla manufacturing	1.5[h]	1	0.8[l]
3119	Other food manufacturing	0.7[l]	1.1[h]	1.1[h]

Source: U.S. Census Bureau (2021)
[h] Highest ratio among the three states. [l] Lowest ratio among the three states.
N/A means that either the industry is not present in the state, or data are not reported due to confidentiality reasons.

Table A4.3: Ratio of Value Added to the Number of Production Worker Hours, 2021

NAICS code	Industry	Iowa	Illinois	Missouri
311	***Food Manufacturing***	***152***	***151.1[l]***	***152.4[h]***
3111	Animal food manufacturing	333.7	241.8[l]	441[h]
3112	Grain and oilseed milling	367.2[h]	359.6	268[l]
3113	Sugar and confectionery product manufacturing	N/A	149.9	N/A
3114	Fruit and vegetable preserving and specialty food manufacturing	N/A	86.2[l]	239.6[h]
3115	Dairy product manufacturing	169[h]	163.9[l]	N/A
3116	Animal slaughtering and processing	100.7	131.1[h]	87[l]
3118	Bakeries and tortilla manufacturing	191.8[h]	93.8[l]	190.9
3119	Other food manufacturing	166.7[l]	204.6	294.9[h]

Source: U.S. Census Bureau (2021)
[h] Highest ratio among the three states. [l] Lowest ratio among the three states.
N/A means that either the industry is not present in the state, or data are not reported due to confidentiality reasons.

Table A4.4: Share of Number of Production Workers in Number of Employees, 2021

NAICS code	Industry	Iowa	Illinois	Missouri
311	***Food Manufacturing***	***82.4***	***78.1[l]***	***83.9[h]***
3111	Animal food manufacturing	76.8	70.6[l]	79.8[h]
3112	Grain and oilseed milling	76.4	73[l]	81.4[h]
3113	Sugar and confectionery product manufacturing	63.2[l]	79.2[h]	72.6
3114	Fruit and vegetable preserving and specialty food manufacturing	87.3[h]	74.7[l]	83.5
3115	Dairy product manufacturing	60.6[l]	81	86.7[h]
3116	Animal slaughtering and processing	87.1[h]	83.4[l]	86.1
3118	Bakeries and tortilla manufacturing	84.3[h]	78.3[l]	79.4
3119	Other food manufacturing	78.2[h]	71.5[l]	77.0

Source: U.S. Census Bureau (2021)
[h] Highest share among the three states. [l] Lowest share among the three states.
N/A means that either the industry is not present in the state, or data are not reported due to confidentiality reasons.

Table A4.5: Ratio of the Value Added to Capital Expenditures, 2021

NAICS code	Industry	Iowa	Illinois	Missouri
311	***Food Manufacturing***	***14.2[l]***	***15.3***	***16.7[h]***
3111	Animal food manufacturing	21.3[l]	28.6	48.6[h]
3112	Grain and oilseed milling	14.4[h]	11.5[l]	14
3113	Sugar and confectionery product manufacturing	N/A	20.1	N/A
3114	Fruit and vegetable preserving and specialty food manufacturing	N/A	17.3[l]	41.3[h]
3115	Dairy product manufacturing	47.8[h]	12.3[l]	N/A
3116	Animal slaughtering and processing	16.5	20.9[h]	8.8[l]
3118	Bakeries and tortilla manufacturing	58[h]	11.8[l]	35.3
3119	Other food manufacturing	4.2[l]	14.9	29.8[h]

Source: U.S. Census Bureau (2021)

[h] Highest ratio among the three states. [l] Lowest ratio among the three states.

N/A means that either the industry is not present in the state, or data are not reported due to confidentiality reasons.

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Teaching and Educational Methods

Undergraduate Applied Microeconomic Research with Demographic and Health Surveys

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JEL Codes: O12
Keywords: Demographic health surveys, development, undergraduate research

Abstract
Undergraduate students have demonstrated a growing demand for research opportunities, particularly concerning the world's poorest people. United States Agency for International Development's (USAID) Demographic and Health Surveys (DHSs) Program offers nationally representative data on more than 90 low-income countries that allow for the study of central issues highlighted by the United Nations Sustainable Development Goals (SDGs) such as good health, education, women's empowerment, and access to clean water (SDGs 3–6). In this paper, we provide an extensive overview of the DHS data, previous research with DHS data, and potential research ideas for undergraduate students. A detailed appendix provides instructors with a framework and resources to teach undergraduates to use DHS data as part of course assignments, course-based undergraduate research experiences (CURE), or theses. Using the DHS data and these resources, students can engage in active learning exercises that address some of the key policy issues of their generation.

1 Introduction

There are clear benefits to students in learning the methods and skills associated with applied economics research that translate to graduate school and the workforce. These skills include how to summarize the current evidence based on a research question, learning to devise new questions, gaining experience with data analysis software, and becoming better writers. Besides the benefit of learning these methods and skills, students need to find inspiration in their chosen research topics to fuel their interest in individual research. Many undergraduates ambitiously choose an area of study that would allow them to play a part in addressing the world's biggest problems. Often, this leads to a focus on the poorest countries in the world, where problems are most acute.

The objective of this paper is to show instructors and students how to use data collected as part of the Demographic and Health Surveys (DHS) Program to research some of the world's most pressing problems such as those highlighted by the United Nations Sustainable Development Goals (SDGs). The DHS are nationally representative, so research done with the DHS data can potentially show how a particular country could make progress on an SDG. The DHS have clear links to SGDs 3–6: good health and well-being, quality education, gender equality, and clean water and sanitation. The DHS Program can also be used to explore child nutrition, a dimension of hunger (SDG 2), by using anthropometric data. Finally, although the DHS Program cannot directly address the SDG 1 of no poverty, measured usually by income or consumption, it can provide asset-based measures.

The DHS can be used for both undergraduate research and traditional economics courses. The DHS are an ideal data source for undergraduate students undertaking both the semester-long course-based undergraduate research experiences (CURE) and year-long theses, as well as for certain specific assignments; using these surveys provides the benefits that undergraduate students want while addressing the cost side of the equation for instructors. In this paper, we provide in-depth detailed exercises on using DHS data with undergraduates. These exercises include teaching survey methods,

data analysis, and writing to prepare students for research. These same exercises could be used in standard courses such as international development, health economics, or econometrics to teach students specific aspects of these methods.

The DHS Program has collected data (more than 400 surveys) on more than 90 low-income countries; many countries have multiple years of associated data, since 1984. The program is supported by the United States Agency for International Development (USAID), which has been providing technical assistance to countries to administer the survey for more than thirty years.[1] The role of the DHS Program is to provide countries with reliable information and analyses to inform policy. The survey provides information on a wide range of possible research topics, including anthropometrics, child labor, contraception, fertility, HIV/AIDS, intimate partner violence, malaria, schooling, women's decision-making power, and women's employment. More importantly, the data are freely available and easy to access. To date, DHS data have been analyzed in more than 5,900 articles published in more than 1,100 journals, including leading journals in economics, health, and demography (DHS Program 2024a).

For instructors, there can be substantial time costs to overseeing undergraduate research (Fenn et al. 2010; Gitter 2021).[2] Helping students find suitable data that can be obtained quickly is important for a semester-long course or, at most, a year-long thesis project. Instructors need to balance the benefits of students pursuing individualized research projects while trying to address the costs of not using the economies of scale typically associated with common assignments and grading in standard courses.

DHS data are particularly well-suited to the potentially large time costs for instructors associated with undergraduate research projects. The DHS consist of mostly the same questions and data structure across countries and time. Selecting an interesting and answerable research question can be time-consuming, especially for undergraduates undertaking their first project. Instructors can guide students to build on the vast amount of existing research by replicating research questions in another country. Instructors can also benefit from economies of scale and scope. For example, to scale the process, a group of students could all examine the same research question with DHS data in different countries, allowing them to share literature and research design; given the 90 countries for which the DHS data are available, this could scale to most class sizes, even with each student choosing a unique country. Instructors can also take advantage of economies of scope and have students answer different questions for the same country, sharing literature and data cleaning work.

This paper provides a framework for instructors and students to use DHS data in the context of undergraduate research in applied economics and provides examples of specific assignments where the DHS can be used in non-research-oriented classes. We divide this paper into five more sections. In Section 2, we provide an overview of the DHS data, detail research from these surveys done in both top academic journals and by students to motivate how to help students select questions. Section 3 discusses data analysis skills, including obtaining and cleaning the data, making descriptive statistics and graphs, and econometric work from basic ordinary least squares (OLS) to more advanced techniques. At the end of this section, we also discuss the potential for linking DHS data to other datasets available, specifically satellite data, food prices, and terrorist attacks. In Section 4, we demonstrate how students can put together the work from qualitative and quantitative parts and create a paper. This section also provides information on where and how to present and publish the work. In Section 5, we offer a few concluding thoughts.

We also propose a framework for instructors using the DHS data for undergraduate research coursework in a series of appendices. The framework is summarized in Appendix A, which provides a nine-unit structure that is linked to learning goals for teaching the DHS along with accompanying readings and suggestions for assignments. Note, however, that some of these units can be used

[1] USAID also uses the surveys to monitor trends in development and inform policy.

[2] In this paper, we use the term instructor to be inclusive of non-tenure track, tenure track, and tenured faculty.

independently or as stand-alone in regular courses. Example assignments are shown in Appendix B. In Appendix C, we provide an example paper and in Appendix D a first-person student experience.

2 The DHS Dataset and Choosing a Research Question

2.1 Overview of the DHS

As mentioned in the introduction, the DHS mostly contain the same basic information across the world on household demographics, health, fertility, and household wealth. There are four main types of questionnaires focusing on the household, women, men, and HIV and/or other biomarkers. The DHS also collects data on GPS location and covariates of the locations such as weather, access to health care, and schools, for the most recent surveys. Some surveys have additional information on specific health outcomes such as chronic disease, disability, and mental health. The first of the DHS was conducted in 1984, and the survey has been changed roughly every five years (DHS Program 2024a), though most of the core questions remain the same.

To start understanding the survey, we recommend a simple exercise where students role-play being the interviewee or the enumerator for the DHS. This exercise could be used for students doing research or learning about survey methods in a standard course. Students can work in pairs or groups with one of them in the role of enumerator and the other (or others) in the role of the interviewee, for different modules. Before beginning this exercise, we recommend a content notice.[3] This exercise allows students not only to read the questionnaire in depth and get familiar with all the questions but also to understand the codes used in the DHS and the overall structure of survey questionnaires.[4] Moreover, it can be used to motivate related topics such as survey design, ethical concerns of data collection in the field, and varying the use of units of analysis (household, household member, etc.).

To provide an overview of a typical DHS, we discuss below the main parts of each questionnaire module, which can be shared with students who are new to survey-based research or instructors who are new to the DHS. We use Tanzania's 2022 DHS as an example because it has one of the most recent reports on a DHS with data available (MoH 2022). Reports are typically hundreds of pages long with descriptive analysis of the data. The full questionnaire is available in Appendix E of the 2022 Tanzania DHS report, and similar reports exist for all DHS datasets (MoH 2022).

The first page of the questionnaire (MoH 2022, p. 689) includes information on the location of the households including subnational units such as region, district, and ward. When showing students the information on the regions, it may be worth previewing that the DHS survey is often representative at the subnational (regional) level and that stratified sampling is used to construct the data (for Tanzania 2022 see MoH 2022, p. xxxiv), which implies the need to use survey weights when analyzing the DHS.[5] The first page of the questionnaire also has information on whether the survey team was able to get a response. As the introduction to the report notes, in the 2022 Tanzanian DHS, "the response rate was very high (99 percent household, 97 percent women, and 91 percent men)" (MoH 2022, p. XX). This rate is consistent or better than historical response rates, which typically exceed 90 percent (Corsi et al. 2012).

[3] The DHS ask women-sensitive questions, and we recommend providing a content notice before beginning work with students and again before the mock survey exercise. In particular, the DHS asks questions about intimate partner violence, including sexual violence between partners. Providing a content notice that the survey discusses sexual violence, miscarriages, and infant mortality, may help students who need it by giving them time to implement strategies to cope with triggering information (see Stanford Graduate School of Business n.d.; University of Michigan n.d.). This content notice is particularly important to reemphasize before having students go through the survey.

[4] Furthermore, this exercise can allow a discussion about survey measurement errors. For example, variables in the DHS such as birth date have low levels of reporting or large levels of error, since they rely on mothers' recall; meanwhile, anthropometric measures have small measurement error because they are methodically collected by the enumerator.

[5] We discuss weights in more detail in Section 3.4.

The questionnaire can also be used to discuss ethical concerns about gathering data in developing countries with the students. First, it is worth showing students the informed consent as part of the survey (MoH 2022, p. 692), and this may be an opportunity to discuss the role of institutional review boards (IRBs) in doing ethical research. Second, the DHS protect anonymity by randomly displacing the actual GPS longitude/latitude information of the cluster (i.e., a grouping of households; DHS Program 2024b) by up to 2 kilometers in urban areas and up to 10 kilometers in rural areas. Data available to the public are anonymized and do not contain names, though names are collected as part of the survey. Third, as mentioned before, the DHS asks detailed questions about sensitive information; this can be used to discuss with students how the DHS approaches these questions, and why not everyone is asked to answer these questions.

The DHS household survey questionnaire gathers comprehensive data on both usual members of the household and visitors (MoH 2022, p. 693). The data cover key demographic details of all household members such as age, sex, relationship to the household head, marital status, marriage age, education, parental survivorship, and if the person resides in the household. The questionnaire also includes household characteristics such as source of drinking water, toilet facilities, cooking fuel, assets owned by the household, and exposure to second-hand smoke. Assets such as livestock animals and durable goods are also detailed, which are used to construct a wealth index (see discussion in Section 2.2).

The household questionnaire contains two main potential units of analysis: the individuals within the household and the household itself. A short YouTube video made by the DHS Program describes that data for these two units are covered by two different data files, which we will discuss below along with other DHS data files.[6] Each survey has a household recode (a unique identifier), which is best for looking at household-level data about household characteristics. It does include a roster with limited information such as relationship to head, sex, age, and education, but it is difficult for students to work with because these variables are contained in a single row with variables for age of person 1, person 2, etc.[7] For individual-level information, the Household Member Recode (PR) uses the individual as the unit of analysis and provides full information on each household member's age, sex, education, and numerous other variables.

The women's questionnaire is given to a woman in the household, age 15 to 49, based on reproductive years, and it is the most extensive part of the survey (MoH 2022, p. 709). There are more detailed questions on standard demographics and employment, a particular focus on women's fertility with detailed information about each of her births (including children who died), reproductive intentions, and contraception. The survey also collects information on antenatal, delivery, and postnatal care along with breastfeeding practices, as well as child health status, including recent experience of diarrhea and fever along with immunization records. Women's empowerment is also measured through questions on decision-making and attitudes toward intimate partner violence. Sensitive information (such as the experience of intimate partner violence, HIV health-related questions, and tobacco use) is also collected, in some countries, but only for a subset of women. All this data has the female respondent as the unit of observation and is contained in the individual women's respondent recode (IR).

A brief set of questions is sometimes also given to the respondent's husband. Samples of men ages 15 to 59 are collected in some countries, and in many cases, this is a subsample of the spouses of women in the sample described above. The questions cover many of the same topics as the women's questionnaire (Vaessen et al. 2005), and data are contained in the men's recode file (MR).

The DHS in some cases collects biomarker data on a subsample of the population; in the case of Tanzania, the subsample was half of the households (see MoH 2022, p. 845). Biomarker data includes

[6] YouTube video link: https://youtu.be/JGRJZCGiCJw.

[7] The advantage of the household module containing a household roster is that using only this household-level data set it is easy to measure household-level variables such as highest education level in the household or the dependency ratio.

tests for malaria and anemia. Anthropometric data, such as weight and height (or length), are also gathered for children under five years old.

2.2 Advantages and Disadvantages of Using the DHS

Besides all the characteristics mentioned in the previous sub-section, we want to emphasize that the main reason to choose the DHS over other surveys is the large comparability across numerous countries and over time, and their easy availability and accessibility. Other surveys conducted in developing countries that can serve the purpose of teaching undergraduate research are the Living Standard Measurement Surveys (LSMS) and the Young Lives surveys. Regarding comparability, both the LSMS and the Young Lives surveys are available for fewer countries and fewer years than the DHS, and the LSMS are less comparable across countries. The LSMS have been conducted for more than fifteen years, mostly in Sub-Saharan Africa, by individual countries' statistical offices with the support of the World Bank, which makes the questionnaires not standardized. The Young Lives surveys are conducted in only four countries, and their questionnaires are standardized across countries. Regarding availability and accessibility, the DHS can be downloaded from the DHS Program website or through the Integrated Public Use Microdata Series (IPUMS), which also ensures the quality of the data. Moreover, for countries in which DHS data are available via IPUMS, other variables (e.g., rainfall) are linked. The LSMS are easy to access from the LSMS website and provide all the data available in the questionnaires, although anecdotal experience of the authors suggests they may have some data quality issues. The Young Lives surveys are also easy to access, but they do not provide important information such as household GPS location, which limits their use (see a discussion on combining DHS data with other datasets in Section 2.3).[8]

Using the DHS data implies restricting undergraduate research to their available information and data structure. Regarding data content, the DHS's largest omissions that are standard in some household development surveys are income, consumption, and time use modules, present in other surveys such as some of the LSMS. Nonetheless, wealth can be estimated using the information on assets in the DHS, and an asset-based measure of wealth is already calculated for some countries (which is not comparable across countries). In most surveys, households are grouped in wealth quantiles, which makes for a good control variable for socioeconomic status in undergraduate projects.

2.3 Examples of Research Papers with DHS Data

In this section, we highlight examples of applied microeconomics research with DHS data. The DHS maintains a database of more than 5,900 articles across more than 1,100 academic journals that have used DHS data across fields (DHS Program 2024a). As examples of papers by economists to share with students, we suggest Jayachandran and Pande (2017) and Brown, Ravallion, and Van De Walle (2019), which use mainly descriptive statistics to better understand malnutrition. To teach students about using difference-in-differences, we suggest assigning McGavock (2021), who examines child marriage bans in Ethiopia, and Gehrke and Kubitza (2024) on the effects of palm oil expansion on fertility in Indonesia. Agüero and Marks (2008) and Sunder (2019) provide good analyses on women's employment and child marriage, while also being useful to teach about endogeneity and instrumental variables.

IPUMS gives out annual awards to researchers and students (though mostly graduate students) who use their data, including the DHS, and publishes the winning papers on their website.[9] In the last two years, researcher award winners include Mruts et al. (2022), who look at birth spacing and anemia, and Stoebenau (2021), who examines socioeconomic status and marriage age both using DHS data from multiple African countries. Student award papers with DHS data include Heng et al. (2020) who test the

[8] Note for the three surveys, a registration is required to prove the status of academic use of these data.
[9] Awards and applications for submissions are available at IPUMS website, https://www.ipums.org/impact/ipums-research-award.

relationship between malaria and low birth weight; Chang (2019) who estimates the influence of abortion laws in African countries on marriage age, births, and schooling rates; and Källmark (2018) who measures the relationship between drought and health outcomes for children in Zimbabwe. Two of the authors have both worked with undergraduate students to find research questions using DHS data. In some cases, students did a simple project such as looking at health care access and infant mortality in Nigeria, or mother's education and infant mortality in Peru as part of course projects. These projects were expanded as part of a longer summer research project and are turning into theses examining food prices during pregnancy and infant mortality (Nigeria), and air pollution and education (Peru) by using DHS data merged with other data sources (geocoded food prices and air pollution). One of the authors was a student who merged DHS data with terrorist attack data in Afghanistan to measure the effect on children's health. This paper is included as Appendix C, and a discussion of their experience is provided in Appendix D. Other students have studied child marriage's effects on education and labor outcomes for women using instrumental variables. Specifically, to use puberty age to predict marriage age (Gitter et al. 2023), which parallels Sunder (2019) mentioned above. Another paper by one of the authors and an undergraduate, under review, combines DHS data from Nepal on women's employment with foreign direct investment at the district level collected by the Nepali government to test the link between the two (Ziard et al., Forthcoming).

2.4 Choosing Research Topics

Applied microeconomic research typically uses an outcome variable and a main variable of interest that causally affects that outcome as seen in the research discussed above. The first requirement for any project is for the data to be available, either in the DHS or in another dataset that could be linked to the DHS (see Section 3 for further discussion on other data sources). Students can build on the first two chapters from *The Effect* (Huntington-Klein 2022) to learn about creating research questions. To help students generate research ideas, first have them identify outcome variables of interest from the DHS dataset, and then ask them to make a list of DHS variables that might influence that outcome (see unit 1 in Appendix A). We also recommend having them do a researcher bio to summarize the work of one researcher to get a sense of potential topics (see Appendix B.1)

The DHS-run website Statcompiler (Statcompiler.com) is an excellent place to start to look at available outcomes and get a sense of descriptive statistics. Statcompiler contains DHS summary data on hundreds of variables in a dashboard that can be used to make within- or between-country comparisons over time. A good classroom exercise is to have students look up the same variable, such as the fertility rate, for different countries. The DHS Program also runs a YouTube channel (youtube.com/@DHSprogram) with brief introductory videos for the survey to teach students about how the survey is conducted.

The structure of semester-long, course-based projects and individualized theses requires different approaches to research question selection. In semester-long courses, choosing a research topic early is important: students will need time for data work and writing. In the sample schedule, making a proposal (see Appendix B.2) or an aspirational introduction (see Shapiro 2022), described below, is done in the second of nine units (see Appendix A), or roughly the second week of a class on the quarter system, or the third week of a semester-long class. As mentioned above, students can form groups based on research questions and share information from their literature search, use similar econometric designs, and help each other with coding and writing.

This last part is particularly important for DHS data, which uses similar variable- and value-naming conventions (e.g., v133 is the mother's years of education, and its missing values are coded as 99). Given the limited nature of time in a semester-long class, instructors may even want to create a set of research questions for students or replicate the same analysis in multiple different countries, assigning each student to a different country's DHS. For example, one of the authors worked with two undergraduates to replicate Sunder's (2019) work on the relationship between child marriage and

education in Uganda by extending the analysis to 11 additional countries (Gitter et al. 2023).

For a course-based research project, the emphasis should be on learning the skills associated with the research process rather than on generating novel ideas. In this case, instructors could assign simple, well-established research topics such as the influence of maternal education on infant mortality. An instructor could also choose a subset of DHS countries for students to work on in groups, which allows students to share resources and does not require the instructor to have as much specialized knowledge of DHS datasets.

For a year-long thesis project, students often need self-motivation, so their interest in the topic becomes more important to their success (see Gitter 2021 for further discussion). Additionally, students with a whole academic year to do research can spend up to a month selecting a research question and still have plenty of time to complete the project. Former CURE students may use their course-based projects as a springboard for a year-long project by getting additional data or extending the analysis. A final step in solidifying a research question can be having students write a proposal. Appendix B.2 provides a sample assignment for a 1-page proposal that asks students to identify the outcome variable, the main variable that influences that outcome and other potential factors, and to begin summarizing the relevant literature. Shapiro (2022) suggests writing an aspirational abstract that can be thought of as a proposal with hypothetical results, which represent the best-case scenario of the empirical analysis.

2.4.1 Pitfalls When Choosing a Research Topic

Students typically make two main errors when choosing a research project with DHS data. First, they sometimes try to choose topics that DHS does not collect data for. We do discuss in Section 3.6 how to link the DHS with other datasets, but this is better for students with more than a semester of time to work on the project. In some cases, the DHS does not always collect the same data for a given country, so certain datasets may be missing information such as anthropometric measures or ethnic categories. Using Statcompiler is a quick way to check if the main variables are available in the country and survey of interest. The second main error is trying to measure the effect with no variation, for example at the regional level, if a whole country experiences an earthquake or a national ban on child marriage. One way to get around that is to find regional variation such as in Khanal (2022), that compares regions within Nepal that experienced different magnitudes of a major earthquake, or in McGavock (2021), that tests regional variation in child marriage bans in Ethiopia.

Students will also often pick research topics with clear omitted variable bias. For example, many students will want to measure the effects of access to resources (e.g., water, electricity, or roads) for health or education outcomes. Access to these resources is likely also related to socioeconomic status, which likely is an omitted variable influencing these health or education outcomes. Students can control for household wealth or include regional fixed effects to lessen these issues somewhat. It is worth remembering that these are undergraduate research papers, and they need not pass the causal identification bar of top economics journals. Discussing omitted variable bias does serve as a learning opportunity and can be written into their papers as a limitation of the work that it is potentially noncausal.

2.5 Conceptual Framework and Existing Literature

Literature reviews in applied economics papers serve a different purpose than students may be accustomed to from other disciplines. Dudenhefer (2006) suggests four purposes for literature reviews in economics: (1) critically analyzing a body of research, (2) putting your own study in the context of others, (3) highlighting your study's contribution, and (4) establishing your scholarly credentials. Typically, for undergraduates doing research, the first purpose can be to establish a theory of change. That is what others have found in terms of the relationship between the main outcome variable and the influencing variable of interest. This previous literature can help support a hypothesis about why a change might occur. Students can then use the literature review for the second and third purposes: to

contextualize their work in light of a contribution. Having students answer how their paper will differ from previous studies is useful in learning about novel research ideas. Students will be most accustomed to the last purpose, establishing that they are familiar with the literature.

To guide students through the process of creating a literature review, it is helpful to have them first find and briefly summarize in a sentence or two a list of ten to fifteen studies they believe are relevant to their work. (The schedule in Appendix A has students summarize articles in the first two units.) Instructors can check this list of studies and their corresponding summaries before students write up their literature review. We suggest guiding students toward the DHS database of 5,900 articles first, and the IPUMS research winners.[10] A good second step after finding a few initial articles is to use Google Scholar to run backward and forward searches of articles (i.e., articles that cite or are cited by the article of interest; see Romem 2012). Starting with Google Scholar is likely to overwhelm students with too many articles, many of which are less relevant; another possibility is searching for papers within the EconLit database.

Helping students understand and identify economics journals or quality journals is difficult, but students can be directed to the Research Papers in Economics (RePec) portal,[11] which ranks more than 3,000 economic or related journals, and the Australian's Business Deans Council, which also provides a letter grade to journals in economics and business fields.[12] This may also be a good opportunity to teach students about journal metrics such as the impact factor, although with the caveat that the measures can be manipulated. Teaching students skills to manage, document, and sort articles is also important to their long-term success as researchers and can help build a database of resources for future research students. Zotero is one of many free citation managers (another is Mendeley) that can be used to teach students how to organize their literature review and how to cite correctly.[13]

After collecting articles, writing up a literature review section that motivates a theory of change is a good exercise to help students synthesize their knowledge; an example is shown in Appendix B.3. Instructors in development or health economics courses could potentially ask students to do the same exercise without the intention of doing a full research project. This will teach students to relate what they have learned in the course to the latest research.

3 Quantitative Skills

Students can learn a broad range of quantitative skills necessary to do applied economics research through working with DHS data. The example of these quantitative skills may be included in economics, statistics, or econometric courses as stand-alone exercises. These skills include obtaining data, cleaning data, doing basic descriptive analysis, econometric analysis, and creating replicable code. Basic quizzes with sample data can be used to introduce these concepts before students begin their own analyses. This section provides an overview of these skills as part of a DHS-based research project.

3.1 Downloading the Data

There are two sources of DHS data: the DHS Program website[14] and IPUMS.[15] The DHS Program website provides access to all DHS data, solely for research purposes, after being granted approval by the DHS Program. Before students or the instructor requests data, they will need to provide DHS with a brief summary of the research question for approval; the approval process typically only takes 24 hours, or a

[10] ipums.org/research-award/previous-award-winners
[11] ideas.repec.org/top/top.journals.all.html
[12] abdc.edu.au/abdc-journal-quality-list/
[13] Note that teaching how to use a citation manager has very little cost. Teaching the most important features of Zotero to students can be done in a one-hour session, which can also be run by a librarian.
[14] https://dhsprogram.com/data/available-datasets.cfm
[15] https://www.idhsdata.org/idhs

few days if GPS information is also requested. This requirement is also necessary to access the IPUMS DHS data. Once access is granted in the DHS Program website, original datasets can be downloaded in several formats, including Stata, SAS, SPSS, and ASCII.

IPUMS only provides data for 45 countries (in Asia and Africa only), but the main advantage of using its data is the harmonization of DHS data between these countries. Another advantage of using IPUMS is the possibility of selecting only the relevant variables for download. Thus, we recommend using the IPUMS DHS website to download data if the objective is doing cross-country comparisons in Asian and African countries or to have all the students work with a harmonized set of variables.

While downloading data either from the DHS Program or IPUMS, students might run into some issues. First, some of the files can be quite large, with file sizes in the hundreds of megabytes, because some files have thousands of variables for tens of thousands of survey respondents. This may be beyond the computing power of some student versions of software or for students with low-end computers such as Chromebooks. A second issue is that students may be overwhelmed with the number of files (see more discussion below) and the number of variables. Third, students may require time and other skills to merge the downloaded datasets at different unit-of-analysis levels. The first two issues can be mitigated by downloading only certain variables from the IPUMS DHS website, but the third issue requires conducting lessons on merging datasets.

To limit these issues, in classes where student experience with data and course time may be limited, the instructor can create small subsets of the original DHS datasets that include only the necessary variables. When teaching a CURE using DHS data, one of the authors creates datasets by country groups, asking students which variables they need. This typically only takes a couple of hours or less for a whole class to give each student a smaller dataset with a few dozen variables. The time saved by helping students navigate the vast amount of data is likely more time than it takes to prepare data for a class. Giving students a simple quiz with a sample dataset can test students' ability to load data and find the number of observations and variable names; these topics are tested in quiz 1 in unit 2 of Appendix A.[16] Downloading data and giving students experience with troubleshooting and data cleaning to keep only relevant variables, helps students when doing research in the future without instructor support.

When downloading the data from the DHS website, it is worth referring back to the previous section because datasets are created around the unit of observation. There is a household recode (HR) data file; an individual recode (IR), which is the female respondent in the household aged 15–49; a household member recode (HR); and a birth recode (BR) that has data on the children of those women. The files use a standardized naming convention that includes the country's name, the data type, the survey version, and the file format. For example, Kenya's (KE) household recode (HR) 2003 DHS phase four (42 for phase 4, version 2) Stata file (DT) is called KEHR42DT.dta.

3.2 Basic Data Cleaning

Students can also be introduced to the process of cleaning data when using the DHS either for their own research or in econometrics and statistics courses. DHS data does not require deep cleaning, but it can be used to show students what a good-quality dataset should look like. The most common data cleaning needed is dealing with missing values, which are often coded as 99. Moreover, the DHS raw data can be used to show students how to transform raw data into variables ready to use in descriptive statistics tables and econometric regressions. Although researchers are accustomed to cleaning the data, it is hard for undergraduate students to do this for the first time. Appendix B.4 provides a detailed set of steps to clean and transform raw data into variables for undergraduate students. In CURE, to ensure students learn these concepts, they can be assessed in a second quiz in unit 3 (see Appendix A). In this quiz,

[16] Quizzes are not provided with this paper so that we may continue to reuse them in our courses; they are available upon request from the authors. We recommend that instructors write their own to link to datasets and topics that will be used.

students can practice concepts such as how to rename, recode, and transform variables and can be asked to make a descriptive statistics table.

3.3 Descriptive Statistics Table for Teaching

Applied economics papers often provide descriptive statistics in the first table of the paper; this table can also be a teaching tool for undergraduate researchers. Table 1 in the sample paper provided in Appendix C gives an example of a typical descriptive table, which can be used to teach students about types of variables (e.g., continuous, categorical, and binary) along with an accompanying statistics textbook such as *The Effect* (Huntington-Klein 2022). Including the maximum and minimum for each variable in the descriptive statistics can also help students with data cleaning and serve as a cross-check for the instructor, particularly to identify where the DHS uses 99 for missing values, such as the number of years of schooling. Including the mean, median, and standard deviation and having students interpret these differences can help reinforce statistics concepts as well. Finally, having students order the variables such that the outcome variable goes first, and the effect variable second will teach them how to hone the argument for the paper. Appendix B.5 provides a sample assignment for students to create a descriptive statistics table.

3.4 Survey Weights

The DHS uses sampling weights to adjust for the differences in sample size needed to be representative at regional levels. For example, in the Tanzania survey, roughly 3 percent of the population lives on the island of Zanzibar, but 15 percent of the sample of the 2022 DHS is taken from the island (MoH 2022, p. xxxiv). The DHS provides YouTube videos to show students how sampling weights work and how to incorporate them in descriptive statistics.[17] The DHS constructs separate weights for each household and female respondent, and in some cases, additional weights are added to correct for sampling differences based on other criteria such as rural/urban residence. In most DHS data files, the relevant survey weights are labeled as the variable v005 or hv005 to designate the women's or household's sampling weight. Encouraging students to use sampling weights in both the descriptive statistics and the econometric work can be useful to teach proper analysis with weighted samples.

3.5 Graphs for Applied Econometrics

Graphs are an excellent way to demonstrate the relationship between the outcome of interest and the main effect variable. The sample descriptive statistics assignment in Appendix B.5 asks students to make a graph with these two variables. First, students need to learn the type of graph to make based on the variables of interest. For example, categorical variables typically work best with bar graphs. Jayachandran and Pande (2017) use a graph showing birth order (a categorical variable) and average height to support their hypothesis that Indian children are shorter, mainly because of limited resources provided to the youngest children in the household. When variables are continuous, a line graph or scatterplot can better show a trend. McGavock (2021) includes an excellent example showing the relationship between child marriage laws and age in Ethiopia using a line graph.

3.6 Econometric Work

To do econometric work, students will first need to create an econometric model, then run the regressions and interpret the results. Students can start with the most basic econometric model, which includes their outcome and their effect variable of interest. Chapter 13 of Huntington-Klein (2022) is an excellent resource to help students design and run their first econometric regressions. Instructors can start by teaching students how to write a basic econometric equation; particularly, if subscripts are used,

[17] https://www.youtube.com/watch?v=SJRVxvdIc8s

they can help emphasize the unit of analysis (e.g., individual, household, or country). Next, students can add the three levels of complexity to the basic equation: control variables, fixed effects, and interaction terms. Section 5 of the sample paper in Appendix C provides an example of a fixed effects model using DHS data. These equations can also help the instructor explain control variables; fixed effects and why many DHS papers use them, as they include multiple surveys or use subnational units or time/cohort controls (see Chapter 16 of Huntington-Klein 2022); and interaction terms and why they are often used (e.g., when specific subpopulations may be of interest). To help students understand the last concept, students can be asked to rerun regressions for rural and urban subpopulations. Jayachandran and Pande (2017) and McGavock (2021) provide helpful examples of interaction terms.

Applied economics and particularly development economics research stresses the importance of causal identification; teaching students about endogeneity is an important part of this process. Chapters 5 through 10 in Huntington-Klein (2022) provide excellent details on these concepts, including a discussion of identification, causal diagrams, and finding front doors. A more condensed discussion of the three types of endogeneity (omitted variable bias, measurement error, and reverse causality) can be found in Bellemare (2016). It is helpful for students as they write their econometric framework to think through each of the types of endogeneity.

The next task for students is to run their regressions and write up their results. The assignment shown in Appendix B.6 has students create a results table with five regressions and interpret the effect sizes. This assignment can also be used to reinforce concepts such as the difference between statistically significant (e.g., *p*-value) and economically meaningful results. It is also helpful to have students review their descriptive statistics to put effect sizes in terms of a standard deviation of the variable of interest and compare the effect size with the mean. In a past CURE, one author typically assigned two quizzes related to econometrics, the first to test both the students' ability to use RStudio or Stata to run a regression and interpret it, and the second to test students' ability to run and interpret a regression with interaction terms and fixed effects.

3.7 Linking the DHS to Other Sources of Data

Linking data from other sources to the DHS can create excellent potential research questions that can be assessed with a causal inference approach. This approach is best for students doing year-long theses who have time to find, clean, and merge a second dataset, while instructors may need to provide the additional data or help with the linking if done in semester-long CUREs. The DHS data typically includes GPS coordinates and other geographic information that can be used to link other data sources. For countries included in the IPUMS-DHS, accompanying geographic data (including shapefiles at harmonized subnational levels) is also available. The DHS program maintains a Spatial Data Repository that collects freely available data from other sources to match with DHS data, including population density, weather, malaria, and livestock ownership (Mayala and Donohue 2022). Weather data can be a great complement to DHS data and allows students to generate unique research topics. Another example of data linkable to the DHS is food prices. Recently, an undergraduate student doing summer research with one of the authors linked data on local food market prices in Nigeria, collected by the World Bank (see Andree 2021), to DHS data to understand the impact of food prices on infant mortality and children's height.

Matching data at subnational unit levels (e.g., provinces or states) is another research approach. In a good example of this approach, McGavock (2021) uses regional variation in child marriage laws within Ethiopia. The sample paper in Appendix C uses another potential dataset for undergraduate research, The Global Terrorism database, to measure the influence of terrorist attacks on children's health and use of health care as measured by the DHS. This dataset provides information on terrorist attacks at the subnational unit level (in this case, Afghan provinces). This dataset can be used to examine the impact of terrorist attacks on demographic and health measures from the DHS. For example, Cahalan et al. (2020) look at the influence of terrorist attacks on women's employment in Afghanistan.

Subnational economic data may also be obtainable from individual countries. For example, another paper, co-written by one of the authors and a third student, uses district-level variation in foreign direct investment in Nepal to estimate its effects on women's employment Ziard et al. (Forthcoming).

3.8 Software

Instructors can choose among data analysis software (e.g., Stata, R, and Python) for students to conduct most applied economics research projects. In a review of submitted code for replications, Nguyen (2019) reported that two-thirds of papers published in top general-interest economics journals used Stata, followed by MatLab at one quarter; R and SAS each accounted for less than 5 percent. Instructors' knowledge of and comfort with a given software package will affect the time costs of preparing the class and likely the benefit for students, as instructors' research experience helps with teaching and debugging code. The DHS Program provides the most technical assistance in Stata, including an entire workbook with exercises (DHS Program 2019). Nonetheless, familiarity with R, SAS, and Python are also useful skills that will likely help students find employment in the private or government sector. Moreover, RStudio and Python can be used for free, while Stata's six-month student license currently costs US$48 for students. One of the authors has taught a CURE with DHS using Stata and then later RStudio. As expected, Stata was easier for students to grasp and had fewer technical issues; however, the differences in price and potential job prospects for RStudio outweighed the reduction in technical issues.

As discussed above, the DHS can be linked to weather data, but there are also R packages that allow the use of some satellite data (e.g., see the "chirps" R package), which is an advantage of using R. Nonetheless, ArcGIS or QGIS can be used to perform features not included in the R packages for weather data and when using other satellite imagery datasets that do not offer R packages. ArcMap and QGIS are user-friendly, may not take a lot of time for students to understand the basics (we recommend the "clip" and "select" tools to start), and allow students to produce high-resolution maps without requiring coding abilities. Moreover, if students have some training in Python, the ArcPy integration in ArcMap is also a great tool to put their Python skills to good use and be able to reproduce maps and file transformations within ArcGIS using only Python scripts.

4 Writing, Presenting, and Publishing

Writing up data analysis helps students link their data work to research and hones their argument. We suggest that all students write a paper to codify their ideas and mirror the research process of the literature they read. Many opportunities exist for publishing including journals specifically for undergraduates in economics, though for many students only writing the paper as an assignment is sufficient. Students should have the opportunity to present in class or to peers. We discuss potential conferences below, but like submitting for publication, presenting outside of the classroom may not be for every student. We provide a set of goals and structure in Appendix A and a sample rubric for a final paper in Appendix B.8.

The goal of writing a research paper is to answer a question of interest to the reader. For a big-picture approach, Chaubey's (2018) book on writing research papers helps students with the RAP method: Research Question, Answer, and Position. This method requires students to ask a question, answer the question, and show how the paper positions itself in the literature. Applied economics papers have a standardized structure that can be used to help support the main goal by breaking the paper into specific parts.

Typically, applied economics papers have six sections based on the standard structure of economics papers (see Bellemare 2018; Neugeboren and Jacobson 2005). Appendix B.7 provides an example outline of a paper. This example is used in one of the author's CUREs and served as the basis for the creation of the sample paper in Appendix C. These sections are the abstract, introduction, conceptual framework, data description, econometric model, results, conclusions, and works cited.

Keith Head's (n.d.) introduction formula links well to Chaubey's (2018) RAP schema and is a good framework to give to students. The formula includes five paragraphs: the hook (why the topic matters), the question, the antecedents (literature review), the value added (or positioning), and the road map (what the rest of the paper does). In the next section, the conceptual framework, students should use previous research to set up hypotheses about why their main outcome of interest will be influenced by the variables they chose. This section will serve also as a literature review, but calling it a conceptual framework reminds students that the purpose is to set up the hypothesis.

For the data description, students need to include the five Ws: who was asked (define the unit of analysis), what they were asked (define the variables), where the survey was given (i.e., is it representative), when the survey was given (year and relationship to relevant events), and why the survey was conducted. Students can use their descriptive statistics (see Appendix B.5) produced with notes as a starter for this section. This section also helps set up the econometric model section that follows.

In writing the econometric model section, Nikolov (2022) suggests starting with the simplest regression—typically, this regression includes just the main outcome and main variable of interest—explaining why other variables might need to be added. Students will often need to learn the process of writing an equation to include subscripts for the unit of measurement of the variable (e.g., household, individual, or time). Having students write a short paragraph on the potential for endogeneity using the three main types (omitted variables, measurement error, and reverse causality) can strengthen the paper and reinforce these concepts.

In the results section, students typically expand on and revise the assignment in which they submitted their main results table. Usually, this includes one paragraph discussing the main variable, a second paragraph discussing other variables of interest, and a final paragraph discussing additional regressions, if undertaken.

To provide structure for the conclusion, Bellemare (2018) suggests a formula that mirrors the introduction formula discussed above. In this case, the four parts of the conclusion are a summary, a discussion of limitations, implications for policy, and implications for future research. Students, based on our experience, struggle the most with identifying what limitations matter; for economists, these limitations typically include issues around exogeneity. Asking students to imagine the ideal dataset for their research problem may help them analyze this issue.

4.1 Peer Learning and Review

In CUREs or instances where multiple students are working on theses at the same time, students can review each other's outlines and first drafts of papers. This exercise serves a few goals. First, students get additional feedback and ensure they are not missing any key sections. Second, instructors can use student peer feedback as a method for describing the peer review process in economics and how it functions. This is especially helpful for underperforming students because they get feedback from those who are performing better and, at the same time, higher-performing students can learn more by explaining concepts to other students.

4.2 Presenting

Students can present in class and at conferences using slides or posters. The presentation can help reinforce the concepts discussed in the student's research paper. Appendix B.9 provides a sample list of slides given to students in the DHS-based CURE for a final presentation. The slides are linked to the sixth section of the paper structure described above. Earlier in the semester, students can present the first half of these slides before they create their result tables, providing a check before students begin to outline or get too far into a paper.

These slides can also be transformed into a poster. In most semesters that one of the authors taught the DHS-based CURE, students presented their work in a university-wide sponsored poster forum. Poster sessions can also be done in class. The biggest gain of using posters is not having each student present for 10 minutes, which can take up many class periods for larger class sizes. In a class-based poster session, half of the students can be at their posters explaining their project, and the others can be consumers of the research. In either presentations or posters, having a simple assignment such as summarizing others' work can further support the peer review process.

4.3 Conferences and Publications

Students can gain further experience by presenting their work at conferences and submitting their research to journals. The regional economics associations (e.g., eastern, southern, midwestern, and western) hold meetings that often include undergraduate presentations. Of these meetings, the Eastern Economics Association has the most established undergraduate research session through the Issues in Political Economy Project, which hosted the 30th annual conference in 2024 at the Eastern Economics Association meetings (Elon University 2023). This group, based at Elon University, runs sessions that have undergraduate research in fields across economics, with many applied microeconomics sessions. The Federal Reserve Banks in Cleveland and Dallas have conferences that include undergraduate presentations as well. Moreover, specialized conferences for undergraduates underrepresented in economics can be found at Williams College (PIER) and the Sadie Collective conference for Black women interested in economics and related fields.

Students can ultimately publish their articles in both undergraduate research journals and academic journals. The American Economic Association lists seven potential economics-focused undergraduate research journals on its website. At Colorado College, undergraduate-coauthored articles have been published in well-regarded field journals such as *Energy Economics*, *Journal of Economic Geography*, and *Journal of Sports Economics* (Fenn et al. 2010). One of the authors of this paper published a work using DHS data with an undergraduate student in *Oxford Development Studies* (Cahalan et al. 2020). That said, there certainly are steep costs for instructors to publish student work in academic journals. Typically, review can take up to a year, by which point many students have moved on to careers or graduate school and have less time and interest in finishing their research papers, leaving the work of polishing a paper and responding to reviews to the instructor or mentor.

5 Conclusion

The DHS offers an excellent opportunity for undergraduate students to research under the guidance of experienced applied economists to examine some of the world's most important issues. As faculty, two of the coauthors have been able to turn this work into papers that have been published or are in the pipeline. We do acknowledge the high time cost to faculty of doing research with undergraduates and feel the DHS structure addresses many of these issues. In Appendix B, we provide numerous sample assignments for CUREs or theses to help with the structure of the paper; in Appendix C, we provide an example student paper. The third coauthor shares her own experience as a student and alumni in Appendix D, which we suggest potentially sharing with CURE or thesis students to demonstrate how to leverage undergraduate research into a career. Overall, the DHS datasets offer an excellent tool for undergraduate research.

Appendices: All appendices for the paper are downloadable as supplementary documents at aetrjournal.org.

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Teaching and Educational Methods

Undergraduate Research in the Andes: Overcoming Barriers to Developing-Country Farm-Household Focused Analysis

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Abstract
This paper provides a qualitative description of a long-term engagement of undergraduate students in an immersive research experience in Ecuador. We describe and analyze factors related to operation under common challenges to field research in developing countries. We address issues of incentives and barriers to faculty and students interested in pursuing international undergraduate research. Our program has engaged students at Virginia Tech eight times since 2007, including a total of 50 U.S. undergraduates, and was designed to attract students of all socioeconomic strata. It begins with a Spring semester three-credit class on research methods, household survey administration, and data analysis and inference. During this time, partners in Ecuador are introduced through remote meetings and joint work on the survey. In mid-May, we fly to Quito, where students take language and culture lessons, finalize the survey, and gain exposure to the various institutions involved in the research. After two weeks, the group travels to the remote survey location, currently near Riobamba in Chimborazo Province. Four weeks of data collection paired with local students follow. Finally, data are analyzed, and a report is prepared and presented to an advisory group in the subsequent Fall semester.

The programmatic goals were to (1) provide undergraduates with a substantive research experience in a developing country; and (2) provide useful data for the project as to the attitudes of Ecuadorian farmers toward adoption of environmentally friendly agricultural practices. The program is built around several principles: (i) end-to-end student engagement from problem identification through presentation of findings to stakeholders; (ii) financial accessibility—all participation costs are covered; (iii) primary data collection from farm-households in the study area; (iv) full partnership with host-country researchers and students; and (v) supportive and complementary past and ongoing agronomic research in the study area. Lessons include challenges related to program structure; administration—the Institutional Review Board (IRB) clearance, travel approvals, and financial matters; technical challenges—questionnaire design, CAPI surveying, teaching, and programming data analysis; and field supervision, language, and cultural awareness. Linkages to high-quality ongoing agronomic research allow the socioeconomic research to focus on technology adoption and technology-relevant factors such as profitability, risk, and access to inputs. These themes are well-addressed through socioeconomic research.

1 Introduction

We designed an international research program to address three critical deficiencies related to the preparation of undergraduate students in social sciences for careers in agricultural sciences and graduate studies. First, undergraduate students in agricultural social sciences often lack meaningful research experience linked to an agricultural policy question of interest. Second, research experiences for undergraduates tend to be narrowly focused and do not engage future scientists in the full range of the research experience. Third, undergraduate students in agriculture often lack international

experience beyond short-term faculty-led travel abroad courses, limiting their abilities to build a deep understanding of another country's language, culture, and institutions (Bruening and Frick 2004; Heinert and Roberts 2016; Bletscher, Gould, and Qu 2022).

The international student research program developed builds on Virginia Tech faculty's research experience and strong partnership with Ecuadorian colleagues, and focuses on measuring obstacles to widespread diffusion of conservation agriculture (CA) practices. The programmatic goals were (1) to provide undergraduates with a substantive research experience in a developing country; and (2) to provide useful data for the project as to the attitudes of Ecuadorian farmers toward adoption of environmentally friendly agricultural practices. In the Spring semester, students enroll in a three-credit class on research methods in applied economics. The course covers the whole research process from literature review, research question formulation, the development of survey instruments, and data analysis. Students also interact with faculty and students in Ecuador to learn about CA principles and the language and culture of Ecuador.

Following the end of the Spring semester, students travel with faculty to Ecuador for six weeks. The first two weeks are spent in language/culture classes in the mornings, while visiting local institutions and piloting field methods in the afternoons. Virginia Tech students partner with Ecuadorian students and embark on four weeks of data collection, interviewing farm households. The program ends with a one-credit research class in the following Fall semester during which students work in groups to address their research questions using the data they collected. The final outputs are a written report and presentation of research findings to a faculty committee.

The objectives of this paper are to provide a qualitative description of the evolution of this undergraduate research program and the factors leading to its ease of operating under common challenges to field research in developing countries. The description is supported by a qualitative survey of former participants. We begin by presenting program background, the features that have made the opportunity enjoyable for students and faculty, and the features that have made it sustainable. We then move to the structure of the program and how that structure has been adjusted over time to strengthen its educational content. We discuss program barriers and opportunities and how barriers were overcome. We then provide perceptions of student participants.

2 Background

The first phase of the Ecuador undergraduate research program began in 2007 in response to strong student demand. Many undergraduate students in the Department of Agricultural and Applied Economics (AAEC), and elsewhere in the College of Agriculture and Life Sciences, had expressed interest in hands-on experience in international agricultural development. The department's faculty conducted international research, supported by external funding, that included graduate students, but provided few engagement opportunities for undergraduates. The faculty thought that it was important to make the research experience accessible to undergraduates.

To address this shortfall, AAEC faculty leaders created an undergraduate research program within a well-established research project. The Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM CRSP) sub-project in Ecuador (and Bolivia) led by AAEC engaged a multidisciplinary team of U.S. researchers and host-country scientists from the Instituto Nacional de Investigaciones Agropecuarias (INIAP) in Ecuador. The project focused on agronomic and economic feasibility and adoption of CA in a small-scale, highly fragile, farming system in the Ecuadorean highlands. Extremely steep slopes, irregular rainfall, and the use of aggressive tillage led to important erosion-related soil loss, declining yields, and overall stress on the system (Barrera, Alwang, and Cruz 2010; Monar et al. 2013). The SANREM project examined agronomic factors including fine-tuning known CA practices; effects on input use; and impacts on yields, soil loss, and soil health. Researchers concluded that CA held significant promise (Barrera, Alwang and Cruz 2010a, 2010b). The

technical feasibility and agronomic attractiveness of CA stimulated interest in examining production costs, economic returns, and an eventual strategy to disseminate the results to potential beneficiaries.

The United States Agency for International Development (USAID)-funded Collaborative Research Support Programs (CRSPs, now named Innovation Labs) run by Virginia Tech had participation from graduate students who experienced a productive research environment in Ecuador. They found that local scientists were fully invested in ongoing research. In addition, safety, often a concern in developing countries, stability, and access to services made Ecuador a favorable environment for student fieldwork. The research itself offered several topics amenable to survey research, such as field experiments, on the cost effects associated with CA practices, willingness to adopt CA practices, and measurement of adoption and its impacts (Alwang et al. 2013; Monar et al. 2013; Barrera et al. 2020). Within this established research program, AAEC faculty created an end-to-end research experience for undergraduates. The experience consisted of design and testing of a survey questionnaire and enumeration of surveys to farm-households as the go-to data-generating experience. Data analysis and reporting completed the undergraduate research experience. The faculty thought that it was important to make the experience accessible to all students regardless of their financial resources or lack thereof. By tying the program to ongoing grant resources, financial barriers to participation were lowered. Spanish language proficiency was emphasized, and we strived to recruit at least some participants with strong language skills.

3 Program Description

3.1 Initial Undergraduate Engagement and the Evolution of the Program

The first groups of undergraduates to participate in this international research program were known as "SANREM Research Interns." The program was built into the SANREM CRSP project plan and held every other year. These groups (eight students in 2007, five in 2009, seven in 2011, and six in 2013) were exposed to a limited research experience, including Spring meetings, two weeks of language training in Quito, and four weeks of data collection in Bolivar Province. Later as described below, the program was expanded to produce a more complete research experience.

In the Spring semester, the first intern group (2007) participated in regular two-hour informal biweekly classes whose content mainly covered findings from the agronomic research, the cultural context, and some Spanish agricultural vocabulary. While at least minimum Spanish language proficiency was a pre-requisite for participation in the program, only a few students were proficient speakers. Students in 2009 and later would have stronger language proficiency. Students were split into two-person teams and asked to develop small-scale research projects that could reasonably be completed in four weeks.

This first attempt at an international research internship produced important observations, which led to changes in the way subsequent SANREM internships were organized. First, we discovered that the entire group should address a common set of objectives rather than encouraging small teams to investigate separate research themes. The program did not have sufficient capacity to supervise multiple teams, and our partners were overextended by requests for transportation to different research locations. For example, one two-person team in 2007 planned to visit health centers and local water utility offices to understand how poor water quality affected farm families, particularly children. Another team conducted research on costing CA practices by interviewing farmers about time spent in different on-farm activities. INIAP researchers specialize in agriculture and were neither prepared nor excited about supervising data collection in the water and health sectors.

Second, we recognized that a large part of the research experience is to bridge the gap between the data and the potential to make inferences about the larger population. We decided to increase rigor and ensure data collected were of sufficient quality and quantity to support statistical analysis. This

decision made it necessary to cover additional topics during the 2009 and subsequent Spring semesters. Added topics included hypothesis testing, sample size (and randomization), and its relationship to statistical representativeness, and questionnaire design. We also introduced programming statistical software for data analysis. While many of the interns had coursework on statistics, they had never employed the techniques in a research context. These additions led to more instructional time as the course credits were increased from one to three hours.

Third, we observed the importance of physical fitness and team building. The Andean highlands are a particularly challenging environment due to high elevations, 2,800–3,800 masl (meters above sea level); walking from household to household during survey enumeration was physically challenging and led to student burnout. We subsequently introduced an exercise regime during the first two weeks of language training in Quito and spent more time during evenings interacting with student groups to understand and help deal with the challenges they faced. Teamwork is also fostered by increased interactions during subsequent Spring semesters with INIAP colleagues.

The four groups of SANREM Research Interns (2007 to 2013) conducted their fieldwork in Bolivar Province and stayed in the town of Guaranda (see Figure 1). They traveled up the mountain into indigenous communities and down the mountain into mestizo communities to interview farmers about the technical and economic potential of CA (Barrera et al. 2016; Barrera et al. 2020). Guaranda was an excellent location for the students because the town was small enough to be safe and large enough to have restaurants and adequate medical care. When SANREM ended in 2014, INIAP research on CA moved to Chimborazo Province in areas around the small city of Riobamba.

3.2 Current Program

Following completion of the SANREM project, AAEC faculty decided to focus on an enhanced opportunity by providing an end-to-end research experience. The idea was to build on the lessons learned from the past Ecuador research internships, and with external funding from the United States Department of Agriculture (USDA) Research Experience for Undergraduates (REEU) program, five years of engagement began in 2019. Lessons learned through the SANREM phase included the need for additional training in research methods, programming for data collection, analyzing survey data, and preparing reports, as well as an understanding of research and the research context.

Structurally, the new program consists of a three-credit course taught during Spring semester, six weeks in Ecuador (two weeks in Quito and four weeks of data collection in Chimborazo Province, current home of ongoing CA research) and a single-credit Fall course on data analysis and reporting (Figure 2). Faculty and students from the Escuela Politecnica de Chimborazo (ESPOCH) participate during the Spring. These students are then teamed with Virginia Tech students during field interviews in June. ESPOCH students use the experience to complete an undergraduate thesis necessary for the degree in Agronomic Engineering and partnering benefits U.S. students through enhanced exposure to Spanish and local context, and by facilitating enumeration.

The Spring class covers research methods and research administration issues, and formally engages partners in Ecuador. The course syllabus conveys expectations for students as well as the content and intensity of the field research. Lectures and exercises in research methods include problem identification and a literature review, an overview of quantitative and qualitative methods, hypotheses and the role of falsification, and questionnaire design and its link to the concepts related to the hypotheses. We require written output at different stages, and the content of the lectures is specifically tailored to the program at hand. Students appreciate the exposure of a “total” research project, and one anonymous participant stated: “Getting experience working through ‘all the steps’ of a large research project helped me to better understand the research process, and this understanding made the concept of research much less overwhelming.”

Figure 1: Map of Ecuador with Study Locations.

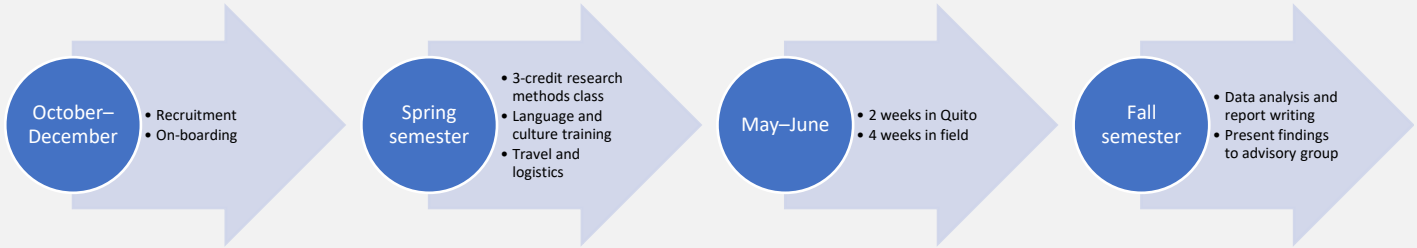

Figure 2: Timeline for Ecuador Undergraduate Research Internship Class.

Prior to 2019, our household surveying had been done using paper questionnaires. This led to heavy burdens on students to input the data into a digital format, a time-intensive activity for which few rewards were received. We decided to switch to a computer-assisted person interview (CAPI) process, whereby questionnaires are entered into a tablet-based format, and software is used to program the survey. Training in CSPro (www.census.gov/data/software/cspro.html), the software used for tablet-based enumeration, was introduced in the Spring semester course. This training helps students think about the links between concepts, the questionnaire, and the structure of the data they will later use for their research analysis. Students are introduced to basic survey fundamentals, such as using matrix formats for themed groupings with scales, skip patterns, and the appropriate use of open-ended questions. The CAPI process introduces an entirely new field experience. Instead of keeping paper copies dry and ensuring that the handwriting was legible, data are immediately available, and the main concern is to keep the tablets dry and well-charged. Modifications to a CAPI-based survey can be made in real time, and there is no need for printing multiple questionnaires.

Students design the questionnaire in partnership with INIAP scientists and ESPOCH students. These interactions help our students to strengthen their Spanish skills and better understand how to communicate the concepts. They are challenged to justify the inclusion of questions and to explain the wording and the information generated from each of the questions. The Ecuadorean students tend to have expertise in bio-physical sciences, but limited knowledge of social sciences, and not all are knowledgeable about farming practices in the communities where the surveying takes place. As CSPro programming is taught, students are forced to consider the ultimate utility of specific questions, the flow of the interview, and how to translate their research concepts into the Andean context. Issues such as what constitutes a household and who might be considered the household head lead to deeper consideration of the cultural context. Interactions with Ecuadorean students and researchers facilitate this process. One participant commented: “It was fun and interesting to work with and learn from the Ecuadorian extension agents and students involved in the project.”

During the Spring semester, the students are also exposed to sampling considerations, research ethics, and best practices for interviewing farm families. Sampling is a key consideration, as the sample and its properties determine the relationship between the household data set and the research questions. A few hours are spent on statistical representativeness and inference, followed by coverage of how sampling affects this relationship. Issues such as optimal sample size and the role of clustering are also covered. The timing is important because we rely on the Ecuadorian partners to generate the random sample. This process, including obtaining village populations, and gathering names and contact information of potential respondents, requires time. We also introduced ethical and administrative considerations such as obtaining approval for human subject research (Institutional Review Board (IRB) clearance), privacy, and how privacy considerations are related to use of software, and regulations related to safety such as the Clery Act.

The first two weeks in Ecuador are used for morning language and cultural training at a Spanish school in Quito, while afternoons are used for visits to INIAP and other research partners, further refinement of the survey instrument, and a physical exercise regime. Rigorous training in CSPro is essential as survey piloting in communities around Quito provides information requiring revisions to the questionnaire. ESPOCH students participate in questionnaire revisions and work with the U.S. students to improve the logic, structure, and flow of the questionnaire.

After two weeks in Quito, our INIAP partners transfer the students to the research site, currently in the communities outside of Riobamba. The first couple of days in Chimborazo are spent meeting the ESPOCH administration, introducing the research idea to the communities, and further refining the questionnaire with local partners. Virginia Tech students are paired with ESPOCH students. Supervision in the field is provided by INIAP, local agricultural extension agents, and Virginia Tech Faculty (Alwang, Bosch, Chen, Larochelle, and Norton).

Two important considerations govern the field research: cost and faculty time. First, cost of surveying in developing countries largely depends on the capacity of vehicles used to transport enumerators to target villages. In our case, paired teams with a single (INIAP or other) field supervisor means that three teams can be transported in a single vehicle; since we are constrained to two vehicles, the optimal number of Virginia Tech students is six—three per vehicle when paired with an ESPOCH student. While in other environments a small bus or minivan might change this calculus, given the roads in our study area, four-wheel drive vehicles are necessary.

The second consideration is faculty time. To manage the burden on individual faculty, we team teach during the Spring semester, and a single faculty member accompanies the student group for two weeks in Ecuador—we rotate participation, so that over the whole of the six-week in-country research, three different faculty members supervise for two weeks each. Our experience tells us that Spanish proficiency is important, and on one occasion when a faculty member was not fluent in Spanish, we engaged a Spanish-speaking graduate student as a research associate.

Following four weeks of surveying, the undergraduate team presents basic descriptive statistics to the communities where the surveying occurred. This exercise is important because it is a way to give back to the communities. The presentations also facilitate ongoing interactions between INIAP and local actors whose participation is needed to continue the agronomic research. The exercise also teaches our students about the value of collaboration and provides some structure to discussions of data analysis. The benefits of CAPI surveying also become obvious as the data are immediately available in a digital format. Since the students programmed the CAPI survey, they are already familiar with the data structure, making it easier to provide descriptive analysis for these presentations. Before we used CAPI (during the SANREM portion), we had students digitizing data and error checking at nights. CAPI eliminated this very burdensome requirement and allowed students to focus on analysis themes for the community presentations as well as subsequent write-ups of the research results.

During the following Fall semester, more rigorous analysis is conducted. Students are exposed to data cleaning and quality control, the value of structured data sets, and hands-on programming for statistical analysis. At the end of the semester, we convene an academic and professional advisory board to review the work and provide suggestions for students and the program. Participant feedback has been an important source of information about successes and failures of the experience. Research themes as well as a brief description of data collection are shown in Table 1.

3.3 Impacts of COVID-Related Travel Restrictions on the Program

In early 2020, the growing COVID-19 pandemic required suspension of the field research. At the time, meetings with our Ecuador partners and students and faculty from ESPOCH were attenuated. While INIAP personnel still worked remotely, the university was closed, and students were not reachable.

Considering our options for Summer 2021, we decided to continue with the program with some modifications. There was no question of the possibility of getting information from the research communities because exposure to the pathogen could have had extremely dire effects on the relatively isolated population. To provide students with the full research experience, the Spring 2021 course included (i) a semester-long project using student interviews to measure the influence of COVID-19 on student educational experience at Virginia Tech, and (ii) an introduction to agricultural conservation practices in the Chimborazo region in Ecuador. The interview project focused on research methods, from formulating a research question to data collection and presentation of findings. The summer involved a six-week paid research internship on data analytics using the Ecuador data set collected by the 2019 cohort. Early in the day, faculty delivered instructional material and went over tasks for the day. Faculty remained available throughout the day to address questions. We concluded the day with students giving an overview of the progress made and challenges faced. The internship started with data cleaning and formulation of research questions. We then focused on more elaborate statistical modeling, data visualization, and steps in preparing a written report.

Table 1: Undergraduate Research Internship: Participants, Research Topics, Survey Descriptions, and Analytical Techniques.

Year	Students Females	Males	Research topic (Location)	Survey description	Analysis
2007	8	1	Effects of water quality on child health, knowledge of causes of erosion, and dairy production costs (Bolivar)	Water and health: 60 household responses; dairy study: 50 respondents interviewed. All data were transcribed from paper.	Descriptive statistics, some multivariate analysis
2009	4	1	Baseline survey (Bolivar): family and farm characteristics, cropping patterns, labor use, and income	Multi-purpose farm-household survey 286 observations with responses recorded on paper.	Descriptive statistics, farm typology creation, gender-specific analysis
2011	4	3	Costs of conventional farming and conservation agriculture (Bolivar)	Paper survey of 88 farm-households interviewed in two watersheds. Input prices collected in market centers.	Descriptive statistics on costs of production and net revenues
2013	6	1	Determinants of adoption of conservation agriculture practices (Bolivar)	Short survey and discrete choice exercise among 233 farmers.	Descriptive statistics on farmer concerns about CA and the value of soil conservation
2019	5	2	Baseline survey (Chimborazo): family and farm characteristics, cropping patterns, labor use, and income	CAPI survey of 392 farm households. Household conditions, farming practices, and attitudes about CA.	Descriptive statistics, multivariate analysis of access to credit, and determinants of CA adoption
2020			Determinants of adoption of CA; attitudes toward environmental damage	*Used data generated in 2019 (Chimborazo).*	Multivariate discrete choice models
2021	4	1	Special project: impressions of COVID-19 impacts on undergraduate learning	*75 telephone surveys of undergraduate students. Short, 10-minute interview.*	Descriptive statistics evaluating alternative learning experiences under COVID-19
2022	4	2	Follow-up survey (Chimborazo): intention to adopt CA, actual adoption	190 surveys completed; data collection suspended due to uprisings in the area.	Multivariate statistical models linking farmer and farm attributes and intention to adopt CA

During 2022, we reinstated the complete in-country program for Virginia Tech students. No problems with COVID-19 were experienced.

4 Barriers and Opportunities

Much of what we learned about running the program is due to the durability of the program over eight research cycles. This durability facilitates learning by doing and the quality of the research experience as it has improved substantially over time. A core group of faculty advisors was maintained throughout the eight cycles, and we put a heavy emphasis on debriefing the students after the program to address problems. The durability owes to faculty success in obtaining external funds to support the program as well as positive feedback from early student participants that helped motivate efforts to continue and improve the program. For further information on the coursework, please see the syllabus in Appendix A.

4.1 Cost

An important barrier for many students is cost. Obtaining a rigorous international field research experience with professional supervision by national experts and U.S. academics would be prohibitively expensive—approximately $3,500 per student. Our project resources paid the bulk of the costs, but in years where funding was limited, students have been encouraged to seek and have received internal funding from Virginia Tech sources, including the AAEC department, the College of Agriculture and Life Sciences, and the University Honors program. The involvement of INIAP in joint research projects has also allowed us to lower costs—project personnel are paid and vehicles are made available through the research funding. This funding, in turn, provides the motivation for the questions addressed by undergraduate research. INIAP has also negotiated favorable rates for accommodations and lunches for the students. To keep costs low, Virginia Tech faculty donate their time; no project funding has been used to pay faculty salaries. As a result, the out-of-pocket cost for each undergraduate participant over the life of the program has been close to zero, except for the tuition paid for the three-credit Spring semester course and one-credit Fall semester course.

4.2 Recruitment

We advertise the program through undergraduate advisors and student listservs. We emphasize the uniqueness of the program and that students formally receive credits for courses taken in the Spring and Fall semesters. We highlight differences between our international research internship program and typical study abroad experiences by stressing its rigor and immersive elements. A six-week immersion in undergraduate research in the Ecuador highlands is both physically and mentally challenging. Early in the program, we learned it is important to select students who are willing to (1) endure full days of rigorous physical and mental exertion, (2) prepare for and adapt to expected minor health issues, (3) work closely with others in a group setting over several weeks, and (4) adjust to nuances of working in another culture with patience. We receive many applications and screen applicants based on coursework, Spanish ability, motivation as demonstrated by a statement of interest, and letters from referees. We generally short-list about ten candidates and conduct short interviews to make final decisions. During the interviews, we stress the physical and mental difficulty of the program and try to gauge Spanish-speaking ability. We seek a gender-balanced group of about six students. Description of participants by gender and year is shown in Table 1.

4.3 Consistent Research Themes

The importance of the research topics cannot be overstated. Our program is unique in that it builds on ongoing biophysical research in the area. Student interns are introduced early in training to the CA practices and the motivation for examining costs, constraints, and mechanisms for diffusion. We learned that, since CA requires a fundamental rethinking of the role of crop residues and tillage operations, farmers are reluctant to adopt without clear evidence of its advantages (Barrera et al. 2016; Delgado et al. 2021). Students learn that public agricultural extension is limited in Ecuador so that information on incentives and barriers to adoption and successful low-cost tools for extension are of critical interest to policymakers. The evolving focus on tools for dissemination helps clarify the practical value of our research. This value motivates participants; they too want answers to these questions.

Continuity in research reinforces the idea that research is an incremental process, and the best researchers build on the shoulders of their predecessors. While we introduce the importance of the literature review, we expose students to the findings of earlier intern groups and challenge them to push the findings further.

4.4 Research Skills and Language/Cultural Training

Since our early efforts, we have modified procedures to enhance student preparation. While learning-by-

doing is a major theme of the program, we found that students lacked practical training in research methods covering the gamut from problem formulation to results reporting. The Spring semester class was necessary to provide a sufficiently broad view of the research enterprise. Introduction of programming and data analysis creates a bridge between quantitative coursework and its practical application. Fieldwork in developing countries requires special skills, and the semester-long course enabled technical, language, and cultural training to provide these skills. We have increased the degree of interaction with our Ecuadorean partners during the Spring semester preparation phase in order to emphasize context-related vocabulary and build cultural awareness. When available, we have incorporated Spanish-speaking graduate students into the Spring class; their own experiences tend to resonate with the interns. The COVID-19 pandemic had an interesting impact on this skill training. COVID-19 made remote meetings more widely acceptable and accessible, enabling students to have more exposure to language and culture via joint meetings with INIAP and ESPOCH students.

4.5 Administrative Burden

Since program inception in 2007, much has changed in terms of university and other requirements for socioeconomic and overseas research. These include student/participant safety, human subject protection in interviewing, and privacy considerations related to data collection and management.

Safety regulations, including adherence to the Clery Act, have not directly affected student participants, but indirect effects have emerged. We adhere to all relevant university and governmental regulations in this regard. Virginia Tech now requires careful consideration of safety (including reports of crimes in relevant areas) prior to approval, and any safety-related issue encountered in the country needs to be reported. These requirements have led us to request information from our partners. The indirect effect on students has come via sensitization to safety concerns. For example, a student reported an issue of harassment during the program. We discussed the issue and why it was a problem with our INIAP partners who have changed their decision-making to mitigate such concerns.

The human subjects review has had a direct impact on how our instruction is structured. We initially sought to minimize the IRB approval process by keeping it in the background; faculty handled the IRB review without engaging students. Over time, we decided to include students in the process for two reasons. First, all research participants are now required to undergo IRB training through an online course, so it became natural to include the subject during coursework. Second, and more fundamentally, as faculty, we decided that research ethics constituted an important consideration in socioeconomics research. In the Ecuador context, subtle questions emerged about who to interview in the households, what types of questions might be sensitive, and how to protect the agency of the respondents. For example, a basic principle of survey research ethics is that the response has to be voluntary. Survey respondents need to give informed consent, researchers should avoid coercion, and the process should respect the people and their autonomy. These considerations now form an important part of our instruction on research ethics, and preparation of a consent script is an important learning opportunity.

Software approval has recently become more burdensome at Virginia Tech for several reasons. One of these is that software users need to be aware of the importance of privacy. When we conduct survey research, we need to communicate that in addition to being voluntary, information from an interview will be anonymous. Approvals for software use require an assurance that individual-specific information will be protected. We use the software approval process to generate discussions about the importance of anonymity and dangers that might result from failure to protect participant privacy. These actions have converted administrative dicta from barriers into opportunities for learning, and we believe that these considerations are an important part of an ethical research process.

4.6 Cultural Considerations and Competencies

The first two weeks in Quito are especially important. Quito provides a gentle introduction to the developing country research experience. The language school does an excellent job at a reasonable cost to the project. In addition to individualized instruction (tailored to student needs), the school provides initial exposure to Ecuadorean culture and history. Afternoons and evenings in Quito provide an opportunity for revisions to the survey and programming in CSPro. More generally, two weeks in a new environment where the food and rhythm of life are different (at an elevation of 2,850 masl) provide a solid introduction to the challenges yet to come. This immersive experience has long-term impacts. One participant said: "My experience in Ecuador motivated me to continue studying Spanish which has opened doors to me personally, professionally, and in my community. Farmers' generosity in responding to my broken Spanish was humbling and motivated me to continue studying the language…the ability to communicate in Spanish has allowed me to engage with farmworkers advocating for workplace safety in my professional role, adult English-language learners as a volunteer English teacher…"

Differences in culture between the United States and Ecuador can be difficult to adequately convey to the U.S. students before the trip. For example, fieldwork can start rather slowly each day, and time needs to be taken for pleasantries with our INIAP colleagues. Time also needs to be taken to introduce enumerators to interviewees. Students are often anxious to get on with the survey and can become frustrated with the pace, but usually adjust after a few days of experience and discussions with faculty leaders. As one participant noted: "The pace at which we did our work was much different from what I'm used to. We spent a lot of time waiting without using that time productively. It was not necessarily a problem, but an adjustment for sure."

Learning to work collaboratively with Ecuadorian students can also take time. Faculty leaders try to facilitate the process by carefully matching U.S. and Ecuadorian students based on their personalities, Spanish skills, and agricultural backgrounds, so each student pair has complementary skills. Joint sports activities usually spontaneously occur, which also helps with acculturation. Exchange of simple gifts is a useful means of showing appreciation by the Virginia Tech students. Most of the student groups enjoyed a joint U.S.-Ecuadorian karaoke night as well. A participant noted: "The opportunity to work one-on-one with students in Riobamba as well as shoring up Spanish in Quito was extremely enriching in understanding what life looked like in another part of the world. When you work with someone for hours each day, you're going to exchange many ideas, nuances, sayings, jokes, stories, and traditions. From walking through the rural highlands to sitting around a fire at night, we learned an incredible amount from the students and faculty we worked with (including the Virginia Tech faculty!)."

4.7 Keeping the Program Fun for Students Despite Its Intensive Pace

We also learned how to structure daily and weekly activities so students could sustain their physical and mental energy, while remaining focused both on the objectives of the research and on enjoying their international experience. For example, we learned that the optimal time to leave the hotel for the field each day is 8:00 a.m. and to leave the field to return to the hotel is 3:00 p.m. so the students are back to the hotel in time for downloading data from tablets, discussing issues arising during the day, and calling friends and family before dinner. The students eat together as a group, and they select as a group where to dine when eating outside the hotel.

With help from our Ecuadorian partners and considering student desires, we select special weekend activities to give the students a flavor of Ecuador beyond their work and routine interactions with the Ecuadorian scientists and students. For example, most groups have climbed the Chimborazo volcano, visited the falls and baths of Baños, and toured local markets. We schedule one day of rest per week when students are free to do what they please alone or together. They shop, sightsee, play sports, sleep, and so forth.

4.8 Preparing for Health Challenges and Other Risks

Any group of students living and working in Ecuador for six weeks will encounter gastro-intestinal and other health problems. Students and faculty follow medical advice on shots before leaving the United States and bring medicines for expected routine health issues while abroad. Faculty leaders obtain information on medical facilities near the hotel in Ecuador and communicate with local partners and hotel staff to obtain advice when special problems arise. It is almost certain that the faculty leader will need to assist one or more students with a health issue during the six-week program in Ecuador. Usually, it is a foodborne illness, often striking late at night. Once it was a gallbladder problem that required surgery. It is most difficult if the faculty leader is the one who is ill, but we have been fortunate over the years not to have a debilitating problem arise for the leader. If that had occurred, the backup plan was to rely on our Ecuadorian partners for assistance.

Health problems are the most common type of risk, but student behavior that requires correction, culture shock for a student, street crime, and political protests are others. In 2022, four and a half weeks into our in-country program, a nationwide protest occurred. Roads were blockaded by protesters forcing gas stations, stores, and restaurants to close and most transportation to shut down. Our survey ground to a halt, and options were assessed with the help of our Ecuadorian partners, project faculty in Blacksburg, and the Global Education Office at Virginia Tech.

We could continue to shelter in place, but food sources were dwindling. We could not drive to Quito to catch our flights back to the United States because of the roadblocks and lack of fuel for ground transport. Domestic flights were stopped. Although the international terminal was open in Quito, the challenge was to get there. Our Ecuadorian colleagues felt that even though the strike was unlikely to last more than another week or two, the situation could worsen.

We decided to charter a small plane to take the seven of us from Riobamba to Quito. Our risk insurance taken out for the trip covered the cost. We held a closing event with the ESPOCH students and INIAP partners, and the next day they dropped us off at the tiny airstrip near our hotel in Riobamba. A man came out and unlocked the chain to the gate to let us in. When the small Beechcraft plane arrived from Quito, the pilot looked at the seven of us and our luggage and shook his head; there was both a space and weight issue. First, while the plane seated seven, only six of the seats were for passengers, so one of us needed to ride in the co-pilot seat. Second, we had too much luggage and needed to leave some of it behind. Another party had contracted for a later flight, so the pilot offered to bring us the extra bags. We boarded, took off, and landed forty minutes later in Quito. We all made our flights home without a hitch. It is hard to plan for everything, so insurance is your friend for research-abroad programs as we discovered on that trip and the previous one when it paid for gallbladder surgery.

4.9 Value of Local Partnerships

An ongoing close partnership with host-country researchers ensured that socioeconomic research topics were consistent with ongoing agronomic research (technology validation and outreach). Through this consistency, our research interns saw the utility of their work. Their study findings have provided important information for the design of an outreach strategy for INIAP. Partners' motivation was strengthened by the allocation of external funding to short- and long-term training, resources for field technicians, and enhancing visibility of the program within Ecuador. Throughout the international undergraduate research program, the projects supported short-term training to build capacity for soil health and productivity analysis. Through the early linkage to the CRSP, project funding also supported degree training for INIAP partners. Mutual benefits from engagement in the projects led to strong support from the INIAP administration.

The undergraduate research program introduced or institutionalized standard socioeconomic research tools into INIAP. In particular, the use of CAPI for household surveys is now the norm. Evidence of the power of this form of data gathering came from their observations of the ease with which the

questionnaire is programmed into CSPro, the time savings in the interview process as electronic skip patterns are followed, time and cost savings from streamlining the data entry process, and data security as data are loaded onto secure online portals within a few hours of survey enumeration.

5 Research Participant Reflections

A brief anonymous survey administered to past participants provides insights into how the program met its goals to train undergraduate students with skills the agricultural sector needs and prepare them for graduate studies. The survey included six open-ended questions, and respondents were asked to select and respond to one or two questions that resonated the most with them. The questions are provided in Appendix B. Some of the comments are integrated (above) into the text, but additional reflections are useful.

> *"It allowed me to expand on and use critical-thinking skills, learn how to problem solve, and encouraged me to not only ask questions but really think about how to ask those questions."*

> "*I learned about survey creation, how to avoid false or skewed data, how to analyze data, and more*."

> "*Interest in pursuing graduate studies was stimulated."*

> "*This experience was the first real opportunity I had to work in a research environment, and it made me feel capable of navigating graduate studies*."

> "*The idea of one day organizing and going through the steps of my own research project became exciting and is a large reason why I did go to grad school. I don't think I would have had the same eager attitude towards research/grad school if I had not been involved in this project*."

While the focus was on research skills, participants indicated that the experience has also solidified interpersonal and soft skills, such as flexibility, humility, teamwork, collaboration, and leadership. Most participants valued the language and cultural immersion, which for some was possibly more impactful in their career trajectory than the research skills they gained.

> *"I had done some traveling before my trip to Ecuador, but never to developing countries. It truly opened my eyes as to both how different my upbringing was as compared to the people in the communities that we visited—the access to education and financial ease, but also how much we had in common—the importance of family and community and hard work. After graduation, I went on to law school and began working in international project finance where I spent most of my career to date working on renewable energy projects in Latin America. I'm now joining the General Counsel's office at the International Development Finance Corporation. I think my experience in this program really solidified my desire to help others and particularly in communities that were the most in need. I still have a picture of the mountains in Ecuador on my desk!*"

6 Conclusion

This paper provides a qualitative description of the evolution of an undergraduate research program in international agricultural development. It identifies factors enabling operation of similar programs under common challenges to field research in developing countries. Fifty undergraduate students have been engaged in an immersive research experience in Ecuador. It begins with a Spring semester three-credit class on research methods, survey administration, and data analysis and inference. Ecuadorian

partners are introduced through remote meetings and joint work on the survey. Students travel to Quito, where they take language and culture lessons, finalize the survey, and gain exposure to the various institutions involved in the research. After two weeks, the group travels to the remote survey location, currently near Riobamba in Chimborazo Province. Four weeks of data collection paired with local students follow. Finally, data are analyzed, and a report is prepared and presented to an advisory group in the subsequent Fall semester.

The program is built around several principles: (i) end-to-end student engagement from problem identification through presentation of findings to stakeholders; (ii) financial accessibility—all participation costs are covered; (iii) primary data collection from farm-households in the study area; (iv) full partnership with host-country researchers and students; and (v) supportive and complementary to past and ongoing agronomic research in the study area.

The program has successfully overcome several challenges including the need for IRB clearance to protect the rights of survey respondents. Program funding ensures that the program is accessible to students from varying socioeconomic backgrounds. Valuable survey information is obtained by questionnaire design and surveying conducted by students supported by faculty and staff from Virginia Tech and our Ecuadorian partners. Students receive language and cultural awareness training to support their survey activities. Linkages to high-quality ongoing agronomic research allow the socioeconomic research to focus on technology adoption and technology-relevant factors such as profitability, risk, and access to inputs.

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Appendix A: Example Syllabus

Agricultural and Applied Economics 4984
Methods and Planning for Ecuador Research Internship
Syllabus and Course Description
Spring 2020

Instructors: Jeffrey Alwang, 215I Hutcheson Hall, Tel: 231 6517, Email: alwangj@vt.edu
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Office hours: Students are welcome to stop by at any time or make an appointment by emailing one of us.
Class time/location: Wednesday 4–6 p.m., 302 Hutcheson

I. Course Description

This course is intended as preparation for a 6-week research internship in Ecuador during May–June 2020. Topics include: (i) Overview of the sustainable agriculture research in the Chimborazo region in Ecuador; (ii) history, culture, and geography of Ecuador and the Chimborazo region; (iii) research methods, including the scientific method, questionnaire preparation, sampling, and IRB approval; and (iv) Spanish practice with agricultural vocabulary (3H, 3C).

II. Learning Objectives

Students completing the course should be fully prepared to undertake the research internship with a clear idea of responsibilities and expectations.

a) Learn to conceptualize multidisciplinary research problems and design a research plan appropriate for a solution to the problem.
b) Convert the conceptual plan into reality by: (i) designing a questionnaire and data collection plan; (ii) creating a sampling plan to make the data representative of the desired population; and (iii) coding the questionnaire into tablet computers.
c) Understand how statistical analysis is used to link the household data to the research questions.
d) Learn about the culture and institutions in the internship project area.

III. Texts and Special Teaching Aids

Required textbook:

Doing Survey Research: A Guide to Quantitative Methods, 4th ed., by Peter M. Nardi (Note: The 3rd edition is good enough and much cheaper).

Additional readings:

Nyariki, Dickson M. 2009. "Household Data Collection for Socio-Economic Research in Agriculture: Approaches and Challenges in Developing Countries." *Journal of Social Sciences* 19(2):91–99.

Devereux, Stephen, and John Hoddinott. 1993. "The Context of Fieldwork. Chapter 1." In Stephen Devereux and John Hoddinott, ed. *Fieldwork in Developing Countries*. Boulder CO: Lynn Rienner Publications.

IV. Course Organization and Expectations for Students

The course will involve interactive discussions and presentations by faculty and students. It is expected that students complete reading assignments prior to the class in question. Readings will be assigned one period ahead. Homework assignments will be specific to each topic, but will include readings, preparation for class presentations, and preparation of a research plan, including questionnaires for data collection. Students are encouraged to complete their homework assignments in groups, unless otherwise specified.

This course is designed to prepare students to conduct research in Ecuador in the Summer of 2020. Students will be evaluated on their eligibility for the program based on their course grade, participation, and attendance in this course. To remain eligible, students are allowed to miss two classes, to remain in good academic standing (overall 3.0 GPA for the semester), and to attain a grade in this course of at least a C or above. A student's final eligibility will be determined following the midterm (3/18). Any student who fails to meet these criteria will not be eligible for the summer portion of the research internship.

V. Syllabus

Topics and readings:

1. **1/22: Introduction to the research project. *Instructors:* Norton (lead), White**
2. **1/29: Overview of prior year research. *Instructors:* Chen, Garber**
3. **2/5: Research methods. *Instructors:* Alwang, Chen**
   Readings: Chapters 1 and 2 in text.
4. **2/12: Research methods & questionnaire. *Instructors:* Chen, Alwang**
   Readings: Chapter 3 in text; Nyakari.

   2/19: Research methods & questionnaire design. *Instructors:* Larochelle, Norton
   Readings: Chapter 4 in text.
5. **2/26: Research methods – Questionnaire design cont'd. *Instructors:* Norton, Larochelle**
6. **3/4: Research methods – Questionnaire. *Instructors:* Chen, Larochelle**
7. **3/18: Research methods – IRB. *Instructors:* Larochelle, Alwang**
   Mid-term exam
   Readings: Chapter 5 in text; Review paper by Nyakari.

8. **3/25: Research methods – Sampling and statistical representativeness. *Instructors:* Norton, Chen**
9. **4/1: Research methods – Data analysis. *Instructors:* Alwang, Garber**
10. **4/8: Research methods – Data analysis. *Instructors:* Chen, Alwang, Garber**
11. **4/15: Finalize data analysis plan – Methods for data analysis. *Instructors:* Larochelle, Norton**
    Readings: Chapters 6–8 in text
12. **4/22: Finalize details of research internship plan. *Instructors:* White, Norton**
13. **4/29: Finalize details of research internship plan. *Instructors:* White, Alwang**
14. **5/6: Finalize travel plans. *Instructors:* Shelton, White**
    Reading: Devereux and Hoddinott.

VI. Evaluation Procedure

Mid-term exam (3/18):	30%
Class participation:	40%
Graded homework assignments:	30%
Total:	100%

VII. Disability Statement

Reasonable accommodations are available for students who have a disability. Students should contact the Services for Students with Disabilities (SSD): http://www.ssd.vt.edu/registering/students_disabilities/students_disabilities.html.

To be eligible for services, students with disabilities are responsible for self-identification.

VIII. Honor Code

The Undergraduate Honor Code pledge that each member of the university community agrees to abide by states:

"As a Hokie, I will conduct myself with honor and integrity at all times. I will not lie, cheat, or steal, nor will I accept the actions of those who do."

Students enrolled in this course are responsible for abiding by the Honor Code. A student who has doubts about how the Honor Code applies to any assignment is responsible for obtaining specific guidance from the course instructor before submitting the assignment for evaluation. Ignorance of the rules does not exclude any member of the University community from the requirements and expectations of the Honor Code. For additional information about the Honor Code, please visit: https://www.honorsystem.vt.edu/

Appendix B: Undergraduate Research Program in Ecuador – Survey of Participant Perceptions

Please consider the six questions below. Select and respond to one or two questions that resonate the most with you.

Survey Questions

Q1. How did your undergraduate research experience in Ecuador influence your decision to attend graduate school?

Q2. How did your experience in Ecuador stimulate your interest in doing international development work?

Q3. In what ways did your research experience in Ecuador strengthen your research skills?

Q4. In what ways did your experience in Ecuador shape your perspective on working in another culture?

Q5. What did you most gain from your experience in Ecuador?

Q6. What changes to the program would have improved your experience?

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