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WIP: From Microbes to Markets: Integrating STEM Research and Entrepreneurial Mindset in an Undergraduate Biology Course

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Abstract
This Work-in-Progress paper describes the implementation and outcomes of integrating STEM and entrepreneurship learning within an undergraduate biology elective at the engineering institution, Olin College of Engineering in Needham, MA, USA. The course, co-taught by faculty in biology and entrepreneurship, paired authentic research in environmental microbiology with entrepreneurship process learning through case studies, guest speakers, and project-based deliverables focused on biological discovery and entrepreneurial thinking. Students applied their own discoveries in the laboratory gained from an authentic research project on the topic of environmental problem solving through microbiology to connect technical skill development and discovery with entrepreneurial mindset. Pre- and post-course surveys and longitudinal student reflections were analyzed to gain insight into student development of disciplinary knowledge and connections in biological sciences and entrepreneurship areas. Longitudinal reflections showed that students were highly motivated by the disciplinary integration, made connections between technical and entrepreneurial thought processes at different points in the course, and demonstrated awareness of the societal context of scientific work. This pilot course extends the institution's entrepreneurship ecosystem by linking entrepreneurship with scientific research discovery at the undergraduate level, and contributions of the course experiment to that ecosystem are discussed.

1. Introduction

Entrepreneurship education in engineering has grown, with a range of course types, co-curricular offerings, and incubator environments documented in the literature increasing in the last two decades [1-4]. These efforts are in the areas of product design, venture creation, or later-stage technology translation. This study examines pedagogical work that introduces entrepreneurship in an undergraduate engineering curriculum within the context of disciplinary science courses. Students are generating knowledge, learning experimental methods, and interpreting data alongside learning and applying entrepreneurship mindset. We examine outcomes of this initial pilot by asking the research questions: *How do students make sense of the integration of authentic STEM inquiry and entrepreneurial frameworks in a CURE context? What patterns of engagement do we see as students connect laboratory discovery to value creation?*

Course-based Undergraduate Research Experiences (CUREs) are a well-known innovation in STEM education and high impact practice. CUREs offer larger numbers of students the opportunity to participate in authentic research without requiring independent lab positions, and have been shown to support disciplinary skill development, scientific identity, and persistence in STEM [5–7]. These learning environments are typically framed around discovery, iteration, collaboration, and communication. These features also have parallels with entrepreneurship processes and CURE literature emphasizes development of scientific skills and identity, rather than connections to innovation and translation for societal impact. Environmental microbiology provides a rich context for exploring integration of STEM and entrepreneurship as microbial processes play central roles in sustainability-focused sectors such as biomanufacturing, bioenergy, waste transformation and a bio-based economy [8]. The intersection offers an opportunity to develop disciplinary expertise and skills to envision research-to-market pathways.

Frameworks for interdisciplinary and transdisciplinary learning inform this integration. Interdisciplinary learning environments have been shown to help students connect knowledge across domains, reason about complex systems, and situate technical work in broader human contexts [9,10]. Experiential learning theories also suggest that deep understanding develops through cycles of action, reflection, and application [11]. These frameworks collectively support pedagogies where students investigate real phenomena in the laboratory and then consider how their discoveries could address stakeholder needs or inform market opportunities.

The institutional context of this work includes a range of entrepreneurship offerings that span the curriculum (Figure 1). All students take a required first-year introductory course that focuses on entrepreneurial mindset [12], value proposition design [13], and the search for product–market fit [14]. About a third of the students pursue intermediate-level entrepreneurship courses, either at the institution or through cross-registration opportunities at Babson College as part of the Babson–Olin–Wellesley (BOW) Three-College Consortium, which expands access to entrepreneurship-focused coursework across partner campuses. In the final year, about 10% of the students are selected by application into a senior capstone program focused on technology venture creation, while other students choose either industry-sponsored or community-engaged capstone options.

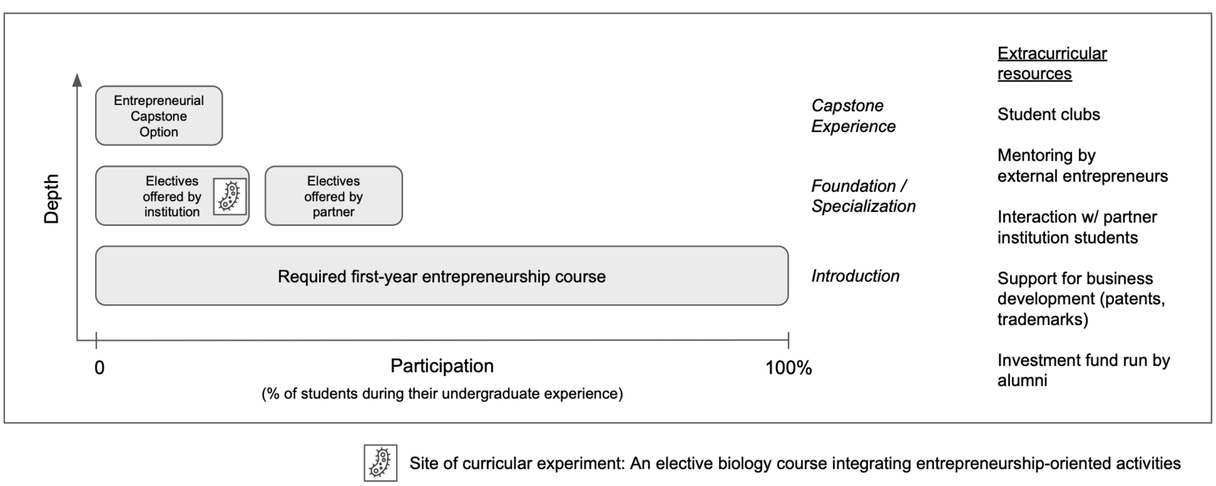

Figure 1. Curricular map of the institution’s entrepreneurship ecosystem. The advanced science course with STEM–entrepreneurship integration, represented by the microbe,

expands the institution's technical offerings and is between the required introductory course and senior capstone options.

The curricular ecosystem provides multiple pathways for innovation, however few courses ask students to begin from scientific research discoveries and form a bridge to entrepreneurial reasoning and market translation. The curricular experiment described in this paper examines a course project framework for undergraduate learning about research-to-market translation. The experience embeds entrepreneurship learning within an advanced biology elective focused on authentic research in environmental microbiology. Students engaged in laboratory discovery while concurrently learning and applying entrepreneurial tools for opportunity recognition, market assessment, and value creation.

This paper adds to the literature in presenting a model for integrating a laboratory research CURE with entrepreneurship processes inside a disciplinary biology course, describes how students experienced the integration of technical and entrepreneurial learning through surveys and qualitative reflections, and contributes to discussions of interdisciplinary STEM pedagogy by examining how undergraduate engineers draw connections between scientific discovery, sustainability contexts, and decision-making for translation to market environments and society.

2. STEM-Entrepreneurship CURE curricular experiment and institutional context

The pilot implementation in the advanced biology elective course involved 14 students, with the majority having had an introductory science and an introductory course in entrepreneurship. Students were 75% Sophomores, 17% Juniors, and 8% Seniors, who each conducted an authentic, environmentally motivated microbiology research project over the course of the semester. Students were invited to formulate a microbiology-based solution to an environmental challenge of personal significance with a prompt: "What microbes may there be from the environment that can degrade a compound of a student's interest?" Many of the compounds selected, such as oxybenzone (a component of sunscreen known to damage coral reefs), pharmaceutical compounds, pesticides, and plastics, were directly associated with environmental challenges for which their remediation could help mitigate impacts. Students engaged in authentic research through a series of scaffolded laboratory project phases designed to build a progressive set of microbiology skills (Figure 2). Leveraging the extensive diversity of environmental microbes and their metabolic capabilities, nearly all students successfully isolated bacteria that performed targeted functions of interest and showed potential for application in environmental problem-solving contexts.

Students examined the impacts of their discoveries by considering how their findings may be translated to society through application of entrepreneurial thinking. They learned about the entrepreneurship process and mindset through case studies and guest speakers in dedicated class times (Figure 2). The entrepreneurship modules encouraged opportunity recognition, market assessment, and thinking about value creation. Disciplinary integration was encouraged through a semester-long project by prompting students to think about ways in which their research findings could be translated into societal value through entrepreneurship. Students examined case studies and existing businesses that are based on microbial innovations and carried out analysis with the Business Model Canvas framework [15]. They developed value propositions based on the findings of their research work in the laboratory and received feedback from guests with entrepreneurship backgrounds about their ideas in class consultation sessions. As project deliverables, students developed posters and a report in scientific format about their research. In their final posters, students presented their scientific findings and analysis of entrepreneurship opportunities associated with their research in presentations that were open to the community. The integrated structure of the course created a learning environment for development of both technical skill and entrepreneurial thinking through authentic research practice.

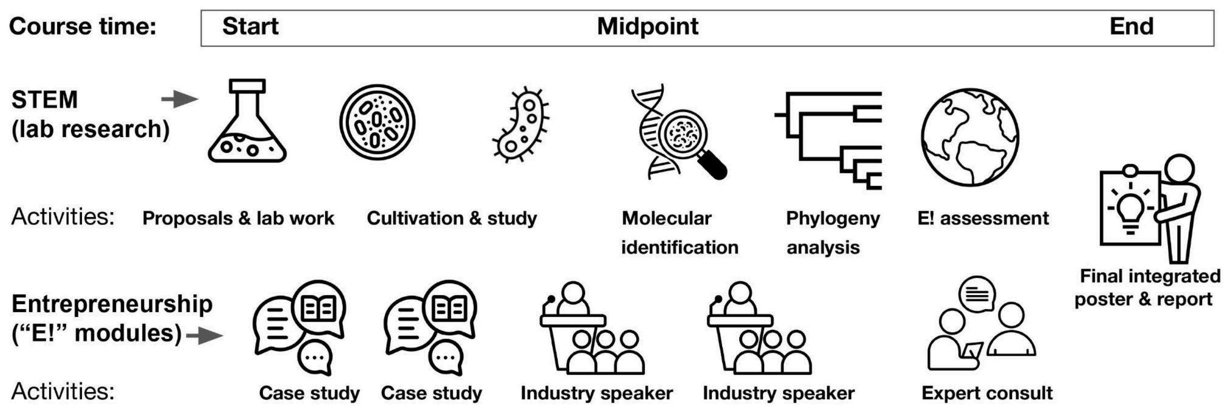

Figure 2.Timeline of an integrated STEM/Entrepreneurship (E!) CURE within an advanced science course. Over a 15-week semester, students conducted authentic laboratory research, developing technical skills in environmental microbiology while engaging with classroom modules, assignments, and expert interactions to build entrepreneurial mindset. The project culminated in a poster presentation and written report that integrated technical research contributions with entrepreneurial assessment.

3. Methods

Pre- and post-course surveys, as well as longitudinal student reflections, were analyzed to understand pathways by which students acquired disciplinary skills, developed entrepreneurial awareness, and built connections between technical and entrepreneurial thinking. Students provided self-reported ratings for skills that were learning objectives for the course through identical pre- and post- course surveys (Figure 3).

Students completed four reflections over the course of the STEM–entrepreneurship CURE course, with a choice of open-ended prompts (Appendix 1). The student longitudinal reflections were analyzed to understand learning outcomes and the experience of individual students within the CURE experience that integrated STEM and entrepreneurship ("E!"). A total of 52 reflections were analyzed (mean 3.7 reflections per student). We used a multi-stage qualitative coding process. First, reflections were descriptively coded by topic using thematic categories developed deductively from the course learning goals and inductively from initial reading of the reflections. Five thematic coding frameworks emerged: Technical/Class Aspects, Research Focus, Interdisciplinary Translation/moving between fields, Entrepreneurial Skills, and Self-Growth. These frameworks captured students' attention to disciplinary content, research processes, translation between science and entrepreneurship, entrepreneurial skill development, and personal or professional growth. Two researchers independently coded subsets of the reflections dataset and then reviewed the coded data and applied a +1 agreement process, marking instances where identified themes aligned with the emerging summary statements. Discrepancies were discussed until consensus was reached. The combined descriptive and thematic approach enabled characterization of how students engaged with technical content, research practice, entrepreneurial thinking, and personal growth from the interdisciplinary study across the semester.

4. Findings and student pathways through interdisciplinary pedagogy

Analysis of student reflections suggested themes for how students experienced the integrated STEM/entrepreneurship course experience. Longitudinal narratives from individual students showed how the interdisciplinary learning was received over time of the course. The results show pathways in which students developed technical skills, entrepreneurial awareness, and research-to-society thinking. A table with representative quotes for each coded theme is in Appendix 2.

Finding 1: Students initially approached technical/STEM and entrepreneurship as distinct disciplines and later made connections between them.

Students entered the course emphasizing either laboratory-based biology or entrepreneurship-oriented thinking and framed scientific discovery and entrepreneurship as separate processes. The pathways over time of the project showed variation in interdisciplinary engagement such as applying entrepreneurship as a lens for evaluating the value of student research findings.

Finding 2: Students expanded their thinking from research as a course project to external, real-world, and market-relevant applications.

Students framed their projects within the scope of laboratory requirements or personal research goals. Over time students made connections to industry, healthcare, environmental remediation, and potential products or services, showing increased connection with research-to-market thinking.

Finding 3: Personal relevance and agency motivated student engagement.

Students showed passion and motivation with the projects where they had autonomy to connect and design their project based on their personal experiences, values, or concerns. Students expressed ownership, intrinsic motivation, and engagement with both technical and entrepreneurial aspects of the course. Students also highlighted personal connections to guest lecturers indicating that this was a motivating and impactful activity for disciplinary integration.

Finding 4: Students demonstrated creativity, resilience, and adaptation in response to experimental and contextual constraints.

Students encountered challenges of authentic research in the laboratory, where results are not guaranteed including failed experiments, feasibility constraints, and limitations suggested by research into market applications. Reflections show that students adapted their goals, revised experimental designs, and reconsidered assumptions showing scientific and entrepreneurial iteration and responses to uncertainty.

Finding 5: Students cited growth in skills and perspective.

The integrated STEM–entrepreneurship experience resulted in learning gains where nearly all students commented on growth within reflections in areas of: research and technical confidence, understanding of societal context, or appreciation of connections between the STEM and entrepreneurship disciplines.

Student self-reported skills

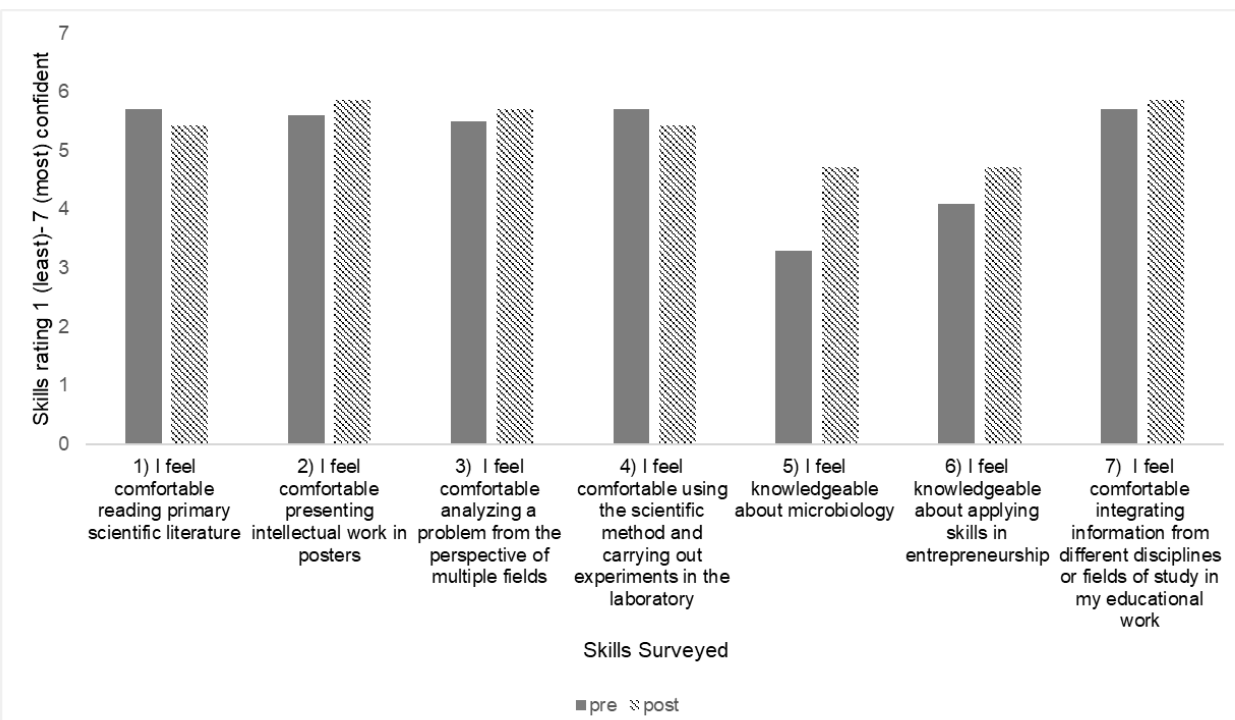

Figure 3. Pre- and post- course survey results from student self- reported skills for the advanced science course with a semester-long authentic research project with entrepreneurship integration. Students reported their self-assessed skills on a 1–7 scale. Averages of student responses are shown for pre (n=12, 85% of students) and post (n=7, 65% of students).

The pre- and post- survey results indicated that the largest self-reported learning gains were in the discipline specific knowledge and applications: Q5 "I feel knowledgeable about Microbiology" and Q7 "I feel knowledgeable about applying skills in entrepreneurship (E!)" (Figure 3). Smaller changes were observed, with students reporting higher baseline confidence in learning skills that are less discipline-specific. Many students had previously completed an introductory science course and had already practiced skills such as reading primary literature and presented technical work in other course contexts.

5. Discussion

The STEM-entrepreneurship curricular experiment within the advanced science elective extends entrepreneurship learning to the research space and places laboratory discovery as a beginning for innovation at the undergraduate level. By embedding entrepreneurship into a biology course with environmental challenges as the theme, the course engages students in envisioning the ways in which their research findings can be translated into solutions and shared with society. This contributes to the institution's entrepreneurship ecosystem, which emphasizes product development and venture creation. Pedagogically, this work illustrates an approach to bridging technical and entrepreneurial learning through experiential engagement and expert interaction within the classroom. The integration encouraged students to draw on their own discoveries to explore translation pathways from research to market and aligns with a sustainability focus for the curriculum. The engagement enhanced student motivation and enabled deeper understanding of how technical competencies connect with real-world application.

This project was motivated by the desire to explore complementarities between science and entrepreneurship education. We believed that we could help students develop as scientists by exposing them to the real-world context of microbial-based businesses, and that we could cultivate their entrepreneurial mindset by grounding the abstract concept of value creation in the specific challenge of harnessing microbial diversity to address human needs. Although additional iterations are needed to strengthen these connections and demonstrate their effectiveness, our preliminary findings are encouraging. Insights from this pilot inform the development of a full course in the future that will further integrate classroom, laboratory, and entrepreneurial learning experiences. In this pilot iteration, the CURE experience consisted of individual student projects; however, the model is scalable to larger class sizes by organizing students into teams to carry out student-designed technical laboratory projects. Reflection and survey data indicated strong student motivation and revealed themes in interdisciplinary engagement that inform approaches for integrating STEM education and entrepreneurship. Future iterations of the technical project could be scaffolded to provide students more opportunities to experiment with customer discovery and additional components of the business model canvas beyond value propositions and market research, alongside their lab experiments.

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IRB statement
The study was reviewed and approved under IRB protocol #19013R-E: Study of Learning Outcomes from Cross-Disciplinary Educational Experiences at Olin College.

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Appendix 1. Reflection prompts
Students were provided a reflection prompt assignment below approximately every 3-4 weeks over time of the course.

We will take time to reflect over the course of the term, also in light of the experimental nature of the course this semester. For each reflection time please write a short reflection (300-500 words) drawing from any of the prompts below and submit your thoughts as a word document through the canvas assignment. You will receive credit for engaging with the reflection activity.

Choose any combination of prompts that is meaningful for you at the reflection time:
1. What was the most interesting research related insight or question you had this week?
2. In what way(s) might or does your work with your research project in class connect with your other classes, or with your personal life?
3. What are your thoughts about the process of doing science and research? What has been surprising about engaging in either Scientific or E! processes so far?
4. What connections might there be between Scientific and E! processes and ways of thinking in these fields? How might the fields inform each other?

Appendix 2. Coded themes from student reflections

Table 1. Key themes with representative quotes from student reflections collected across the STEM/Entrepreneurship course. Each quote is labeled with an anonymized student identifier followed by a number (1–4), indicating the timing of the reflection, where 1 corresponds to Week 3 of the CURE and 4 to the end of the course.

Finding / Theme	Supporting Quotes	Illustrative Journeys
1. Students initially approached technical/STEM and entrepreneurship as distinct disciplines and later made connections between them.	"Since I do want to be in the biology industry after college, I'm using this class to help me figure out what kind of work I would like to do, whether it be more in the lab." (12-1) "I want to be able to gain an ability to understand the worldly context with which the discoveries found through my research project will be useful for." (10-1) "I didn't particularly feel connected with the E! parts of the class, but I guess it did alter my thinking." (12-4) "If a scientific discovery is more harmful than helpful, there seems to be pressure for the business to still put out the product." (4-2) "Scientific discovery and marketing for funding simultaneously feed back into one another." (4-4)	Early reflections from Student 4 describes entrepreneurship as following completed scientific breakthroughs. Later reflections following entrepreneurship modules and course activities showed a shift towards making connections between the fields as interrelated processes. "I originally thought that these two were separate steps… however, after discussing the case study in class and getting insights from our CA, I was able to understand how interconnected these two are." (4-2) Reflections showed greater disciplinary integration where scientific research and business development influence one another: "Funding for the research… comes from proper pitching of the startup idea, and without progress in the research, the business itself is not able to make enough profit to continue." (4-2) This course made the connection between biology, engineering, and entrepreneurship really clear to me. I've gained a much more nuanced understanding of how these areas are interconnected—not separate, as I originally thought. (4-4) There was movement from disciplinary separation towards thinking about connections between and STEM and entrepreneurship processes.
2. Students expanded their thinking from research as a course project to external, real-world, and market-relevant applications.	"I also didn't realize how interconnected all these processes are, especially when first starting a business." (4-3) "A great business application… beta-carotene could possibly be used to modify vegetables to make them more resistant to spoilage." (10-2) "By finding a microbe that can degrade Narcan… clean up pharmaceutical waste… aligns with my eventual goal." (6-1) "Studying microbial degradation of pharmaceuticals… extremely relevant." (7-3)	Early reflections identified real-world applicability of microbial research and the student sought industry examples to guide their thinking: "microbes that degrade gasoline/diesel have multiple applications… it would be really easy to market a potential product." (3-1) "I have been looking into the bio company Novo Nordisk… to learn marketing strategies that will help me create insights from my own product." (3-1) Later reflections demonstrated more critical engagement with feasibility and investor perspectives:

		“I am a little skeptical that investors would be interested in microbes that only can grow when paired with another.” (3-3) The example reflects development of market considerations grounded in technical discovery rather than hypothetical product design.
3. Personal relevance and agency motivated student engagement.	“It is exciting to go to the lab each class period and see what progress has been made.” (10-3) “By engaging in a research project of my own choosing… I had a lot of freedom… helped me grow a larger passion.” (10-4) “Case studies and recent papers bring a sense of relevancy…” (8-2) "It really made me think about re-evaluating a lot of the work I do in life and my current trajectory...her (guest speaker's)presentation has been a driving factor in some upcoming life changes I am trying to implement" (3-3) “My work is motivated by my passion for marine sustainability” (9-2)	Student 9’s work on microbial degradation of oxybenzone was motivated by environmental concerns rooted in personal experience: “Growing up in Hawaii, I have seen the changes that have happened in marine systems… now the coral is entirely gray with hardly any fish.” (9-2) The personal relevance translated into sustained engagement and meaning-making: “Being able to do this microbe degrading project has been extremely interesting and motivating… I am able to directly see how microbes can be used to solve very important issues to me.” (9-2)
4. Students demonstrated resilience, and adaptation in response to experimental and contextual constraints.	“I am a little skeptical that investors would be interested in microbes that only can grow when paired with another.” (3-3) “This is the first time I have been able to create an experiment from scratch… iterate and scale down.” (4-1) “I have been encountering challenges… prepared to explore new strategies.” (8-2)	
5. Students cited growth in skills and perspective.	“I’ve definitely become more comfortable with reading research papers and conducting research.” (2-4) “Thinking in different fields was able to shape my research work because it helped drive a purpose and reasons behind doing decisions on an experiment.” (9-4) “I learned how to read scientific literature efficiently…” (4-1) “One of my major takeaways from the course was my appreciation for the intricate connections between technical and entrepreneurial processes, which I have not considered prior to entering the class” (8-4) “My perception of research has undergone a significant transformation…” (8-4) “I got more familiar and confident using lab equipment…” (9-4)	