Chapter 7
An Interdisciplinary Model to Diversify STEM Participation:
College, High School, and Industry Partnerships

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ABSTRACT

This chapter describes an interdisciplinary program between a College of Education and a College of Natural Resources and their partnerships with rural high schools, regional colleges, and bioeconomy industries. The overarching goal of the program was to provide engaging professional development and support for teachers and diverse undergraduate students to prepare and promote diverse students to consider STEM majors and careers related to bioproducts and bioenergy. A team of faculty and graduate students from a Forest Biomaterials department and a Science Education department developed online courses, workshops, and laboratory activities and internship placements for undergraduate students and high school science and CTE teachers. This chapter details the need for the program, its context, online course development, and laboratory activities. For each of the key partners in the program—the faculty and graduate students, the high school teachers, and the undergraduate students—key strategies, lessons learned, and recommendations are shared.

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INTRODUCTION

There is a need to develop the workforce in bioenergy, bioproducts, and the bioeconomy (Energy Independence and Security Act, 2007). Biobased product employment (excluding biofuels) grew from 2014 to 2016 by 17% and continues to grow, contributing $459 billion to the U.S. economy (Golden et al., 2018). In addition to the technical/scientific knowledge specific to the bioproducts and bioenergy industry, there are technological skill sets required in 21st century manufacturing environments. These include skills in chemistry, biology, experimental design, process control, written and oral communication, data management, and working across disciplines (Glaser, 2013). Accomplished individuals in these areas are highly competitive in today's workforce. Jobs in these industries span the educational spectrum: from 2-year technical school to advanced, professional degrees (Glaser, 2013). Currently, many sectors of the STEM workforce lack the diverse perspectives of underrepresented minorities and females (National Science Foundation, 2017). Increasing the diversity of this workforce will help to provide new perspectives for innovation and sustainable solutions (Herring, 2009). Given this, there is a need to build these skills into high school curricula (NEA, 2012).

STEM experiences can vary greatly between students, with socio-economic factors, geographic region, racial background, and gender influencing course persistence and future careers (Alegria & Branch, 2015; Andersen & Ward, 2014; Brown et al., 2016). Approximately 25% of K-12 US students are enrolled in rural schools that primarily enroll Black and Brown students, 14% of which are designated as high-poverty schools (Lavalley, 2018). Schools designated as high poverty tend to have fewer teachers who are certified in their content areas, fewer advanced courses offered in STEM subjects, and higher turnover than in wealthier schools (Darling-Hammond & Hammond, 2015).

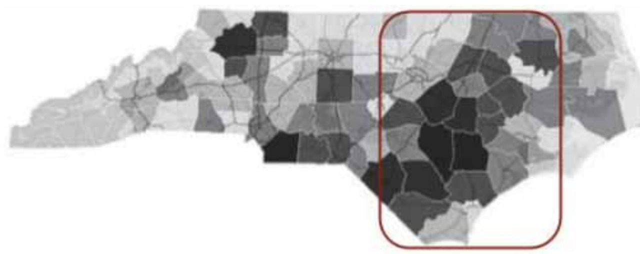
North Carolina Context

This program was focused in North Carolina, which is a tremendous agricultural and forest based biomass region, having the seventh highest degree of bioproducts industry concentration in 2013 (Golden et al. 2018). North Carolina's 18.6 million acres of forest land cover 60% of the state, and timber receipts at the first point of delivery totaled $807 million in 2015 (McConnell, Jeuck, Bardon, & Hazel, 2016). In total, the forest products industry directly supports over 70,000 employees at 2,000 businesses located in ***all*** counties of the state, making it the seventh highest bioproducts industry concentration in the U.S., in 2013 (Golden et al., 2018). The total value added that is returned to North Carolina by forestry and forest products activities is $11 billion (McConnell et al. 2016). Much of this biomass based industry is concentrated in Eastern NC (see Figure 1). Farming is equally important in NC, supporting about 700,000 jobs on more than 8 million acres of land. North Carolina leads the nation in sweet potato, egg and poultry production, and ranks in the top three for Christmas trees, pork, trout, and turkeys (Adams, 2019).

Eastern North Carolina is a more rural region that has lagged in several socioeconomic indicators (U.S. Census Bureau, 2016). Therefore, the ability to leverage the human resources of the state with the needs of an emerging bioproducts and bioenergy industry made this region uniquely positioned for the program. Discussions with stakeholders have indicated the combination of this science/technology knowledge and skills is highly valued, requiring more preparation and skill development. One way to build these skills and promote interest to advance the opportunities for rural youth was to add these skills to high school curricula.

Figure 1. Distribution of farm and timber receipts per county

Note. Darker shading indicates higher values. The red box indicates the area the program serves. Figure reused with permission from Venditti & Blanchard (2016) and created based on data available from the North Carolina Department of Agriculture and Consumer Services (2015) and McConnell et al. (2016).



In rural, eastern North Carolina, school districts tend to be small in population and spread out over a larger geographic area. Most of the schools serve low income families, with approximately 70% receiving Free and Reduced Price lunch (F&RL) and about 54% of whom are minorities, with the majority of high schools designated as high poverty (North Carolina School Report Cards, n.d.; School Digger, n.d.). The charter schools tend to be an exception to this, as they pull from a larger area and families who attend are able to transport their children to school. In spite of the difficult conditions of the region, physical conditions within schools have improved over the last ten years, with wireless infrastructure, computers, and instructional technologies brought in from grant funds (e.g., Blanchard, 2010; Blanchard et al., 2014) and federal *Race to the Top* funds (US DOE, 2012). The superintendents from these rural districts are eager to provide professional development opportunities for their teachers, and enhance the students' exposure to STEM content, experiences, and to support their pathways to potential careers.

Pillars of Sustainability

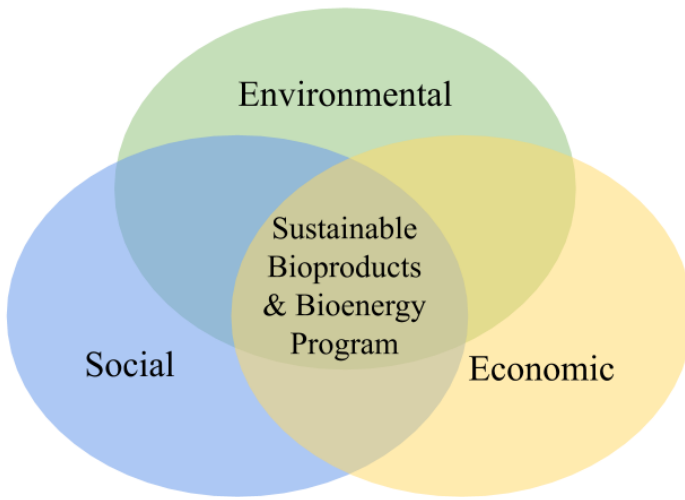
To integrate bioproducts and bioenergy concepts into existing high school science and Career and Technical Education (CTE) curricula, the program drew from the field of sustainable development, broadly defined as using innovation and engineering approaches in development to meet the needs of the present without compromising the ability of future generations to meet their own needs (Keeble, 1988).

Central to the program's approach, the Sustainability conceptual framework Venn diagram (Purvis, Mao & Robinson, 2019) includes environmental, social, and economic components as the three pillars of sustainability. In Figure 2, we have situated the program in the center, although the program tended to emphasize environmental considerations more than economic or social elements. For example, students could weigh the costs and benefits of traditional plastic versus bioplastics for bottles in terms of biodegradable properties of the materials, water requirements for manufacturing and pollution (Environmental), cost of the materials and processes (Economic), and what workers are paid and working conditions in the US versus other countries for manufacturing these products (Social).

PROGRAM DEVELOPMENT

The program *Preparing Diverse and Rural Students and Teachers to Meet the Challenges in the Bioenergy and Bioproducts Industry* was designed to address challenges of shortages in Bioeconomy industries through an educational innovation (Figure 3). It was funded by a United States Department of Agriculture (USDA) NIFA grant for $2.75 million from 2017-2021 (#2017-67009-26771) (Venditti & Blanchard, 2016).

Figure 2. Situating the project within the Sustainability framework
Adapted from Purvis et al. (2019)

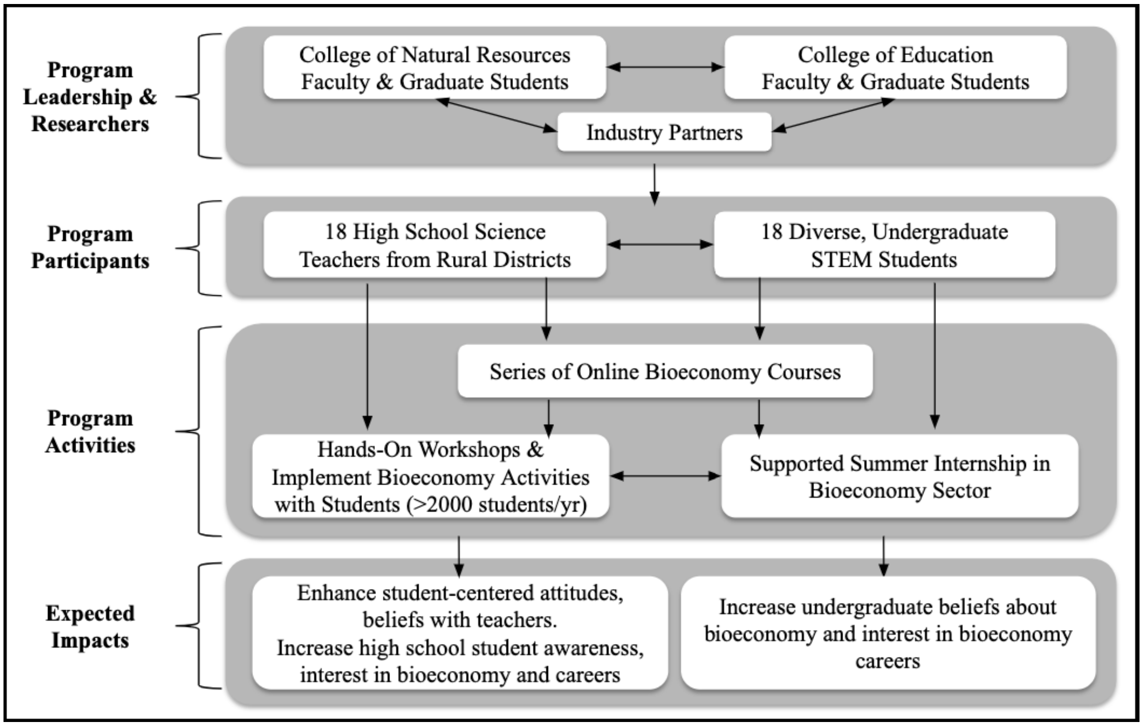


The program was an interdisciplinary collaboration between a College of Education and a College of Natural Resources at a university with very high research activity. The design tapped into: 1) the expertise of researchers in bioproducts and bioenergy and in science education at a major land grant institution, NC State University, 2) the experience of industry stakeholders understanding the needs of the workforce, 3) high school teachers in rural areas of the state who had a strong interest in the Bioeconomy and were committed to the success of their students and communities, and 4) the talent pool of college undergraduates in several regional universities and colleges with a diverse student population.

The program was designed to show diverse high school students and undergraduates the opportunities and rewards that exist in STEM fields, motivate them to attain degrees, and promote their awareness and interest for a range of careers in the bioproducts and bioenergy industry. The primary activities of the program included:

1. Developing engaging distance courses about the bioeconomy for rural high school science teachers and undergraduate students attending regional community colleges, colleges, and universities.
2. Co-developing and testing laboratory-based activities with faculty and graduate students.
3. Preparing the high school teachers during summer professional development workshops so that they can implement the activities in their classrooms.

Figure 3. Program model of participants, activities, and impacts



4. Providing all laboratory supplies and equipment, and supporting teachers as they implemented bioproducts and bioenergy activities and shared relevant careers in their classrooms.
5. Arranging for stimulating summer internships for the undergraduate college students at bioproduct and bioenergy companies and organizations.

Developing Industry Partnerships

Industry partnerships were developed through existing departmental contacts and newly recruited organizations. These partnerships helped to inform the program curriculum, highlight various careers and the knowledge and skills required for specific roles, and to provide summer internship placements.

The program team arranged travel to industry sites (ethanol plant and paper mill) and captured video footage to demonstrate operations in North Carolina. Video-recorded interviews with people in various job roles and from different educational backgrounds were incorporated into online courses. At a summer workshop with high school teachers, a panel of young professionals who actively worked in the bioeconomy sector shared their educational and career experiences.

Internship recruitment efforts were conducted via announcements at a bioproducts trade conference, an article in a bioenergy trade journal, social media posts, and through existing departmental contacts in industry, government, and research institutions. Participating undergraduate students were encouraged to identify additional organizations which might serve as internship hosts. Over 100 organizations were contacted by email with program details and an invitation to participate. Forty companies and organizations expressed interest in hosting internships with the program. Ultimately, seventeen perspective hosts conducted interviews with students, and ten of these successfully hosted student interns for the summer.

Creating and Teaching Online Courses

Team members from both departments collaborated to co-develop and teach a series of four asynchronous, online courses about the bioeconomy: The Sustainable Bioeconomy, Biomass Conversion for Bioproducts and Bioenergy, Strategic Business Analysis for the Bioeconomy, and Environmental Life Cycle Analysis. Each course's main topics and examples of their activities are described below.

The Sustainable Bioeconomy

The Sustainable Bioeconomy course explored the opportunities and challenges of producing environmentally, socially, and economically sustainable bioproducts and bioenergy and their potential to replace petroleum-based products in society. Numerous sectors of the bioeconomy were highlighted, including biofuels, wood and paper products, and advanced bioproducts such as biopharmaceuticals and bioplastics. Students examined the roles of various stakeholders in the bioeconomy, such as producers, consumers, and policy-makers. Forest Biomaterials faculty and other industry professionals provided several guest lectures to share their diverse expertise and perspectives on the bioeconomy (Figure 4). In addition to the lecture videos, online discussion forums comprised a large portion of the coursework and encouraged reflection and interactions between students. As an example, one forum asked students to use the U.S. Department of Energy's Bioenergy Career Map (Office of Energy Efficiency & Renewable Energy, n.d.) to explore entry-level to advanced-level careers in different sectors (e.g., engineering and manufacturing, operations and management, and education, communications, and outreach), select a career of interest, describe why they selected it, and reply to two other students. The forums and assignments allowed students' interests to guide their learning and exploration of the bioeconomy. A modified version of the course is now freely available through a MOOC (https://campus.extension.org/enrol/index.php?id=1641).

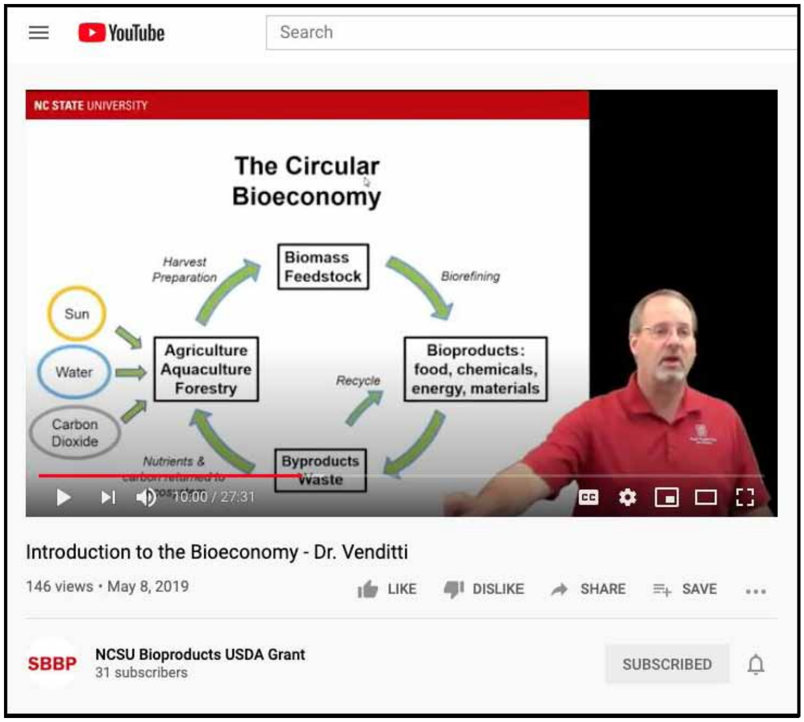
Example assignments from the Sustainable Bioeconomy course include:

- SDGs (Sustainable Development Goals): Students completed research on SDGs from provided links, focusing on one goal. In an online forum, they discuss how their goal connected to Zero Hunger and created a list of organizations and initiatives in their area that actively address SDGs and beyond (nation, world).
- Amazon Effect Poll: After reviewing the "Amazon Effect" article, students consider market demands and desires for sustainability. Based on this information, they created a 3-5 question poll to gather information about consumer behavior and preferences about packaging, gathered data from at least 3 people, and summarized their findings.

Biomass Conversion for Bioproducts and Bioenergy

The Biomass Conversion course was based on the fundamental science and engineering concepts, processes, and technologies involved in converting biomass resources (e.g., trees, crops, agricultural residues, and municipal solid waste) to usable chemicals, energy, and other bioproducts and biomaterials. Through the lecture videos, students learned about topics such as biorefineries (facilities that process

Figure 4. Example of a lecture video from the Sustainable Bioeconomy online course.

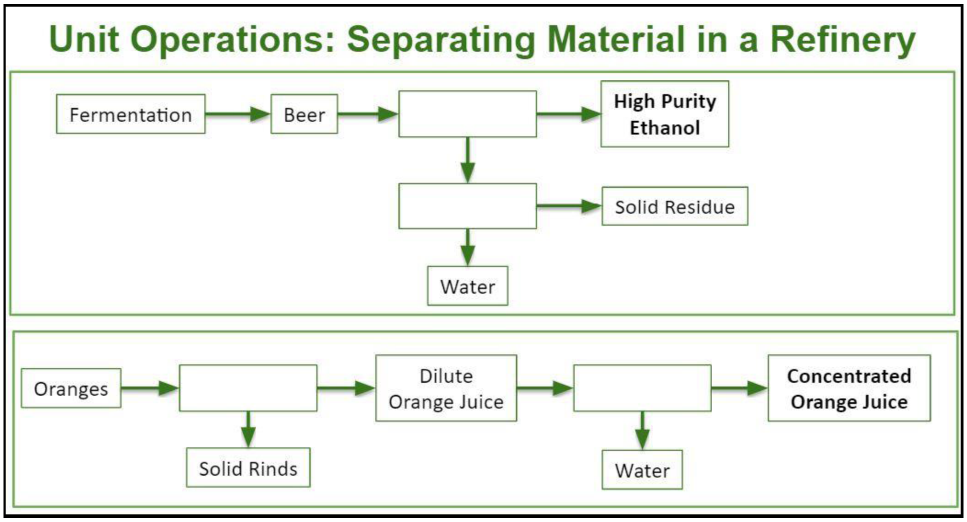


biomass into a range of higher-value products and byproducts) and the chemical composition of biomass, in addition to specific biomass conversion processes, including pretreatment, hydrolysis, fermentation, distillation, and anaerobic digestion. The lecture videos featured pop-up quiz questions and served as formative assessments for students and the course instructors. A majority of the course assignments focused on mathematical, chemical, and engineering concepts and calculations. Examples of calculations are comparing U.S. energy consumption and sources over time (e.g., solar, wind, biomass, and petroleum) and how much material is flowing through each unit operation in a conversion process (see Figure 5). A modified version of the course is now freely available through a MOOC (https://campus.extension.org/enrol/index.php?id=1642).

Example assignments from the Biomass Conversion course include:

- Circular Bioeconomy = No Waste: Students read the Ethanol Producer Announcement about Gevo's work on isoprene. From this article and class discussions, students chose one co-product from the biomass conversion to discuss where it was made, the conversion process used to turn this waste into a valuable product, how the co-product was marketed, its uses, and who would buy it.
- Engineering Challenges: xPrize – Transforming CO_2: In the xPrize competition, teams around the world compete for 20 million dollars by engineering the best process and product for turning CO_2 into a valuable product(s). After exploring the website, students selected which finalists they thought were more promising and why, then elaborated on how this project connected to biore-

Figure 5. Example of a unit operations problem for the Biomass Conversion online course.



fineries and/or biomass conversion. Finally, students discussed what they thought of incentivizing engineering challenges and what advantages and disadvantages exist for such competitions.

Strategic Business Analysis for the Bioeconomy

The Strategic Business Analysis course guided students to examine the major drivers behind the growth of the bioeconomy through a series of lecture videos, quizzes, and assignments. Course topics included a survey of macro and micro economics, financial concepts and statements, cost structures, marketing and pricing theory, value chain, and economic challenges for commercialization of biobased products. Students practiced basic conversion economics and financial analysis. A modified version of the course is now freely available through a MOOC (https://campus.extension.org/enrol/index.php?id=1777).

Example Assignment:

- Students built upon their prior knowledge from Course 1 and Course 2 along with new financial content to develop a brief (2 page) research plan proposal for the following items:
    - How did consumers perceive sustainability?
    - What environmental impacts were associated with different fibers and technologies?
    - What fiber blend could provide a better performance, achieve the minimum sustainability acceptance without substantial increases in manufacturing cost?
    - What is the supply chain of the alternative fibers?
    - Provide excel with calculations.

Environmental Life Cycle Analysis

In the Environmental Life Cycle Analysis (LCA) course, students explored various methods used to systematically determine the sustainability of products and processes. One case study compared the raw material and energy inputs and outputs of organic milk production compared to conventional milk production. Students surveyed aspects of conducting and interpreting an environmental life cycle analysis through video lectures, software practice sessions, and projects, all emphasizing systems thinking. In-depth case studies utilizing OpenLCA software, allowed students to construct a life cycle inventory, a life cycle assessment, and interpret their results. A modified version of the course is now freely available through a MOOC (https://campus.extension.org/enrol/index.php?id=1778).

Example assignment

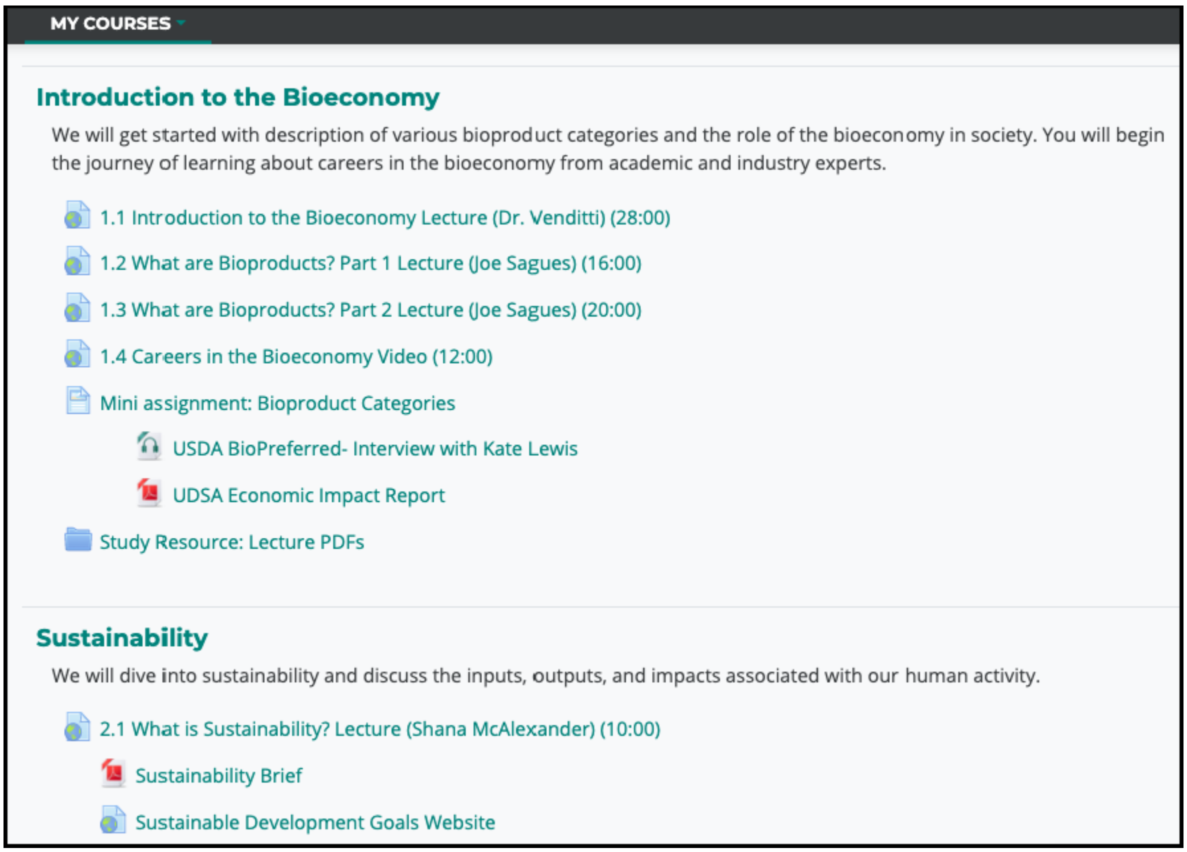
- Assignments were differentiated for the graduate and undergraduate sections of the course. Participating high school teachers and science and engineering graduate students conducted LCA for a product/technology/serve related to their area of interest. They first conducted a research literature search and review. Students delivered 1-2 page project proposals comprised of:
  - Introduction and Background discussing the topic and why a LCA for the product/technology/service was needed.
  - The plan for the LCA study defining the goal and scope of the LCA, determining the functional unit and system boundary, expected sources of LCI data and LCIA categories
  - Expected Results
- For their final projects, students created video presentations about LCAs they conducted. Each video included:
  - Four phases of LCA and all mandatory components
  - A process flow diagram showing the system boundary of their study
  - LCA results with necessary hotspot analysis
  - Conclusions and insights from the LCA

Course Staffing

The Program Manager and an Instructional Designer in the Department of Forest Biomaterials assisted with the course development and implementation process. The four courses were taught by four Forest Biomaterials faculty members who were experts in that particular course content. Although they were the primary course instructors for their one course, a total of 17 faculty in the College of Natural Resources and College of Agriculture recorded guest lectures to contribute to the online courses. A Forest Biomaterials or Science Education graduate student served as a teaching assistant for each of the online courses. The teaching assistants were responsible for grading coursework, co-developing assignments, communicating with students, and facilitating online discussion forums on Moodle. The Forest Biomaterials faculty primarily recorded lecture videos (most were 15-30 minutes) and designed the assignments and assessments.

The courses were dual-listed at undergraduate and graduate levels. Homework assignments were differentiated for the two groups. This dual-listing allowed the high school teachers and undergraduate student participants in the grant program, as well as other students at the university, to develop a learning community with diverse perspectives and backgrounds. All of the program participants' course credits were paid for by the grant. Teachers who were interested in pursuing graduate programs in Science Education or Forest Biomaterials could use the courses toward their degree programs. Undergraduates could transfer the course credits back to their home institution. The online courses were also converted to Massive Open Online Courses (MOOCs, see Figure 6) to provide course content at no cost to anyone interested in learning more about the bioeconomy (https://research.cnr.ncsu.edu/sites/sustainablebioproducts/online-courses/).

Figure 6. Example of the Sustainable Bioeconomy MOOC content and structure



Co-Developing and Piloting the Laboratory and Classroom Activities

The interdisciplinary team of faculty and graduate students initiated the development and testing of bioeconomy-related laboratory and classroom activities that were refined and carried out during the teacher professional development (PD) summer workshops. The activities were implemented by science teachers with their high school students. The activity development process was enhanced by the interactions of the interdisciplinary team members from both departments, drawing on technical and scientific expertise from Forest Biomaterials faculty and graduate students and pedagogical and classroom experience of the Science Education members. Led by the graduate student team, fourteen hands-on laboratory and classroom activities were co-developed and tested for alignment with Next Generation

Science Standards (NGSS) and NC State Essential standards. Programs such as this one, that partners teachers and scientists together, are considered a productive way to help teachers develop the skills and knowledge needed to design and carry out lessons that provide students opportunities to participate in the practices of science (e.g., Blanchard & Sampson, 2018; Enderle et al., 2014).

During the first summer, the program hosted orientation days when teachers, undergraduate students, and program leaders met for the first time and connected throughout the day over their shared experiences and interest in the bioeconomy. For instance, in the Year 1 summer orientation, the high school teachers (and the undergraduates) completed an ink flotation paper lab (Figure 7) and an enzyme optimization lab and were introduced to the program goals, expectations, and research participation.

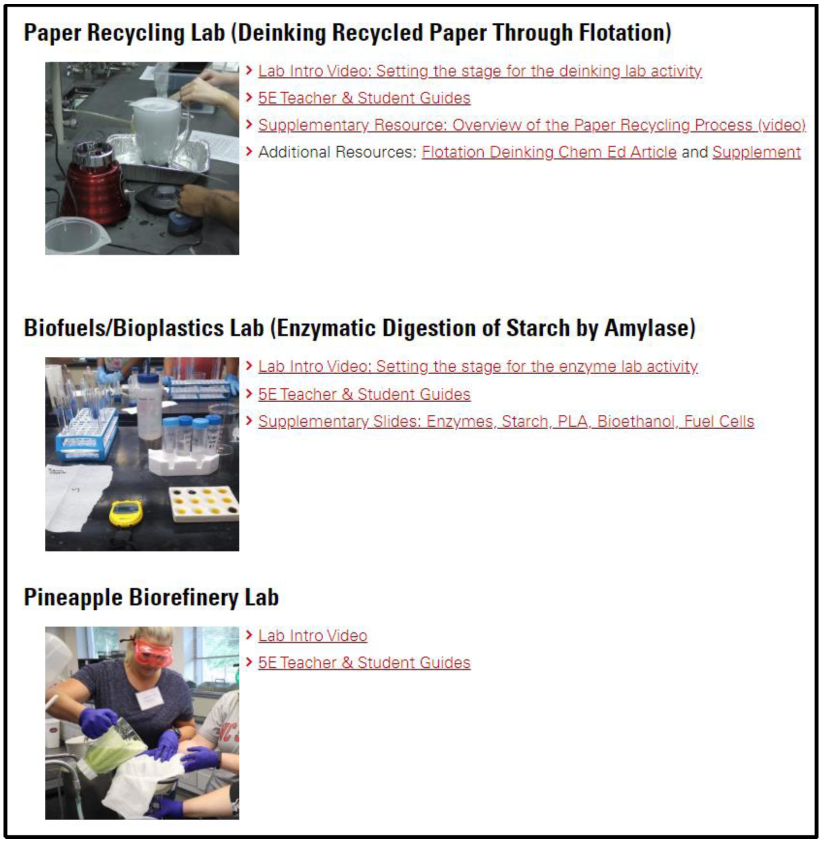
Figure 7. During the Year 1 Summer Orientation, high school teachers and undergraduate students worked with graduate students and faculty in an ink flotation paper lab.

Hands-on laboratory activities developed for the Year 2 workshop included: 1) biorefinery modeling with pineapple biomass to ethanol and paper, 2) modeling of greenhouse gases and global warming potential, 3) production and characterization of biopolymers, 4) yeast bioreactor design and fermentation optimization, 5) photosynthesis lesson with algae, 6) paper recycling, 7) enzymes for biofuels, and 8) life cycle analysis comparison of three different types of shoes. For Year 3, six more activities were developed, including: 1) anaerobically digesting organic waste to generate biogas, 2) assessing biomass availability with big data analytics, 3) mixed waste recycling, 4) renewable packing peanuts, 5) soap-making factory, and 6) wastewater treatment simulation. Graduate students led the development effort of these labs, and mentored undergraduate students in the Forest Biomaterials department who assisted in developing and/or pilot testing the lab activities.

The labs were constructed to follow the 5E Instruction Model: Engagement, Exploration, Explanation, Elaboration, and Evaluation (BSCS Science Learning, n.d.), and included a teacher lesson guide and student version. For each activity, short videos were created and posted on YouTube and the program website as seen in Figure 8. Access lessons at https://research.cnr.ncsu.edu/sites/sustainablebioproducts/.

These videos were to be utilized by teachers to introduce their high school students to the concepts of the activities from the perspective of the science curriculum and the bioeconomy. The videos provided

Figure 8. Sample of Laboratory and Classroom Activities available on the program website.



career connections for the students and also featured real-world applications of the activity content. These included footage of industries located in eastern North Carolina that are involved in the bioeconomy and their operations connected to the objectives of the activity, such as recycling. Some of the labs were modified from existing published methods or those previously used in the department, and others were newly created (Table 1). The graduate students were responsible for testing and piloting the activities in the lab. The Forest Biomaterials and Science Education team members worked together to ensure the activities emphasized connections to the bioeconomy, bioproducts, and/or bioenergy, potential careers, and the national and state science standards.

In the next section of the chapter, we describe the activities of the Graduate Students, Teacher Participants, and Undergraduate Students. In each of the sections, we include the strategies, research focus & theoretical frameworks, lessons learned, and recommendations.

GRADUATE STUDENT INVOLVEMENT IN THE INTERDISCIPLINARY TEAM

The interdisciplinary program team was formed by a Forest Biomaterials faculty member and Science Education faculty member who wrote and were awarded the USDA grant that funded the four-year program. A Program Manager, who was a full-time staff member in Forest Biomaterials and a part-time

Table 1. Details for select Laboratory and Classroom Activities

Name of Activity	Technologies & Tools	Description	Real World Applications
Assessing Biomass Availability with Big Data Analytics (2 x 45-minute class period)	Microsoft Excel or Google Sheets	Using Microsoft Excel or Google Sheets, students will create Pivot Tables to assess biomass resource availability in the United States. Students will learn to quickly and efficiently retrieve data from a large, master data set with nearly 80,000 data points.	Data Analysis
Bio-based Polymer Films (2 x 45-minute class period)	Vernier Go Direct® Force and Acceleration probeware, Opacity scale, General Laboratory Equipment	Students will create three bio-based polymer films and study the mechanical, optical and barrier properties. Students will compare the features of bio-based polymer films with petroleum-based polymer films to establish performance differences and the challenges of transitioning to bioplastics from petroleum-based plastics.	Bioplastics
Designing the Greener Shoe: A Lesson in Sustainability and Life Cycle Analysis (1 x 45-minute class period)	Microsoft Excel or Google Sheets	Students will make observations of the materials that make up their shoes. They will consider inputs and outputs of those materials and map out where and how those materials are made. The students will review current media and literature sources about the environmental impacts of various materials. Next, students will explore the making of mathematical models to apply quantitative measures to compare the sustainability of different shoes/materials using Excel or Google Sheets.	Bioproducts for Consumer Goods
Renewable Packing Peanuts (2 x 45-minute class period)	Corn Starch, Baking Powder, Glycerol, Iodine, Paper Cups, Microwave, General Laboratory Equipment	Students will produce a more environmentally friendly option using starch to produce starch-based packaging peanuts and compare its performance to polystyrene-based packaging peanuts.	Environmentally Friendly Packaging Material

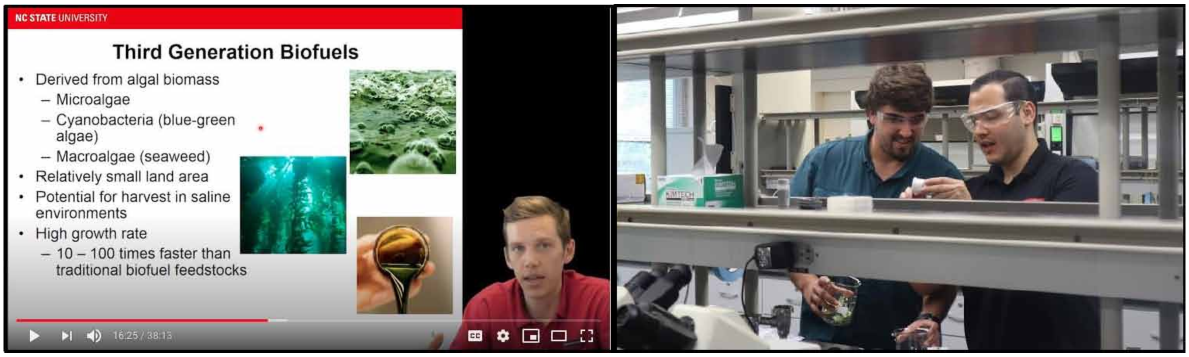
Science Education doctoral student, was hired to manage all aspects of the grant and program activities. The interdisciplinary team also funded three Science Education graduate students and nine Forest Biomaterials graduate students, who were assigned to work a portion of their time with the program. Several undergraduate students, both in Forest Biomaterials and in Science Education, were hired to assist with program activities as needed during the academic year, as well as summer.

Activities: Graduate Students

The graduate students played a critical role in the program development and implementation. There were full-time graduate students from Forest Biomaterials and from Science Education, and their involvement in the program differed. The Forest Biomaterials graduate students contributed to the grant and program activities in numerous ways, including serving as teaching assistants (TAs) for the online courses, developing high school laboratory activities, and facilitating lab sessions during the teacher PD (Figure 9).

However, their primary responsibility as graduate students was conducting bioproduct and bioenergy-related laboratory research for their degree programs, and their laboratory-based research was not directly tied to the program's educational goals. Additionally, some of the graduate students were funded by and

Figure 9. Graduate students served as teaching assistants for the online courses (left), and developed and piloted laboratory activities for the high school teachers and students (right).



worked for the grant program over multiple years, while others flowed on and off of the project for a semester or two at a time, serving as TAs and helping with lab activity development as needed.

The responsibilities of the Science Education graduate students included working with the Forest Biomaterials graduate students in the development of the courses and the laboratory activities. In addition, and in contrast to the Forest Biomaterials students, the Science Education graduate students' research and grant program commitments were closely aligned with the program's educational activities. The Science Education graduate students were typically funded on the grant program for multiple consecutive years. This allowed the research and dissertation work of the Science Education graduate students to be directly related to the grant program, and they were responsible for designing and conducting research on the grant program participants as well as studying interactions of the interdisciplinary team, itself. The Science Education graduate students also worked closely with the Program Manager to coordinate various aspects of the program, such as planning for the summer teacher professional development workshops, particularly making the laboratories consistent with state course objectives and effective pedagogical practices. The Science Education graduate students also maintained communication with the program participants and dealt with a wide range of logistical aspects, from ordering equipment to going out to schools to video record program lessons.

Strategies: Graduate Students

Develop Clear Agendas and Objectives for Team Meetings

The interdisciplinary team held frequent in-person team meetings, lasting 60 to 90 minutes each, throughout the process of co-developing the high school laboratory activities and online courses. Typically, the Program Manager or a Science Education graduate student created an agenda to guide each meeting. Feedback from the graduate student members of the team indicated they felt that having clear agendas and objectives promoted more productive meetings. These meetings consisted of discussions about the development of the high school lab activities. The graduate students took turns sharing about their progress, and other graduate students and faculty provided feedback, offered suggestions, and asked questions to collectively enhance the lab activities. To close out each meeting, the team identified "next steps" and assigned each member tasks to complete by the next meeting.

Incorporate One-on-One Sessions with Graduate Students

In addition to the large-group team meetings, the Program Manager and the Science Education graduate students also offered one-on-one support to the Forest Biomaterials graduate students during the lab activity co-development process. These meetings were scheduled early on when beginning to conceptualize the lab activities, during the lab activity development and pilot process, and also toward the end of the lab activity development. At this point, the graduate students created formal lesson plans and prepared to use best teaching practices to facilitate the lab activities during the summer workshops. This was an opportunity to provide specific, targeted feedback and enhance the collaborative interactions between team members.

Hire a Program Manager who has a Background in Science and in Education

The Program Manager played a critical, supportive role for the team, working closely with team members from both the Forest Biomaterials and STEM Education departments. The Program Manager was employed by the Department of Forest Biomaterials and was also a graduate student in Science Education. Importantly, the Program Manager had experience in both fields and was well-connected with both departments, which helped to bridge the two departments' efforts on the grant and merge the science, engineering, and pedagogical expertise from both departments.

Provide Opportunities to Connect with High School Teachers and Students

The interdisciplinary program team collaborated to coordinate STEM and Bioproduct/Bioenergy events that specifically focused on career exposure for the high school students. The team helped organize field trips to local industry sites and sent graduate student team members to Curriculum Nights at the high schools where they spoke with students and parents about college programs and careers related to the bioeconomy (Figure 10).

Figure 10. The Program Manager and a graduate student visited a high school Curriculum Night to discuss career opportunities and college majors.

These events educated and gave students exposure to possibilities for future careers they personally could seek out. Following the Year 2 summer workshop, graduate students also were available to visit schools and assist with lab activities. Many of the teachers did not utilize the support that was offered, but they acknowledged struggling to carry out labs, and many failed to complete the quantity of labs they originally planned.

Research Focus and Theoretical Framework

The graduate students participated in a research study to enable us to better understand their experiences and interactions within the project. A Science Education graduate student and interdisciplinary team member conducted interviews with the Forest Biomaterials graduate students and the Program Manager during the second and third years of the grant program. Interviews were transcribed and qualitatively analyzed using constructs from the Community of Practice framework (Wenger, 2010). Detailed research findings are communicated in a research paper (McCance et al., 2020). The interviews served as data for the science education research study. They also provided findings back to the participating graduate students, and formative feedback to the program team on how to modify and improve grant program activities.

Lessons Learned: Graduate Students

The ‘Team Meeting’ Model Enhanced Accountability and Team Relationships

The iterative process of conducting frequent whole-team meetings, assigning work to complete in between meetings, and providing substantive feedback during meetings was a model that seemed to enhance accountability for the graduate student team members and allowed the members to more effectively utilize their time together. Additionally, during the earlier team meetings, some of the graduate students seemed less confident in sharing their ideas. However, as the team members spent more time together and the graduate students continued to make progress on their lab activities, they developed confidence in contributing to team discussions and felt more agency in their work.

Diversity of Expertise with Shared Goals Strengthened the Program

The amount of time, nature of the tasks, and level of involvement and commitment on the grant varied among the program team members. During interviews, some of the graduate students expressed that they felt like the two departments had different levels of commitment with the grant program; it seemed as though the Science Education team members felt more invested in the program than did the Forest Biomaterials members. One factor that could have contributed to this was that the graduate students were assigned to work on specific tasks as needed; the grant program was multifaceted, as mentioned earlier, and required the graduate students to participate in various ways. Because of this, some of the graduate students had multiple roles, and they were sometimes asked to take on new responsibilities on short notice such as working as a course teaching assistant, serving as an undergraduate resume coach, organizing classroom kits, or attending classroom visits. Understandably, this was stressful for the graduate students. Despite the Forest Biomaterials and Science Education team members having somewhat different levels of commitment and motivations for working on the grant as well as bringing different perspectives to their work, all team members clearly cared about producing a high-quality program, and this diversity of expertise was necessary for carrying out the program activities.

The Grant Program was a Challenging Yet Valuable Experience for the Graduate Students.

The TA experience and the development of laboratory activities were influential experiences in giving the Forest Biomaterials graduate students exposure to reform-based teaching practices, improving their teaching and communication skills, and enhancing their understanding of their own field. However, learning to balance their own science laboratory research and grant program expectations was challenging for several of the students in Forest Biomaterials. This was particularly the case when they first joined the grant team and were learning about - and expected to practice - reform-based pedagogies, often for the first time.

For instance, when developing the lab activities based on the 5E learning model, the Forest Biomaterials graduate students struggled the most with designing the ‘engage’ portion that was intended to grab high school students’ attention and increase their interest and excitement about the lab activities and learning about the bioeconomy. During multiple team meetings, graduate students presented for three to five minutes to practice how they would pique students’ interest and engage them in the lab activities. After each graduate student’s presentation, the team members provided constructive feedback for improvement, and students said they liked and appreciated the feedback. Their learning process about these pedagogical practices was gradual, but clearly was enhanced by the interdisciplinary team’s collaboration. When the graduate students presented the lab activities and their ‘engage’ presentations during the online PD workshop in the third summer, almost all of the teacher participants felt that the graduate students’ presentations were effective and that the laboratory activities were better than in previous years. (This was in spite of the need for the professional development to be held online due to COVID-19.)

The Science Education Research Components were not Clear to all Team Members

During the interviews with the Forest Biomaterials graduate students, it was apparent that several of them felt they did not fully understand the nature of the Science Education team members’ research and that it was not sufficiently explained to the team. The Forest Biomaterials graduate students were not directly involved in conducting the educational research activities for the grant program (e.g., designing the research studies, collecting and analyzing data, and writing up results), but they mentioned they would have been interested in receiving occasional updates about the Science Education team members’ research projects throughout the duration of the grant.

Interviews with Program Team Members Provided Opportunities for Reflection and Feedback

The interviews were a productive way for team members to reflect on the ways in which they felt they personally benefited from working on the grant program. The interviews were also informative for the project team to gain an in-depth understanding of what was working well and what needed improvement from the perspective of the graduate students.

Recommendations: Graduate Students

1. Increase the graduate students' engagement with the high school teachers and their students through formal, expected class visits and video calls with the students where they could share about science and engineering majors and careers and assist in conducting the laboratory activities.
2. Increase the transparency of the Science Education team members' work with the graduate students by mapping out the progress of the different research projects, explaining how and why data was being collected, and sharing preliminary results.
3. Improve communication of roles and expectations with the graduate students well in advance of duty transitions to reduce stress and enhance results.
4. Build graduate students' agency, investment, and motivation by matching students' interests to tasks and asking for their ideas.

HIGH SCHOOL TEACHER BIOECONOMY PROFESSIONAL DEVELOPMENT

Recruitment and Selection

Recruitment for high school teachers was done by emailing all of the science and science-focused CTE teachers in the high schools of participating districts, with an attached program flyer, which included program requirements, benefits, a link to the application, and deadlines. Additionally, over 200 mailers were sent to eastern North Carolina high school principals and administrative assistants leading to more than 80 high school teacher applicants, predominantly from schools designated as Title I. Nineteen high school teachers from ten counties in Eastern North Carolina were selected, based on their expressed interest in the bioeconomy, demographic information, and their teaching experience. Selection also favored 'paired' teachers who applied from the same school to enhance teacher support and student impacts. Six of the 20 teacher participants were paired teachers from three high schools. Five of the original 19 teachers dropped out early in the program, due to feeling too overwhelmed to participate fully. Subsequently, two additional teachers from schools with similar demographics joined the program.

There were two main parts of the program for the teachers: two online graduate-level courses and workshops over three summers, with the option for teachers to enroll in one additional online course. Additionally, teachers selected from various additional bioproducts and bioenergy career experiences for their students; field trips to an industry or the university, a career night, or graduate students visiting class for an activity and providing role models. The team also regularly emailed teachers about STEM activities and events available for participation, such as a STEM day at a science museum in the region.

Activities: High School Teachers

Onlines Courses

During School Year 2, the high school teachers enrolled in Fall and Spring online courses (with the undergraduate students), the Sustainable Bioeconomy and Biomass Conversion. In the Fall of Year 3, teachers had the option to take a third course. Throughout several of the courses, teachers' assignments included creating lesson plans - some individually and others in small groups - to incorporate content from the online courses into immediately transferable high school lessons and activities. Teachers were encouraged to share bioeconomy-related assignments they created throughout the program, using a shared Google Drive folder. Teachers also were able to take assignments from the graduate courses and utilize them within their classroom, modifying them to be simpler or more appropriate for their high school students. The classes also had a strong career exploration element for the teachers. This piece was extremely useful for it provided resources, via websites and a plethora of YouTube videos, to share with students about careers in the bioeconomy.

In addition to career connections, the courses provided excellent resources to be incorporated into science classrooms, such as videos for enzyme modeling with computers, green fluorescent dye as an indicator in cells, and tree harvesting. Through the workshops and the online courses, teachers developed a learning community to share ideas, resources, and support throughout the program. The benefit of this support is further exemplified by the positive comments from teacher pairs who worked together at the same high schools. Two of the pairs were separated after Year 1 due to changes in assignments, and all teachers involved in the separation acknowledged the greater difficulty in completing tasks, such as labs or courses, without their partner teacher. The development of comradery between teachers within this program through summer workshops, online courses, and teacher pairs supported teachers in the successful completion of the program. A high school teacher commented about the influence of the courses: *"I have changed my curriculum to include more focus on bioproducts, bioproduct production, and bioindustry careers."*

Summer Professional Development Workshops

For the Year 1 Orientation & Year 2 Summer Workshops, the high school teachers practiced and offered refinements for the laboratory activities (Figure 11). One high school teacher wrote: *"This workshop was one of the best professional development courses that I have attended in a long time. The labs were well written and the debriefing sessions were helpful for classroom implementation."*

Figure 11. High school science teachers working with university faculty and graduate students to model greenhouse gases and global warming potential at the Year 2 Summer Workshop.

Teachers learned about the bioeconomy through industry panels and presentations. In Year 2, a panel of five young professionals actively working in the bioeconomy - including a Senior Research Associate, a Process Engineer, and a Bioanalytics Technician - shared their experiences with teachers (Figure 12). They discussed their educational backgrounds, job responsibilities, and career expectations. In addition to the industry panel, three professors within the College of Natural Resources conducted individual presentations throughout the four-day workshop about their role in the bioeconomy and what they were researching. Both of these facets, the industry panel and professors' presentations, provided research updates and information about career opportunities that teachers could share with their students. During the Year 3 summer virtual workshop, a professional in the industrial hemp sector also conducted a presentation about hemp bioproducts and the role of hemp in the state's economy.

Figure 12. Young professionals actively working in the bioeconomy shared their experiences with teachers.

Also during the Year 2 summer workshop, teachers ventured on a field trip to a forestry research area near campus that studies breeding in trees and spoke to the individuals who oversee the research (Figure 13). Teachers also visited a facility on campus that made paper from various fiber sources. On the day they toured, the facility was making paper out of banana leaves. Similar to the presentations by the industry panel and professors, the field trips provided memorable experiences for teachers to share with students about ongoing activities in the bioeconomy and to encourage them to consider career possibilities in this sector.

Figure 13. Teachers learn about new technologies in silviculture and tree cultivation at a research forest near the university's campus (left) and about paper production at a facility on campus (right) during the Year 2 summer workshop.

Due to constraints of social distancing, the Year 3 workshop was hosted online via a virtual platform over two days (Figure 14). Despite the physical barriers, graduate students were able to share background information regarding their new lab activities through slide presentations and share videos and pictures of the labs, still in development. Teachers displayed high interest in the new activities and had many conversations about possibly converting several of the activities to remote learning lab activities during the period of social distancing. Also during the workshop, each teacher shared which labs and information they had incorporated into their classrooms, along with successes and challenges that arose with each. These presentations allowed teachers to reflect on activities they conducted in their classrooms and provided motivation for other teachers to incorporate more activities in the upcoming school year.

Figure 14. The Year 3 workshop was held online during COVID-19 required social distancing. Teachers shared about their experiences implementing bioproduct lessons with their students.

During the summer workshops, strategies and activities were modeled by the research group during pedagogy sessions that encouraged hands-on, inquiry based learning by the teachers, which tends to foster more reformed based teaching methods (Blanchard et al., 2010; Blanchard et al., 2009). Sessions included information on conducting class discussion on science topics, such as a Marine Plastics Case Study, conducting better labs, facilitating career exploration, and utilizing technology and data in a science classroom.

Teachers also completed a variety of surveys for the program. Teachers completed a post-lesson reflection describing how it went and what could be done differently. This information provided feedback for the research group about possible modifications that may be needed for the activities. The other portion of the surveys related to teacher practices with a Teacher Beliefs Interview (Luft & Roehrig, 2007). The surveys further encouraged these reform-based practices by providing insightful reflection on teachers' beliefs and practices. Teachers completed these surveys at several points throughout the first year. The workshops and surveys connected content knowledge with pedagogical methods to facilitate inquiry-based teaching methods.

Following the workshops, teachers selected science equipment and supplies to use for all of the bioproduct and bioenergy lab activities they anticipated implementing in their classroom, funded by the

Figure 15. Examples of supplies and lab equipment used during the summer PD and available for inclusion in teachers' supply kits.

grant program (Figure 15). Many teachers had sufficient grant funds to purchase additional laboratory materials or equipment to benefit their classroom instruction.

The supplies ranged from activity-specific equipment, such as handsheet molds to create recycled paper, to more general lab supplies, including glassware. Digital probeware to measure variables such as pH, temperature, and force were also available to include in the kits to enhance technology integration and collect and analyze data. During the last day of the 2019 summer workshop, the teachers were provided with a spreadsheet detailing all the equipment required for the lab activities and their prices. From this spreadsheet, teachers were able to select items they specifically needed to complete the labs. This allowed teachers to avoid duplicating lab equipment they already had in their classrooms and also tailor their equipment request for the lab activities the teachers were most interested in. These materials were delivered for use in mid-September. The lab supplies were either delivered to the schools or available for pick-up if teachers were close to Raleigh.

Through participation in the workshops, teachers also were able to earn continuing education credits (CEU's) for participation in the workshops at a rate of 1 hour of contact time for 0.1 CEU. The teacher professional development workshops were designed as collaborative sessions for teachers, faculty, graduate students, and industry partners to share experiences and gain experience with engaging bioeconomy-focused lessons for high school science classes.

High School Supports

Lesson Implementation and School Support

Assessment

For Year 2, eight activities included pre- and post-quizzes for the high school students, with questions created by the graduate students. The graduate students worked with each teacher to create unique quiz question sets pertaining to the laboratory activities each teacher planned to carry out during the school year. The quizzes could be completed on an array of electronic devices (e.g., computers, tablets, or smartphones). High school students took one inclusive pre-lab quiz at the beginning of the semester that included questions from all the activities their teacher planned to carry out. After each lab activity was complete, students took an immediate post-quiz related to that specific lesson. The university team converted class quiz results (collected in Qualtrics) into graphs and data tables the teachers could access via a google drive. This provided insightful feedback for the teachers relating to what the students already knew (inclusive pre-lab quiz), learned from the activity (specific post-lab quiz), and areas needing additional reinforcement. Some teachers used the results to prompt a discussion with their students regarding their lab experience and the bioeconomy. Results also provided formative feedback for the research team to consider quiz item revisions.

School Year PD Support

As additional support, there were two video calls between one of the Science Education graduate students and the teachers. The teachers shared strategies they had for completing the lab(s), issues they may have run into, such as the pineapple fibers binding up the blenders or long drying times for biofilms, and to ask questions. Teachers reported good rapport with the Science Education graduate students working on the program and felt able to contact them with any concerns about the activities via email or by phone throughout the program. On several occasions, graduate students visited high schools to assist teachers in carrying out the activities. Not only was this beneficial for the teachers in completing a new lab activity, but the visits also provided college role models for high school students. During these visits, the graduate students gave an informal presentation about attending college, their graduate program of study, and careers in the bioeconomy.

Graduate students led conference presentations to disseminate the grant work and members' experiences. On several occasions, high school teachers co-presented with Science Education graduate students on a range of activities from laboratories and online course assignments (Figure 16). The conference allowed this activity to be shared with other professionals in the field of K-16 STEM education.

Figure 16. Teacher participants share the Energy Diagram activity with their peers at a local K-12 education conference (McAlexander et al., 2019).

Career Nights, University Visits and Field Trips

The interdisciplinary program team and graduate students coordinated STEM events to introduce the high school students to the bioeconomy, potential careers, and role models. Tabling events were organized for school curriculum nights. To highlight one outreach event held at the university, fifteen biology and chemistry high school students visited campus to learn about natural resources majors and careers. Their teacher wrote: *"Our students learned a lot of science as well as realizing that there are other fields of science that are equally satisfying career-wise and financially."*

Funds were made available to school for organizing Bioproducts/Bioenergy in STEM events. The Program manager helped coordinate several class field trips to industry facilities. Unfortunately, a number of the events were cancelled due to the COVID-19 pandemic and resulting shut-down.

Strategies: High School Teachers

Recruitment focused on teachers interested in the Bioeconomy, pair teachers were recruited from the same schools, and schools serving underrepresented students had priority.

On the application, teachers wrote an essay describing their interest in taking part in the program. An explicit part of the recruitment process was to make sure there was an expressed interest in sustainability, and a clear desire to translate their learning into their classrooms. Their school site was checked to see if it was serving underrepresented students (first generation, minority, low socio-economic status, rural). From prior research, we knew that having multiple teachers in the same school could hold greater benefits for student learning and teacher support (Blanchard et al., 2016), so we indicated in the application that it would enhance their chance of being selected if they had a partner teacher (three sets of partner teachers were selected).

Design of online course curricula was linked to the skills and knowledge teachers could use in their high school classes.

The high school teachers were able to take up to three online graduate-level courses during the program. Topics ranged from the parameters of sustainability, life cycle analysis, biomass conversion to business concepts of the bioeconomy. Many of these topics were easily woven into high school classrooms regardless of the subject. The online courses provided a large array of supplemental videos, forum discussion prompts, and homework assignments for teachers to utilize, many of which were directly transferable to the high school classroom. In addition, the information from course lecture videos could be incorporated and connected to concepts in most science high school courses. Some courses, like environmental science, had a higher degree of transferability, but many concepts were transferable to other courses, such as biomass conversion problems in chemistry and utilizing enzymes utilized to digest wood in biology.

Design activities that engage students.

The lab activities were jointly created between the Department of Forest Biomaterials and STEM Education. With the talents and skills of both departments, high quality inquiry-based activities were developed for the students. The lab activities were developed with the 5E Learning Model: Engage, Explore, Explain, Elaborate, and Evaluate. The labs also incorporated concepts from a variety of curricula (e.g., biology, environmental science, and chemistry), so they could be incorporated into various classrooms with ease. Design and engineering were a central focus for many of the inquiry-based labs. In many of the labs, students designed modifications to the initial experimental design for consecutive trials. For students, the ability to create part of the experiment and observe the results produced was highly engaging. Also, the labs correlated to topics of the bioeconomy, of interest to many students. By the labs having real-life connections, such as paper recycling or fermentation using pineapples, students' engagement was high.

Provide laboratory equipment and supplies to teachers to support bioeconomy lab activities and other hands-on lessons in the classroom.

One area of difficulty for rural science teachers is a lack of supplies. Even if teachers want to incorporate labs and utilize inquiry-based learning, many of the classrooms lack basic laboratory supplies and glassware and have a huge deficit in more advanced technology. The grant funded all of the supplies needed, all of which were selected by the teachers and ordered, organized, and delivered (as needed) by the program team.

Connect teachers to regional industry professionals

For all online courses, there were many connections to careers in the bioeconomy. Several of the assignments were career exploration tasks that provided teachers with resources they could easily use with high school students. Likewise, many of the supplemental videos utilized in the courses focused specifically on companies located in eastern, rural North Carolina near the school sites. In the summer workshops, teachers participated in industry panels of young professionals working in regional bioeconomy positions and listened to presentations from professors about their locally-based research in the bioeconomy. Ongoing regional career connections were made with field trips and guest speakers. As one teacher commented on the workshop evaluation, *"The guest speakers and the discussion topics were relatable for me as a teacher and will impact my classroom for years to come."*

Provide implementation support during the school year

Graduate students and program staff were available to teachers for help with lesson planning, obtaining additional materials, and classroom visits. Graduate students also were able to visit classrooms on several occasions to help facilitate the laboratory activities and assist teachers in collecting student data for ongoing education research projects.

Provide access to materials through online resources

The program activities and high school lessons were made publically available with written teacher and student manuals and introduction videos supplied freely on the program's website and YouTube Channel (Figure 17). Modified versions of the courses taken by undergraduates and high school teachers are available at no cost via MOOC.

Research Focus and Theoretical Framework

Figure 17. Video Introductions were created and made public for each lesson to help draw connections between global challenges, bioproducts industries, and science curricula.

Seventeen high school teachers participated in a research study to help us to better understand their motivation to add new Bioeconomy-focused laboratories, information, and career connections to their instruction. Informed by Expectancy-Value Theory (Wigfield & Eccles, 2000), online coursework posts, interviews, summer workshop presentations and classroom implementation of Bioeconomy topics and laboratories were analyzed. Research findings are detailed in a research paper (Blanchard et al., 2020), based on qualitative analyses of value and cost constructs paired with teacher implementation data. Findings suggest that teachers' level of implementation of new bioeconomy-focused lessons is influenced by their focus on its value for their students.

Lesson Learned: High School Teachers

Teachers do better with a support person, including reminders for data collection, pre-quizzes, and other accountability measures.

After the Year 2 summer workshop, many teachers had high motivation and detailed plans of how they were going to incorporate many of the new activities in the upcoming school year. However, for many teachers, those goals were not met and some teachers failed to implement any new activities. Possible solutions to assist teachers in achieving goals of lab implementation include connecting stipends to labs implemented and data collected. Furthermore, increased use of partner teachers could also be used as an accountability factor in addition to providing a resource for lab implementation and problem solving.

Teachers and their students enjoyed authentic and relevant laboratory experiences.

Feedback from teachers indicated their students displayed high engagement and interest in labs that were authentic and relevant to their lives, such as the paper recycling and fermentation of pineapple to ethanol. From Summer 3's workshops, teachers had the highest interest in completing the packing peanuts and soap factory activities in the upcoming year, which can be attributed to the authentic and relevant nature of the activities.

Teachers valued online course materials that they found relevant to their teaching, and reactions were mixed about the quality and nature of assignments.

The feedback from teachers on the online courses presented two different viewpoints. Some teachers found the material intriguing and enjoyed the assignments. Another teacher group found the work more tedious, considered responding to Moodle posts as ‘busy work,’ and did not appreciate the material that was not immediately implementable into their classrooms (e.g., chemistry problems are difficult to implement into environmental science). Also, some teachers found the online lecture videos ‘boring’ and as an antiquated teaching method while others expressed a more positive opinion of the lectures.

There was a wide range of criticalness on the part of the teachers about the program.

Much like the two groups of opinions for the courses, the same pattern was repeated regarding teachers’ perspective of the program. Some teachers expressed their excitement about being back in school, and several teachers have left the classroom to pursue graduate degrees while others are pursuing graduate degrees while also maintaining a teaching position. Other teachers expressed the program was not ‘cutting edge’ or different enough.

The asynchronous nature of the courses during the year delayed the development of the learning community of the program participants, for teachers who didn’t have other involvement.

For the online courses, the lectures were pre-recorded and videos and assignments were assigned to respective weeks. All tasks had due dates, but timing of completion was up to the teachers’ discretion. Though this model was convenient, it seemed to contribute to feelings of isolation for some participants. The teaching cohort displayed a delayed comradery, which is attributed to the asynchronous course design. For other teachers, a greater sense of community developed earlier in the program, and this is attributed to those teachers being more involved in the program (e.g., they utilized graduate student class visits and participated in conference presentations). By the Year 3 summer workshop, a stronger sense of community was evident between the teachers. Therefore, the learning community was capable of developing but possibly delayed due to the asynchronous courses.

More time is needed for teachers to figure out where new lessons can fit into their curriculum.

At the end of the Year 2 summer workshop, some time was dedicated to teachers planning where they would incorporate the labs into their curriculum. However, many teachers failed to carry through with their plans, and during interviews it seemed clear that not enough time had been dedicated to planning where the labs would work best for each of the teachers’ intended courses. More time could be spent by the research team and teachers to find places the labs would be best utilized and students could gain the most from their experience.

Recommendations: Teachers

1. Focus more on teacher pairs or triads in participant selection.
2. Utilize accountability pieces for lab implementation and data collection, e.g., connecting it with stipend funds or receiving laboratory supplies for future activities.
3. Facilitate the creation of learning communities with the participant group through biweekly virtual meetings and/or synchronous course design.
4. Prioritize lab activity placement in high school curricula to greater assist teachers in the ease and frequency of classroom implementation.

UNDERGRADUATE STUDENT BIOECONOMY TRAINING PROGRAM

Recruitment and Selection

Participant selection was guided by the grant's goal to provide opportunities for individuals who are historically underrepresented in science and engineering careers (i.e., females, minorities, first generation college students). A unique aspect of the program was the recruitment of undergraduate students from other institutions of higher education - with the goal of diversifying participation. Program staff recruited students at community colleges and primarily sophomores and juniors from Historically Black Colleges and Universities, a women's college, and regional universities. A number of strategies were used: administrative contacts at the partnering institutions assisted with forwarding emails to faculty and student groups with a program flyer, which included program requirements, benefits, a link to the application, and deadlines. Tables were set up in student centers, and some short class and science club presentations were delivered. Over 80 undergraduate students applied for the program. The program team selected participants based on students' expressed interest in the bioeconomy, demographic information, and their academic background. Twenty-one students, representing 8 institutions, were selected to participate in the program.

Activities: Undergraduate Students

Online Courses

The undergraduate students participated in an on-campus orientation event, three university courses, and a 10-12 week summer internship. Students joined the university's Non-degree Studies program where they could enroll in courses without being admitted to a degree program. Grant funds paid for tuition and fees. Using a cohort model, the students enrolled in The Sustainable Bioeconomy course in the Fall and the Biomass Conversion course in the Spring. The Fall of their second year, students chose to take a third course based on their interest area; either Environmental Life Cycle Analysis or Strategic Business Analysis. Each of the courses could be transferred for credit hours at the student's home institution, for up to 9 credit hours. Students who completed the first two courses with a C+ or better were eligible for the summer internship program.

Internships

The internship program gave most of the students their first science/engineering work experience. Each student engaged in a resume review and coaching session with the program staff. Students were asked which of the organizations they were interested in working with and each company was sent a curated packet of student resumes. Companies responded with a short list of students they wanted to meet, and the Program Manager introduced the students to company representatives via email for scheduling on-line and in-person interviews. Twelve students who successfully completed the required courses were matched to internships.

Each internship was funded with a base stipend of $8000 for 10-12 weeks. Additional funding provided support for students moving within the state and for students traveling outside the state. Each internship included an independent project in which students engaged in research, project development, and/or operations. The Forest Biomaterials Department benefited from the new and further established relationships with internship hosts (Figure 18) as they also may serve as future student and graduate employers and research collaborators.

Figure 18. Undergraduate students were matched with bioproduct and bioenergy companies and research organizations within North Carolina and across the United States.

Internship Hosts

Algaen (NC)
Arbiom (NC)
California Polytechnic State University (CA)
Domtar Plymouth (NC)
Lignetics R&D (CO)
North American Plant Production Office (NC)
North Carolina State University (NC)
Novozymes Biofuels R&D (NC)
RTI International (NC)
Velocys (TX)

Students identified the summer internship as their most influential career development experience to date. A female student shared "I learned more in 10 weeks than I would have in an entire semester...I am so grateful for this amazing experience and program."

Strategies: Undergraduate Students

Gain Entry Into Institutions of Higher Education Through a Liaison

While many regional institutions were contacted to encourage their students to participate in the program, the most successful recruiting efforts occurred at institutions when there were existing relationships between program host faculty or administrators and instructors at the institutions. This facilitated access to classes, encouraged students to read emails and posted flyers, and allowed for campus recruitment events.

Holistic Criteria for Acceptance

Contrary to other special programs in the Forest Biomaterials departments and many science and engineering programs, student applicants GPA's were not the first criteria for selection. In an effort to increase the participation of underrepresented students, a more holistic review process was used, including the student expressing passion for sustainability and career interest related to the bioeconomy.

Industry Career Panels and Video Tours

Industry professionals shared about their career experiences through videos in the course. On-site footage of local and national research and development and production sites highlighted various bioproduct and bioenergy settings and potential jobs. Video interviews and tours at Tyton Biofuels and Domtar Paper demonstrated the scale of biorefineries in North Carolina. An undergraduate, first generation college student shared his experience: *"I have really enjoyed learning about the bioeconomy, bioproducts, and bioenergy* [class]... *I learned a lot about the various jobs available in this industry. From education program specialist, to engineer, to communication."*

Resume, Interview, and Internship Matching Support

Professional development elements were embedded within the curriculum of the coursework. Program staff provided resume coaching sessions and mock interviews in an effort to match all students with an internship in their area of interest. Some students had multiple internship offers and some companies didn't find a compatible match. The Program Manager helped with negotiating matches to satisfy both the needs of the students and the companies.

Research Focus and Theoretical Frameworks

The first study was the development and validation of two quantitative surveys for use with the program participants to understand student perceptions and beliefs about bioproducts and bioenergy (McAlexander, Noble, et al., 2021). Over 200 undergraduate students who were enrolled in natural resources courses completed the surveys for the validation. The items of the Beliefs about Bioproducts/Bioenergy (BABB) highlighted personal and global beliefs based on task values of Expectancy Value Theory (Wigfield & Eccles, 2000). The Career Interest about Bioproducts/Bioenergy (CIBB) measured overall intention to pursue a career in Bioproduct/Bioenergy, with items addressing specific job settings. These validated surveys serve to assess changes in student beliefs and interest over the course of their program experience.

In a second study, reflective writings and interviews that focused on career development experiences were analyzed through the lens of Social Cognitive Career Theory (Lent et al., 1994, 2000). This study focused on six of the undergraduates who were transferring from the community college to a four-year institution. Reflective prompts embedded in online course forums asked students to write about their expectations for the internship prior to starting; then, following the internship, students compared their initial expectations to their experiences. In reflective interviews a few months after the internships, students were asked to review all of their writing reflections and discuss what they learned about themselves. Each student created a career narrative timeline and reflected on barriers and supports to their career development. Student materials were analyzed based on the contextual and intrapersonal supports and barriers they experienced. These led to recommendations for supporting community college transfer students support for internship placements (McAlexander, Blanchard, et al., 2020a).

A third study compared the motivations and perceived outcomes of students and industry partners who participated in the internship program (McAlexander, Blanchard, et al. 2020b). Industry partners were motivated to host program interns for a number of reasons that included: a desire to give back or mentor, building their industry or recruiting employees, and to diversify their workplace. Two internship supervisors attributed their decision to accept a student intern due to the extra technical knowledge that students acquired from the bioeconomy-focused program. Students were motivated to participate in the internship primarily to try out a particular industry or setting, either to reinforce or eliminate a potential career interest. Ten of the twelve students focused on positions where they could gain more laboratory experience.

Lessons Learned: Undergraduate Students

The two instruments that were developed were found to be valid and reliable with a population of undergraduate students.

The new survey instruments, the CIBB and the BABB, may be useful for educators and bioproduct/bioenergy professionals interested in: establishing a baseline of beliefs for a certain group; examining changes due to a course, program, or other intervention; or comparing beliefs between demographic groups (McAlexander, Noble, et al., 2021). The four Likert-type CIBB items measure career interest for bioproducts and bioenergy of a given population. The fifteen Likert-type BABB items measure beliefs and values about bioproducts and bioenergy; eight items reference personal beliefs and seven items reference global beliefs and these items may be used together or separately.

Students honed their career ideas through online coursework and internships.

The students in the program showed consistently positive beliefs about bioproducts and bioenergy. Their interest in bioproducts and bioenergy careers also remained high, although their career goals changed as they became more aware of various STEM jobs.

Extra support was needed for online courses.

Students entered the program with varying science backgrounds, experience with university-level course work, and comfort with asynchronous online courses. Though faculty and teaching assistants provide regular office hours via online conferencing tools, this population of students needed more support than the instructors were accustomed to. Most students balanced full-time course work, part-time jobs, and family responsibilities. The Program Manager served as a liaison between students and instructors, helping students better understand the course expectations, relaying student feedback to instructors, and helping manage requests for extensions or modifications to coursework.

Externally-funded internships incentivized internship hosting.

The companies and organizations were more interested in hosting interns due to the available funding. Because companies were competing for the pool of interns, some offered additional compensation including housing stipends, relocation reimbursement, and extra stipend amounts.

For smaller organizations, many were hosting interns for the first time as it had previously been cost prohibitive. With no precedent for mentoring interns or designing an internship project, students at these organizations had less structured experiences. More communication was required between the Program Manager and internship host to coordinate projects and expectations. For larger organizations, or those with established internship programs, students joined the ranks of other summer interns and had significantly more mentorship support for their projects and their professional development. Some unexpected challenges arose due to the external-funding and had to be resolved with the company's Human Resource departments including liability insurance, time tracking, and taxes.

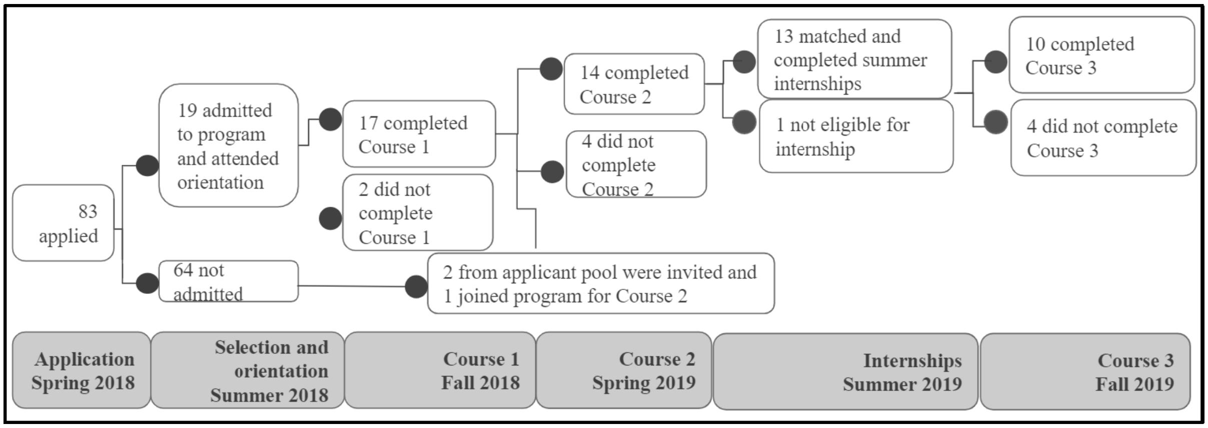
Student interviews provided more information about supports and barriers for career development.

During reflective writing and interviews, students described their career journeys including events and people that influenced their career direction. Students also described personal and contextual barriers and supports that they faced during their internship experience. Contextual supports included family, program staff, internship host staff and supervisors, stipend funding, program courses, and resume support (McAlexander, Blanchard, et al. 2020a). Although the internships were fully funded, students shared that the financial logistics, housing, travel, transportation, fear of the unknown, and lack of confidence were the greatest challenges. Following the internships, students expressed a new-found confidence in their career journeys. One female student shared about the experience: *"I learned more in 10 weeks than I would have in an entire semester [of school]...I am so grateful for this amazing experience and program."*

Program attrition occurred for many reasons.

Of the twenty-one students who started the program, ten completed all program activities. Students left the program for multiple reasons and at multiple points of the program, as seen in Figure 19. As students prioritized the many demands for their time and energy, their participation in the program was understandably low on their list, particularly given that program participation was completely voluntary and separate from their degree requirements at their home institution. Credit for the courses was transferable to home institutions, but these credits were not necessarily counted toward their requirements for their degree program. Working more closely with academic advisors, we would have liked to ensure the alignment of the online course with the student's major curriculum. Alternatively, offering an official 12-credit undergraduate certificate was originally in the project plan, but the year-long process to make

Figure 19. Undergraduate student persistence throughout the program.



the certificate official and the lack of historical data for the courses created a delay between the students' participation and the availability of the official certificate.

Recommendations: Undergraduate Students

1. Provide extra academic support for students and prepare faculty for added flexibility in course expectations.
2. Boost communications with students' home institutions. Work with students' academic advisors and career advisors to align student academic goals with the program.
3. Create a formal program of study certificate to encourage student persistence and ensure the sustainability of the program activities.
4. Create an internship guide and engage in summer-long discussion with internship hosts especially for companies new to hosting interns. This will include a proposed schedule of events, expectations for interns, supervisors/mentors, and project guidelines.
5. Providing funding to students is not enough. Engage students in discussions about housing, travel and transportation, and budgeting so they are better prepared to take on the responsibilities of moving and starting a professional role.

REFLECTIONS AND NEXT STEPS

As we reflect back on the project, we realized that many of our participants have advanced professionally. Two of the teachers were honored as their school district's Teacher of the Year. One of the teachers became the State Teacher of the Year for North Carolina. One of the graduate students from Forest Bioproducts was hired as a faculty member in the College of Agriculture and Life Science at NC State University. Four of the teachers became graduate students: two master's students in the College of Natural Resources and two in the College of Education (one Master's and one Doctoral).

We also noted the active use of the online materials through the College websites, not only by the teachers, but also by the broader community. The MOOCs and online courses will be sustained for the future, and the lessons are becoming available on the website and in relevant practitioner publications. Therefore, these materials will be sustained with fairly low maintenance.

Sustaining the innovation in the schools is more difficult. We noticed that the teachers who had a partner teacher or who worked in the same school district tended to support one another. Although we are continuing to be available to the teachers for materials and technical support, the long-term support for continuing and the recruitment of new teachers is more tenuous. At two of the schools, we invited new teachers to replace one who is retiring and one who is out of the school for a year as the NC Teacher of the Year. As we think about future funding opportunities, we have submitted proposals that harness the expertise of teachers who are experienced with the Bioeconomy program content and activities, who can serve in a support capacity for new teacher recruits. With the inevitable teacher turnover, we hope these more seasoned teachers can serve in a 'train the trainer' model. Ultimately, turnover in high needs schools requires constant tending and creative solutions with help from the school districts.

Clearly the undergraduate internship experiences were impactful. We want to know more about their career pathways, and will work to stay in contact with these students. They hold the potential of being the next role models for high school students in the program teachers' classrooms.

Finally, we have learned a lot about our interdisciplinary work. Ongoing research projects study how to work in meaningful ways with industry professionals, science and education university faculty and graduate students, diverse undergraduates, and high school teachers. We hope that this program will inspire and inform others who want to build positive and productive partnerships.

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KEY TERMS AND DEFINITIONS

Bioeconomy: Using renewable biological resources and waste streams to produce value-added bioproducts, such as energy, fuel, chemicals, and consumer goods; an alternative to a fossil fuel-based economy and manufacturing processes.

Bioenergy: A form of renewable energy that is produced from biological materials including wood, agricultural residues, municipal solid waste, and algae.

Bioproducts: Products, such as biofuels, bioplastics, biopharmaceuticals, and other biomaterials, that are made from renewable biological resources and waste streams.

Community College Transfer: A student who moves from a community college (two-year postsecondary institution) to a four-year college or university.

High School: A secondary school, usually grades 9 through 12, that students attend after primary and middle school.

Interdisciplinary: Involving two or more academic disciplines.

Internships: A short-term position (paid or unpaid) with a company or organization to gain work experience in and exposure to a career or field of interest.

Online Courses: A course that is conducted in an online format rather than face-to-face.

Rural Education: Schools in rural areas that face unique challenges such as economic distress and high teacher turnover.

STEM Careers: Any career in science, technology, engineering, or mathematics fields.

Undergraduate: A student attending a postsecondary institution and who has not yet obtained an associate's or bachelor's degree.