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Interdisciplinary Product Development Framework for Food Science Capstone Course and Undergraduate Research in Collaboration with a University Dining Center

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ABSTRACT

A framework for two undergraduate food product development courses involving interdisciplinary work between food science and foodservice (university dining center) was implemented. We surveyed former students to determine the framework's impact. Students agreed that the framework gave them experience with larger-scale food production equipment, and taught them about foodservice perspectives (feasibility requirements, how dining centers operate) and the scale-up process. Students also developed research/laboratory skills, soft skills, and food production knowledge. In return, students developed new recipes for the dining center. This framework could be implemented at other universities to develop interdisciplinary relationships between dining centers and food science programs.

Keywords: Foodservice; Interdisciplinary; Undergraduate research; Food product development

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INTRODUCTION

Food science is focused on the chemical, microbiological, sensory, safety, regulatory, and quality assurance aspects of food, as well as the processing and engineering principles required to produce food on a large scale (IFT, 2018). Meanwhile, the field of foodservice focuses on the preparation and serving/distribution of food products for consumers to consume outside their homes (Edwards, 2013; *USDA ERS - Food Service Industry*, n.d.). Many universities have academic programs such as Hospitality Management, Dietetics, Culinary, and Business which focus on foodservice systems as part of their curriculum and often their areas of research. While food science education has emphasized experiential learning through industrial partnerships and case studies (Hollis & Eren, 2016; Bohn & Schmidt, 2008). The foodservice education has explored multi-professional collaboration in school meal settings (Janhonen & Elkjær, 2022). However, research examining how food science and campus foodservice operations can collaborate to create applied learning experiences for undergraduate students remains limited. Although campus dining services have been utilized as sites for nutrition education and sustainability initiatives (Malan et al., 2020; Caspi et al., 2021), these programs have primarily focused on consumer education and environmental outcomes rather than integrating food science curriculum with operational foodservice units. This represents a significant gap in understanding how interdisciplinary partnerships between academic food science programs and campus dining centers can enhance students' learning outcomes in product development, scale-up processes, and foodservice operational constraints.

Interdisciplinary collaboration brings diverse perspectives, which can improve not only the product being developed, but also the research process (Reinventing Undergraduate Education, 1998; Specht & Crowston, 2022; Struijk et al., 2022). Multi-professional collaboration in food education has been shown to create valuable learning outcomes when participants from different disciplines work together toward shared goals (Janhonen & Elkjær, 2022). Undergraduate research has been shown to be beneficial to students, providing them with scientific skills, soft skills, and experience (Adebisi, 2022; Linn et al., 2015; Petrella & Jung, 2008; Reinventing Undergraduate Education, 1998; Russell et al., 2007).

From a theoretical perspective, Kolb's Experiential Learning Theory (ELT) provides a strong foundation for understanding how interdisciplinary food product development experiences enhance student learning. According to Kolb (2014), experiential learning is "the process whereby knowledge is created through the transformation of experience." The ELT framework is built on a four-stage learning cycle: (1) concrete experience (CE), where learners engage in hands-on activities; (2) reflective observation (RO), where they reflect on their experiences; (3) abstract conceptualization (AC), where they develop theories and concepts from their reflections; and (4) active experimentation (AE), where they test their new understanding in practical applications (Kolb & Kolb, 2017). This cyclical process aligns exceptionally well with food product development activities, where students experience hands-on formulation work, reflect on formulation challenges and results, conceptualize solutions based on food science principles, and actively experiment with recipe modifications and scale-up procedures. Research in food science education has shown that students who participate in such hands-on, experiential activities demonstrate improved retention, application of course concepts, and enhanced collaboration skills (Bohn & Schmidt, 2008; Masdarina & Martsiti, 2024).

Integrating experiential learning with campus foodservice operations offers unique pedagogical benefits beyond traditional classroom instruction or external industry partnerships. Campus dining services represent readily accessible learning laboratories where students can apply theoretical knowledge to real operational constraints, including food safety regulations, cost limitations, equipment availability, and consumer acceptability requirements (Caspi et al., 2021). These partnerships bridge the gap between academic food science and foodservice practice, providing students with insight into feasibility

requirements, large-scale production considerations, developing foods for target audiences, and effectively communicating with foodservice professionals (Janhonen & Elkjær, 2022; Malan et al., 2020).

This framework has broader educational implications beyond food science programs. The model of integrating academic coursework with operational campus partners can be adapted for hospitality management, nutrition and dietetics, and culinary programs. By demonstrating how existing campus resources can serve as experiential learning laboratories, this approach offers a replicable model for institutions looking to enhance applied learning opportunities without requiring extensive external partnerships or additional resources. The framework also addresses calls from the food science profession for curricula that develop students' success skills—including communication, teamwork, and problem-solving—alongside technical competencies (IFT, 2011).

FarmUS: a farm-to-campus collaborative was a project funded by the United States Department of Agriculture's Federal State Market Improvement grant. The goal of the project was to allow students to see the connection from field to lab to kitchen to table. Three pillars of the project were to innovate, scale, and connect. The innovation began with students in a senior-level capstone research and development course developing new concepts for students eating in the dining center, then scale-up refinement by undergraduate students majoring in food science and lastly having students consuming new products that contained mostly wheat or sorghum. Grounded in Kolb's experiential learning cycle, this project exemplified how experiencing the complete product development cycle—from initial concept through consumer testing—enables students to gain practical skills that are difficult to develop through classroom instruction alone.

Learning Outcomes

Our project-based case study assessed the impact of a food science/foodservice interdisciplinary product development/undergraduate research experience framework, where food product formulations are created, scaled up, and developed into quantity recipes to be served in the dining centers. We assessed the framework's impact by interviewing and/or surveying students about their experiences while working on this project.

METHODS

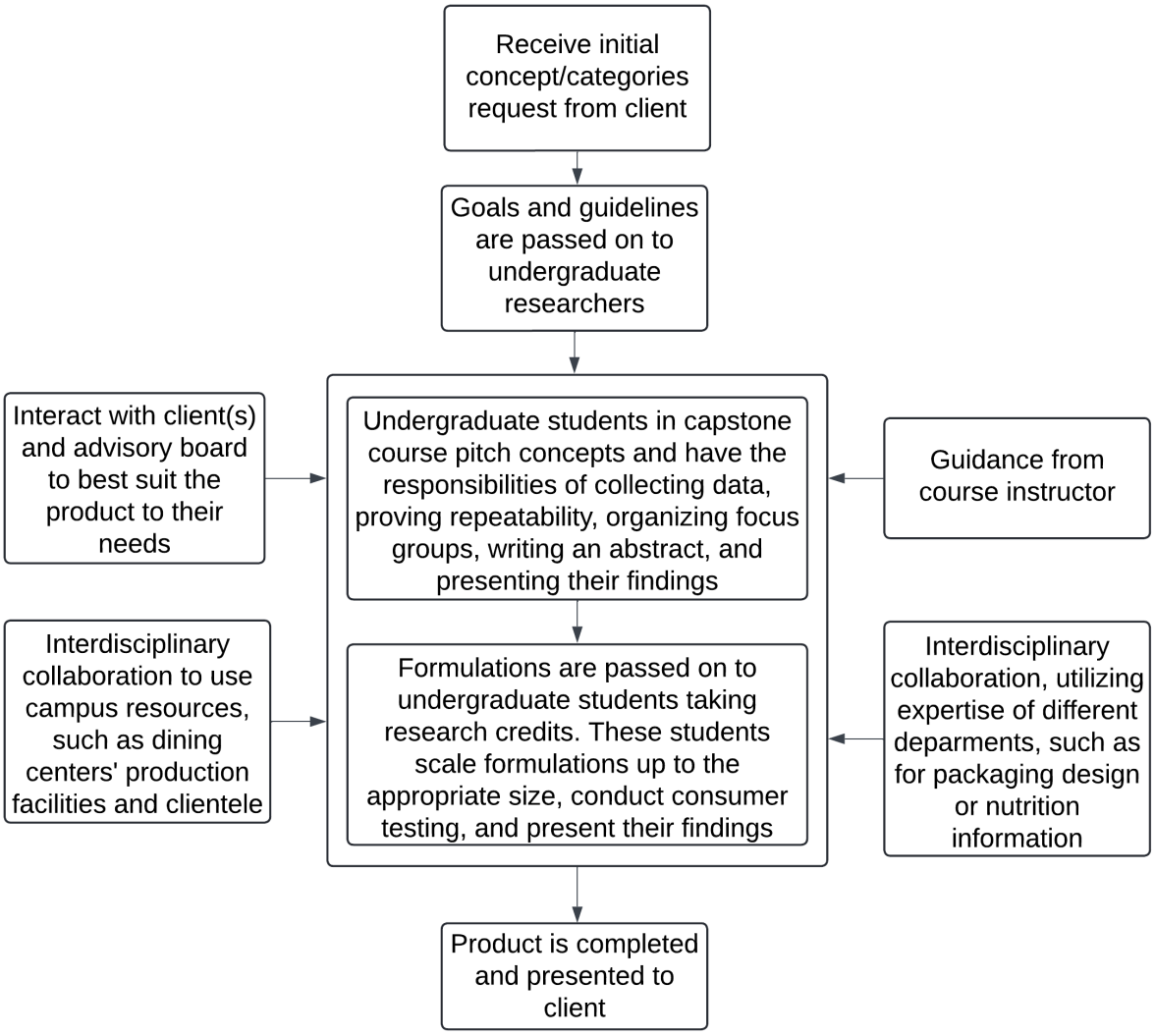
Subject of this Case Study

The Kansas Department of Agriculture (KDA) and the Center for Sorghum Improvement (CSI) sought to increase the consumption of Kansas sorghum and wheat in college students' diets by developing products to be served in campus dining centers. The goal of this project (FarmUS) was to increase students' knowledge of whole grain and gluten-free food product options. To carry out this project, we decided to have "University" food science students in a senior-level capstone research and development of food products course and/or undergraduate research credits develop food products while collaborating with "University" Housing and Dining Services for scaling up those food products.

The FarmUS project was a three-year project that was continued for a fourth year in a slightly different framework. Each year had a different category of sorghum and wheat products, determined by the Center for Sorghum Improvement (CSI), the Kansas Department of Agriculture (KDA), and Dining Center representatives. The three categories were entrées, snacks, and baked goods. For each of these categories, Dining Services was specifically looking for items that could be sold at the recreational complex, on-the-go baked products, par-baked/frozen buns, and "on trend" baked items. As an enhancement of this framework, the 2024 food science senior-level capstone course students worked directly with Dining Services to experience the process of developing products from an initial concept to

a finished scaled-up quantity recipe and conducting a consumer acceptability study within one semester. Students in the undergraduate research course were involved in the course for all four years.

Figure 1. Course Framework (senior-level capstone course in product development and undergraduate research course for further development of products in a dining center).



Framework of Case Study

The goal of the framework was to give undergraduate students an experience similar to product development in industry. Throughout product development, students interacted with the clients and an advisory board to ensure they met the client's needs. They also communicated and collaborated to use additional resources on campus such as dining center production facilities. The framework (Figure 1) includes two parts: a senior-level capstone course in food product development and an undergraduate food science research course.

FarmUS Capstone Course Previous Years (PY)

In the senior-level capstone course in food product development, students were given basic guidelines in the form of categories or concepts from the dining center staff. Students then conducted market screenings and pitched product concepts that fit within those guidelines. The professor and dining center representatives selected the best concepts (determined by feasibility, creativity, and market potential) to move forward to development. Students began to develop formulations during the lab section of the course [either alone or in groups, and either at home (due to COVID) or in a food science lab on campus] and collected data throughout development. The course instructor(s) guided students during the lab period and provided feedback.

There was an additional interdisciplinary project-based learning approach for students to collaborate with undergraduate agricultural and natural resources communications students in a layout and design course. Food science students provided content (product name, photos, net content, nutritional facts panel, ingredient statement and a company name/address) for a packaging label. Undergraduate agricultural communications students enrolled in a layout and design course (AGCOM 345) submitted draft packaging designs that were reviewed by the course instructor and edited. The labels were then provided to the food science students to respond with additional feedback and suggested revisions for students in the layout and design course. This allowed food science students to learn about the creative process and agricultural communications students to learn about labeling requirements while gaining experience in making an appealing packaging design. Students completed a reflective survey on their assessment of working with an undergraduate agricultural communication student. In addition, the capstone instructor graded the final packaging project using a rubric to determine if all required labeling elements were included.

Food science students then organized and conducted a focus group to sample their products. Students prepared a focus summary report that was graded by the instructor using a rubric. Sensory aspects of products were also evaluated by the KDA, CSI consortium, and dining center students and management staff. Once all data was collected, students prepared a final report and presentation in an industry-style format. The final report was written using work from the entire semester and included an executive summary, market screening, project description, a formulation in percentages, description of each ingredient's function, process description (including a process flow diagram and specific equipment to be used), quality and safety parameters, package prototype, regulatory requirements, and a production cost analysis. They also gave a final presentation on their findings. A rubric was also used to evaluate learning outcomes for the final report.

A senior-level capstone course in food product development requires skills and knowledge students have accumulated throughout their degree program. Students used good manufacturing practices and food safety principles as they prepared product prototypes in the laboratory. Students also used their knowledge of physical, chemical, and sensory properties of ingredients to guide them on how to adjust formulations to create a better product. When writing the process flow diagram and calculating the scaled-up formulation, students used the skills they learned in their food processing and process calculations courses. Their knowledge of regulations was used when writing the quality and safety section of the report, which includes creating critical control points. The capstone course gives students the opportunity to combine and apply skills and knowledge learned throughout their degree, which further prepares them for careers in food science. The experience of interdisciplinary work and research in this course prepares them for a typical collaborative industry experience.

Undergraduate Research Credits (UR)

At the end of the capstone course, formulations were passed on to undergraduate students taking food science undergraduate research credits or work experience as a summer internship. In foodservice the

term "recipe" is used instead of "formulation" as in food science. A formulation only lists ingredients and percentages. A recipe includes production details, cooking equipment, garnishing tips, serving sizes, and consumption quality standards. These students then began to scale up the product using larger scale equipment in the dining center. They also collaborated with and received feedback from dining center staff. Throughout the development process, they collected data in the form of pictures, processing steps, yields, and descriptions of the formulations they tested. Once they had satisfactorily achieved the desired flavor profile and scale, they conducted consumer testing (university students and staff) in the form of convenience sampling. For example, they offered samples and a consumer acceptability questionnaire to patrons at the entrance of the dining center during mealtimes. Undergraduate food science research students then analyzed the data collected from consumer testing. Students also input their recipe(s) into the dining center recipe system (Computrition). This system allows for accurate recipe formatting, costing, and nutritional/allergy labeling. Once all data was collected and analyzed, students prepared a 400-word abstract (assessment included organization and completeness, readability and professionalism (grammar, spelling, word choice), and conciseness. They presented an oral poster presentation (3 to 5 minutes) at an undergraduate research symposium. An evaluation rubric for the symposium, which includes assessment for the abstract, poster, and presentation. Presentations were evaluated for students' understanding and communication of project components, as well as ability to answer questions about the project. A mentor survey was used to evaluate student performance.

2024 Capstone Course with Scale-up (TF)

The 2024 senior-level capstone course in food product development was unique from previous semesters due to students' increased interactions with the dining center. Ten students were seniors majoring in food science and one student was a graduate student majoring in grain science. Students toured the dining center. The Registered Dietitian (RDN) who led the recipe development and menu writing process provided students with product concepts (such as a unique meatball product, vegan burger patty, and plant-based breakfast item). Students conducted market screenings based on concepts provided and presented their product pitches to another RDN. The two RDNs (Baogna and Schrader) selected five products for benchtop development. Students were divided into groups (2-3 students) to develop these products. Midway through the semester, RDNs selected two products for scale-up in the dining center using their large-scale equipment. Students were re-divided into two groups to scale up the two products so that all students had the opportunity to use the large-scale equipment. Consumer acceptability testing was conducted in the dining center for all products developed. The 2024 capstone course students also had the opportunity to interact with agricultural communications students to develop labels. They also prepared and presented final reports similar to previous years, but with the addition of quantity-formatted production recipes.

Collaboration with Dining Center

At the beginning of the semester, the dining center staff met with the capstone instructor to determine potential recipe needs within each category. These suggestions were provided to the students to complete a market screening and provide product concepts to the dining center staff. Several concepts (5-6) were selected each semester for the students to begin developing on the benchtop. Throughout the semester, the dining staff evaluated products and provided students' feedback. For the F24 semester, the dining staff encouraged the students to use ingredients only available to the dining center and then selected two products that two groups of 5 or 6 could produce in the dining hall.

For the undergraduate research students, the dining staff and capstone instructor worked directly with the individual student. Products were scaled up in the dining hall and consumer acceptance was also completed in the dining hall.

Assessment of Framework

The proposed framework was assessed using two main metrics: tangible results and student learning outcomes and impact. The tangible results include the products developed, the publications, and the symposium posters and presentations that came from this framework. The student learning outcomes and impact were evaluated using reflective surveys and interviews.

Reflective Assessment of Student Learning Outcomes and Impact

Two surveys and one interview were used to evaluate the framework. The assessment tools and informed consents were reviewed and approved by the "University" Institutional Review Board (IRB approval # 12516). All participants provided informed consent before participating in the reflective survey or interview. The debriefing statement was sent to participants following their participation. A Qualtrics (Provo, UT) survey (Table 1) using a 5-point Likert scale (where 1=strongly disagree and 5=strongly agree) and open-ended questions asking about their overall experience and suggestions for course improvement was developed and distributed to FDSCI 740 students. Reponses were collected anonymously. The question categories were "Research and Laboratory Skills," (RL) "Food Production Knowledge," (FP) "Interdisciplinary Aspects," (IA) "Soft Skills," (S) and "Career Preparedness and Course Experience/Personal Impact" (CP).

Students who took part in the undergraduate food science research course or work experience were interviewed over a recorded Zoom meeting by a third-party interviewer or were offered to type out their responses to the interview questions over email if they preferred not to meet over Zoom. For each of the 33 questions (Table 2), interviewees were asked to respond on the 5-point Likert scale and then elaborate on why they selected that rating. There were also open-ended questions that did not feature a scale.

Students of the 2024 fall capstone course were given a separate survey (Table 3) because they were the only capstone class that worked directly with the dining center. This was also a Qualtrics survey with the same categories as the other survey featuring 5-point Likert scale and open-ended questions. Because extra credit was offered for survey completion, some bias may have been present.

Table 1: Previous Years (PY) Survey Statements and Abbreviations.

Label	Abbreviation	Full Question
Research and Laboratory Skills (RL)		
PY RL Q1	**Scientific Method**	**This product development course/project improved my understanding of the scientific method.**
PY RL Q2	**Scientific/Technical Writing**	**This product development course/project improved my scientific/technical writing skills.**
PY RL Q3	**Collecting Data**	**Collecting data helped me to better understand product development research.**
PY RL Q4	**Data Interpretation**	**This product development course/project improved my data interpretation skills.**
PY RL Q5	**Analytical Equipment**	**This product development project gave me experience using analytical equipment.**
PY RL Q6	**Focus Group**	**This product development course/project taught me how to organize and run a focus group.**
PY RL Q7	**Evaluate Consumer Needs/Wants**	**Organizing and running a focus group helped me to understand how to evaluate consumer needs and wants.**

PY RL Q8	**Improve Product's Sensory Attributes**	**Organizing and running a focus group helped me to improve my product's sensory attributes (flavor, texture, color, etc.).**
PY RL Q9	**Informed Consent Practices**	**This product development course/project taught me about common informed consent practices.**
PY RL Q10	**Allergy Statements**	**This product development course/project taught me about the importance of including allergy statements when conducting consumer testing.**
Food Production Knowledge (FP)		
PY FP Q1	**Dining Center Categories/Guidelines**	**The categories/guidelines provided by the dining center helped me to develop an initial product concept.**
PY FP Q2	**Concept Pitch**	**Putting together a food product concept pitch after doing market screening developed my understanding of market desires and trends.**
PY FP Q3	**Novel Ingredients**	**This product development project gave me the opportunity to work with ingredients I had not previously used.**
PY FP Q4	**Ingredient Functionality**	**Developing a product increased my understanding of ingredient functionality.**
PY FP Q5	**Food Safety and Regulatory Controls**	**This course/project put my knowledge of food safety and regulatory controls into practice.**
PY FP Q6	**Quality Control Parameters**	**This course/project taught me about quality control parameters (such as color and size of product, specifications, grade standards, etc.) for food products.**
PY FP Q7	**Labeling Requirements**	**This course/project increased my understanding of nutritional and ingredient labeling requirements.**
PY FP Q8	**Economic Feasibility**	**This course/project helped me to understand economic feasibility and cost analysis when developing products.**
Interdisciplinary Aspects (IA)		
PY IA Q1	**Packaging Design Perspectives**	**Collaborating with the packaging design class gave me different perspectives on packaging design and layout.**
PY IA Q2	**Different Major's Skill Set**	**Collaborating with the packaging design class taught me about the skill set of a different major.**
PY IA Q3	**Collaboration Elevated Experience**	**Collaborating with the packaging design class elevated my experience in this class.**
PY IA Q4	**Dining Center Perspectives**	**Interacting with the dining center staff and advisory board gave me a different perspective on how to improve my product.**
Soft Skills (S)		
PY S Q1	**Communication**	**Presenting to and interacting with the dining center staff/advisory board provided experience that enhanced my communication skills.**
PY S Q2	**Teamwork**	**Working in a group enhanced my teamwork skills.**
PY S Q3	**Public Speaking**	**Giving a presentation enhanced my public speaking skills.**
PY S Q4	**Problem Solving**	**Facing difficulties while developing my product enhanced my problem-solving skills.**

PY S Q5	**Adaptability**	**Facing difficulties while developing my product enhanced my adaptability skills.**
PY S Q6	**Organization**	**Being responsible for managing, labeling, storing, and requesting more ingredients enhanced my organizational skills.**
Career Preparedness and Course Experience (CP)		
PY CP Q1	**Capstone Course**	**FDSCI 740 connected material I learned throughout my degree program.**
PY CP Q2	**Enjoyed Course**	**I enjoyed this product development course/project.**
PY CP Q3	**Influenced Career Path/Goals**	**My experiences with this course/project influenced my career goals/path.**
PY CP Q4	**Relevant Skills and Knowledge**	**I use/will use the skills and knowledge I learned in this product development course/project in my career.**
PY CP Q5	**Insight into Industrial Product Development**	**This course/project provided me with insight into industrial food product development practices.**
PY CP Q6	**Professional Presentation**	**Preparing and giving a presentation in this product development course/project was a similar experience to presentations I have given/would give in a professional setting.**
PY CP Q7	**Prepared for Career/Grad School**	**My experiences with this product development project prepared me for a career in food science and/or graduate school.**
PY CP Q8	**Similar Experience to Industry**	**The benchtop food product development project in FDSCI 740 is similar to product development in industry.**

Figure 5. Previous Years (PY) Research and Laboratory Skills, for Full Statements (Table 1).

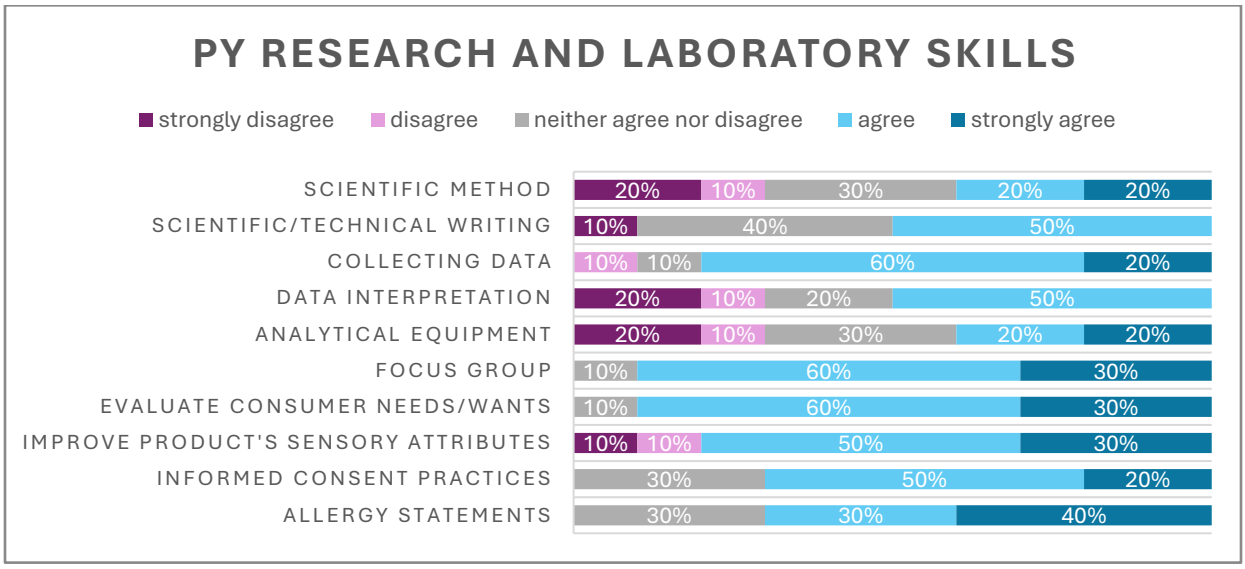


Figure 6. Previous Years (PY) Food Production Knowledge, for Full Statements (Table 1).

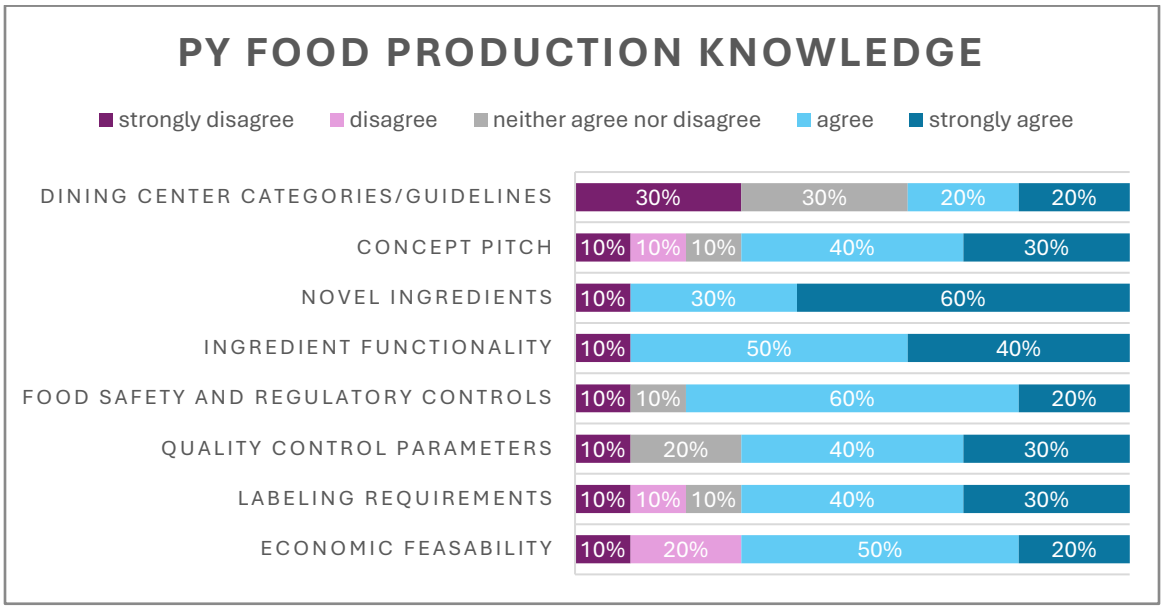


Figure 7. Previous Years (PY) Interdisciplinary Aspects, For Full Statements (Table 1).

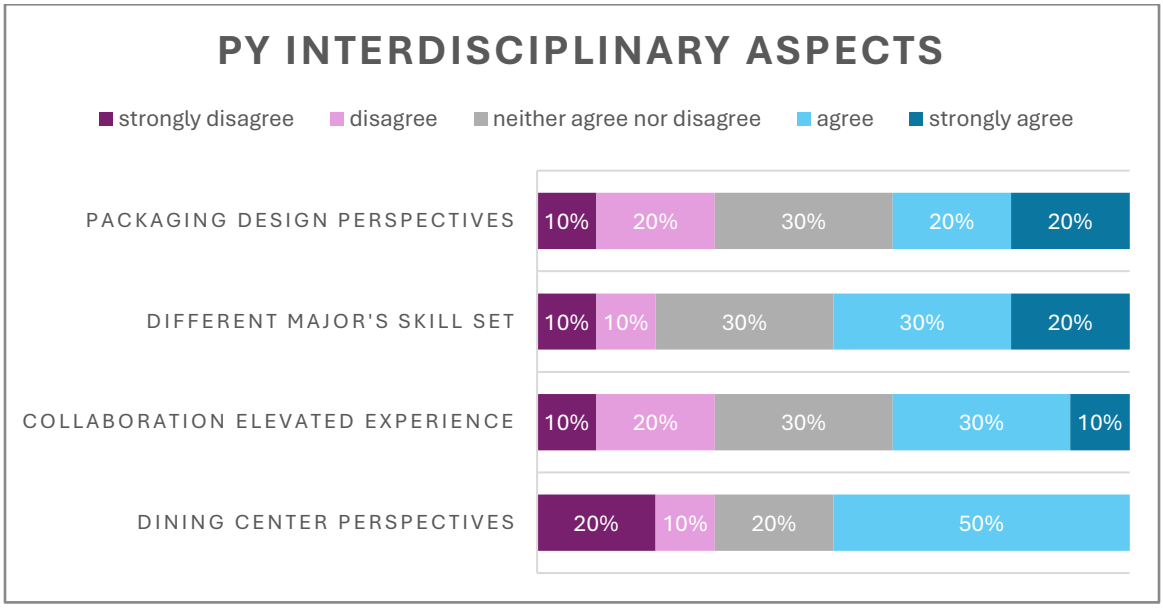


Figure 8. Previous Years (PY) Soft Skills, for Full Statements (Table 1).

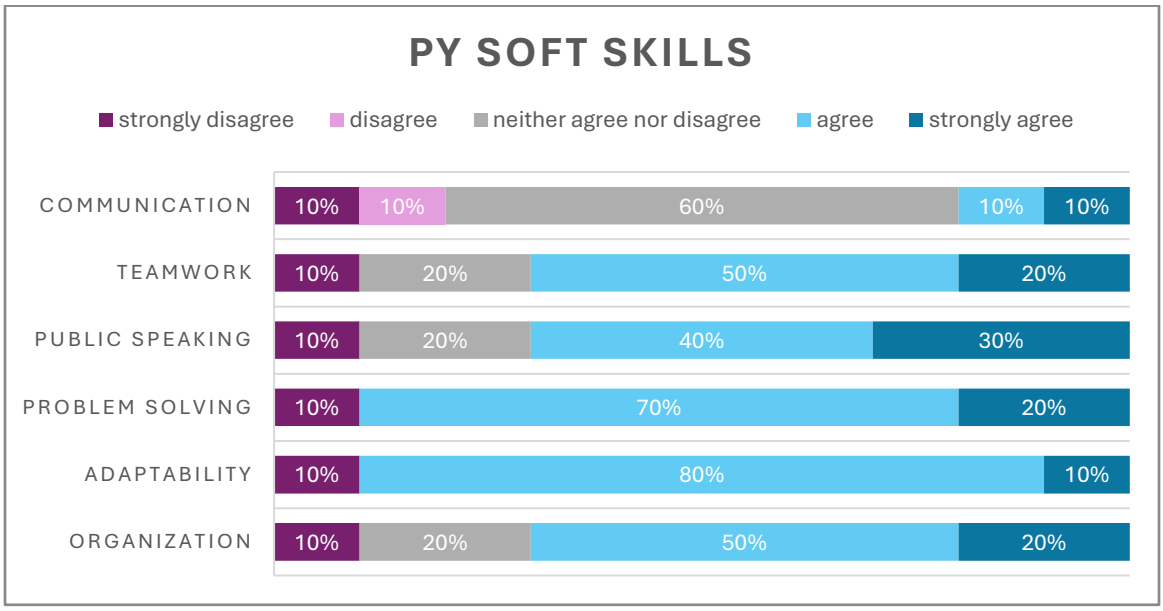


Figure 9. Previous Years (PY) Career Preparedness and Course Experience, for Full Statements (Table 1).

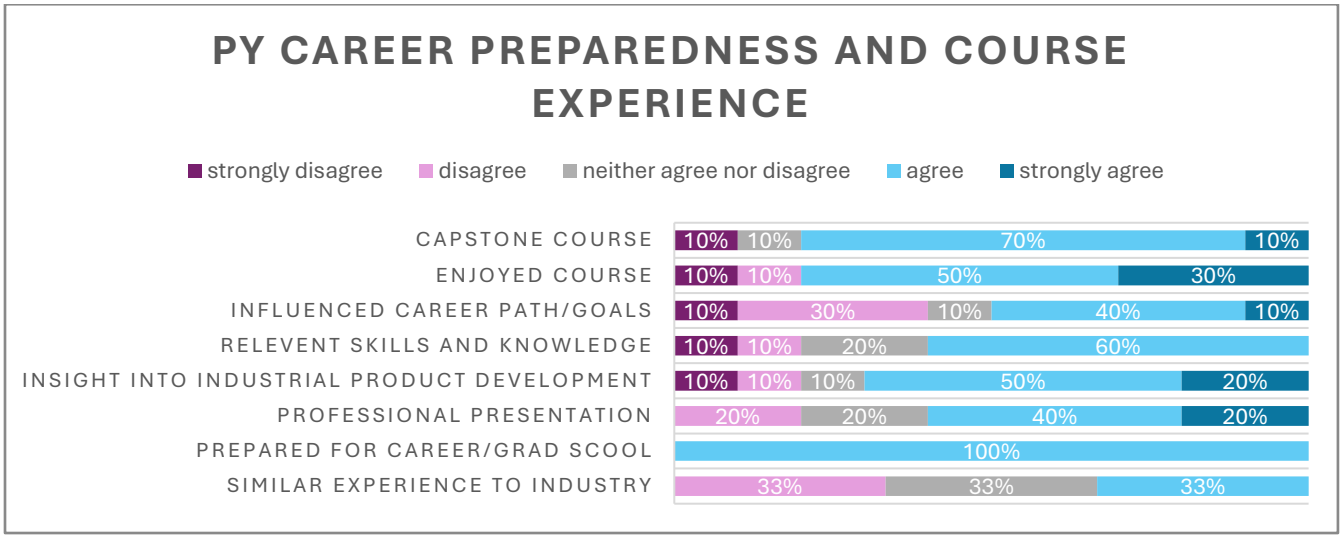


Table 2. Undergraduate Research (UR) Interview Statements and Abbreviations.		
Label	**Abbreviation**	**Full Question**
Research and Laboratory Skills (RL)		
UR RL Q1	**Collecting Data**	**Collecting data helped me to better understand product development research.**

UR RL Q2	**Scientific Method**	**This product development project improved my understanding of the scientific method.**
UR RL Q3	**Scientific/Technical Writing**	**This product development project improved my scientific/technical writing skills.**
UR RL Q4	**Analytical Equipment**	**This product development project gave me experience using analytical equipment.**
UR RL Q5	**Consumer Acceptability Test**	**This product development project taught me how to organize and run a consumer acceptability test.**
UR RL Q6	**Evaluate Consumer Needs/Wants**	**Organizing and running consumer acceptability test(s) helped me to understand how to evaluate consumer needs and wants.**
UR RL Q7	**Improve Product's Sensory Attributes**	**Organizing and running consumer acceptability test(s) helped me to improve my product's sensory attributes.**
UR RL Q8	**Data Interpretation**	**This product development project improved my data interpretation skills.**
UR RL Q9	**Scientific Abstract**	**This product development project enhanced my ability to write a scientific abstract.**
UR RL Q10	**Research Poster**	**This product development project enhanced my ability to put together and present a research poster.**
Food Production Knowledge (FP)		
UR FP Q1	**Larger Scale Food Production**	**Scaling up a product in the dining center increased my understanding of larger scale food production.**
UR FP Q2	**Dining Center Operations**	**This product development project increased my understanding of how dining centers operate.**
UR FP Q3	**Larger Food Production Equipment**	**This product development project gave me the opportunity to experiment with larger food production equipment I had not previously used.**
UR FP Q4	**Writing Processing Methods**	**Using Computrition, gave me experience with writing detailed methods that can be understood by dining center staff.**
UR FP Q5	**Dining Center Goals**	**This product development project increased my understanding of dining center menu goals related to wheat, sorghum, and/or soy products.**
UR FP Q6	**Technical Feasibility**	**This product development project increased my understanding of technical feasibility requirements in food service**
UR FP Q7	**Dining Center Perspectives**	**Working with the dining center staff gave me different perspectives on product development and scale up.**
UR FP Q8	**Impact of Scale on Formulation**	**Scaling up a product gave me insight into how scale-up can affect formulations/recipes.**
UR FP Q9	**Novel Ingredients**	**This product development project gave me the opportunity to work with ingredients I had not previously used.**
UR FP Q10	**Ingredient Functionality**	**Developing a product increased my understanding of ingredient functionality.**
Soft Skills (S)		
UR S Q1	**Public Speaking**	**Giving a presentation improved my public speaking skills.**

UR S Q2	**Communication**	**Working with the dining center staff improved my communication skills.**
UR S Q3	**Problem Solving**	**Facing difficulties, such as unacceptable flavor profile or texture, while developing my product(s) improved my problem-solving skills.**
UR S Q4	**Adaptability**	**Facing difficulties, such as unacceptable flavor profile or texture, while developing my product(s) improved my adaptability skills.**
UR S Q5	**Time management**	**Borrowing kitchen space and equipment from the dining center improved my time management and coordination skills.**
UR S Q6	**Organization**	**Being responsible for managing, labeling, storing, and requesting more ingredients improved my organizational skills.**
Personal Impact (CP)		
UR CP Q1	**Enjoyed Course**	**I enjoyed this product development project.**
UR CP Q2	**Influenced Career Path/Goals**	**My experiences with this product development project influenced my career goals/path.**
UR CP Q3	**Prepared for Career/Grad School**	**My experiences with this product development project better prepared me for a career in food science and/or graduate school.**
UR CP Q4	**Relevant Skills and Knowledge**	**I use/will use the skills and knowledge I learned in this product development project in my career.**
UR CP Q5	**Networking Connections**	**This product development project gave me networking connections**
UR CP Q6	**Work was Published**	**Participating in this product development project led to my work being published.**
UR CP Q7	**Presented Work at Conference**	**Participating in this product development project led to me presenting my work at a conference.**

Figure 10. Undergraduate Research Experience (UR) Research and Laboratory Skills, for Full Statements (Table 2).

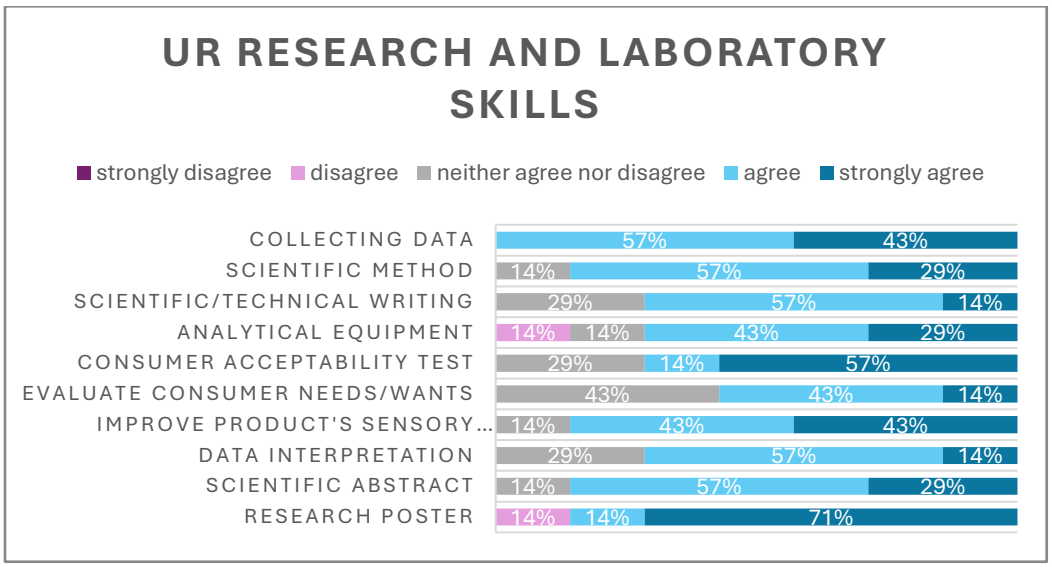


Figure 11. Undergraduate Research Experience (UR) Food Production Knowledge, for Full Statements (Table 2).

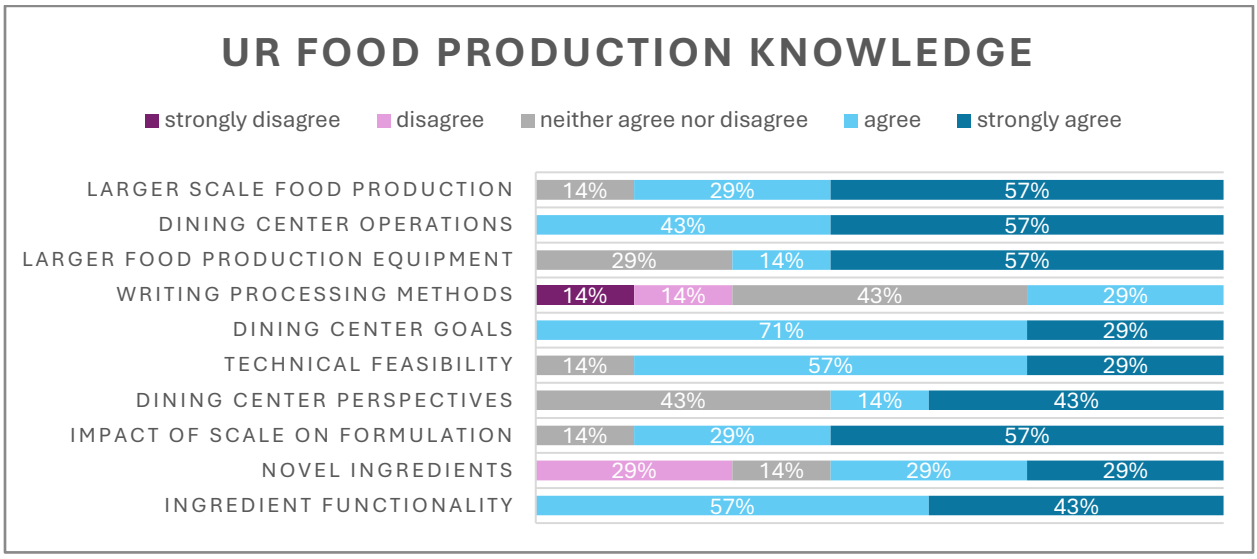


Figure 12. Undergraduate Research Experience (UR) Soft Skills, for Full Statements (Table 2).

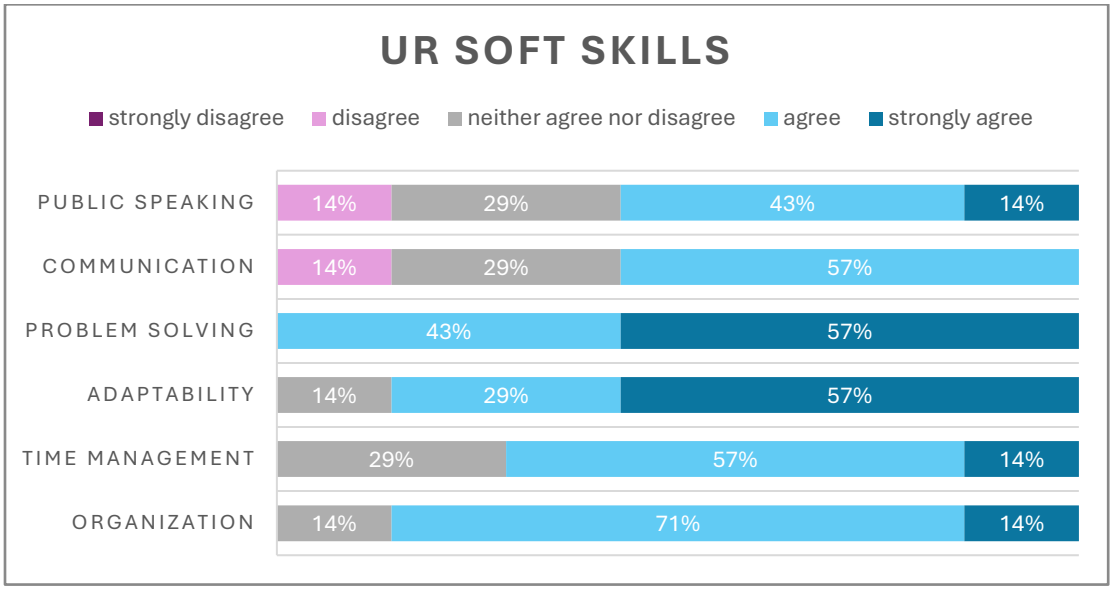


Figure 13. Undergraduate Research Experience (UR) Personal Impact, for Full Statements (Table 2).

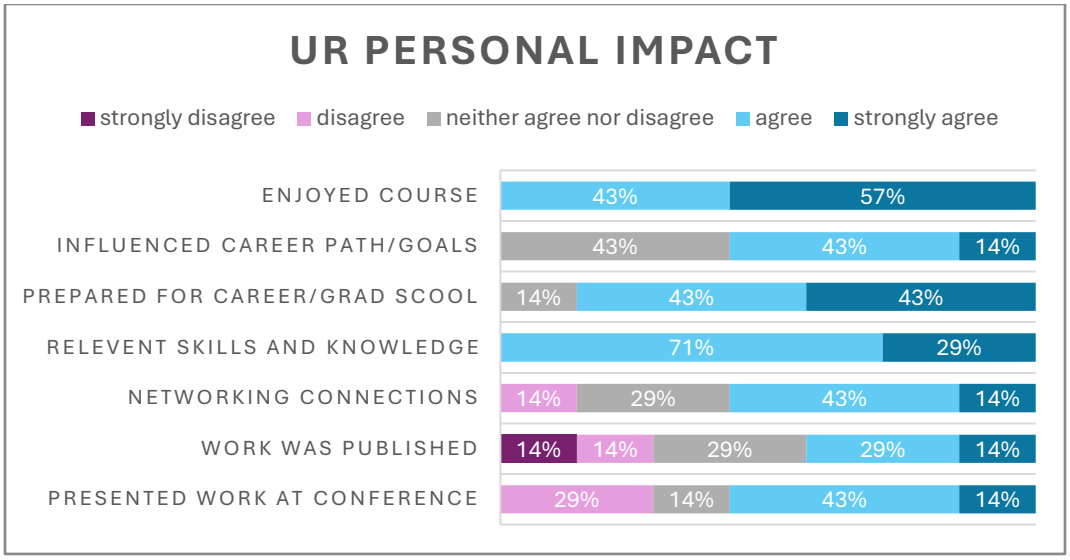


Table 3. 2024 (TF) Survey Statements and Abbreviations.		
Label	**Abbreviation**	**Full Question**
Research and Laboratory Skills (RL)		
TF RL Q1	**Scientific Method**	**This product development project improved my understanding of the scientific method.**
TF RL Q2	**Scientific/Technical Writing**	**This product development project improved my scientific/technical writing skills.**
TF RL Q3	**Collecting Data**	**Collecting data helped me to better understand product development research.**

TF RL Q4	**Data Interpretation**	**This product development project improved my data interpretation skills.**
TF RL Q5	**Analytical Equipment**	**This product development project gave me experience using analytical equipment.**
TF RL Q6	**Consumer Acceptability Test**	**This product development project taught me how to organize and run a consumer acceptability test. (This is referencing the consumer acceptability test you conducted in the dining center.)**
TF RL Q7	**Evaluate Consumer Needs/Wants**	**Organizing and running a consumer acceptability test helped me to understand how to evaluate consumer needs and wants.**
TF RL Q8	**Improve Product's Sensory Attributes**	**Organizing and running consumer acceptability test(s) helped me to improve my product's sensory attributes (flavor, texture, color, etc.).**
TF RL Q9	**Informed Consent Practices**	**This product development project taught me about common informed consent practices.**
TF RL Q10	**Allergy Statements**	**This product development project taught me about the importance of including allergy statements when conducting consumer testing.**
Food Production Knowledge (FP)		
TF FP Q1	**Dining Center Categories/Guidelines**	**The categories/guidelines provided by the dining center helped me to develop an initial product concept.**
TF FP Q2	**Concept Pitch**	**Putting together a food product concept pitch after doing market research developed my understanding of market desires and trends.**
TF FP Q3	**Novel Ingredients**	**This product development project gave me the opportunity to work with ingredients I had not previously used.**
TF FP Q4	**Ingredient Functionality**	**Developing a product increased my understanding of ingredient functionality.**
TF FP Q5	**Technical Feasibility**	**This course increased my understanding of technical feasibility requirements in food service.**
TF FP Q6	**Food Safety and Regulatory Controls**	**This course put my knowledge of food safety and regulatory controls into practice.**
TF FP Q7	**Quality Control Parameters**	**This course taught me about quality control parameters (such as color and size of product, specifications, grade standards, etc.) for food products.**
TF FP Q8	**Labeling Requirements**	**This course increased my understanding of nutritional and ingredient labeling requirements.**
TF FP Q9	**Economic Feasibility**	**This course helped me to understand economic feasibility and cost analysis when developing products.**
TF FP Q10	**Larger Scale Food Production**	**Scaling up a product in the dining center taught me about larger scale food production.**
TF FP Q11	**Impact of Scale on Formulation**	**Scaling up a product gave me insight into how scale-up can affect recipes.**

TF FP Q12	**Benchtop Development to Full Scale**	**Taking my product from an initial concept to a scaled up and ready-to-produce formulation gave me insight into the product development process and how all the steps fit together.**
Interdisciplinary Aspects (IA)		
TF IA Q1	**Packaging Design Perspectives**	**Collaborating with the packaging design class gave me different perspectives on packaging design and layout.**
TF IA Q2	**Dining Center Goals**	**Interacting with the dining center staff helped me to better understand their needs and goals.**
TF IA Q3	**Dining Center Perspectives**	**Working with the dining center staff gave me different perspectives on product development and scale up for food service.**
TF IA Q4	**Dining Center Operations**	**This product development project increased my understanding of how dining centers operate.**
TF IA Q5	**Larger Food Production Equipment**	**Working with the dining center gave me the opportunity to experiment with larger food production equipment I had not previously used.**
Soft Skills (S)		
TF S Q1	**Communication**	**Interacting with the dining center staff provided experience that developed my communication skills.**
TF S Q2	**Teamwork**	**Working in a group improved my teamwork skills.**
TF S Q3	**Public Speaking**	**Giving a presentation improved my public speaking skills.**
TF S Q4	**Problem Solving**	**Facing difficulties while developing my product improved my problem-solving skills.**
TF S Q5	**Adaptability**	**Facing difficulties while developing my product improved my adaptability skills.**
TF S Q6	**Organization**	**Being responsible for managing, labeling, storing, and requesting more ingredients improved my organizational skills.**
TF S Q7	**Time management**	**Collaborating with dining center staff to borrow kitchen space and equipment improved my time management skills.**
Career Preparedness and Course Experience (CP)		
TF CP Q1	**Capstone Course**	**FDSCI 740 connected material I learned throughout my degree program.**
TF CP Q2	**Enjoyed Course**	**I enjoyed this product development project.**
TF CP Q3	**Influenced Career Path/Goals**	**My experiences with this course influenced my career goals/path.**
TF CP Q4	**Relevant Skills and Knowledge**	**I will use the skills and knowledge I learned in this product development project in my career.**
TF CP Q5	**Insight into Industrial Product Development**	**This course provided me with insight into industrial food product development practices.**
TF CP Q6	**Professional Presentation**	**Preparing and giving a presentation in this product development project was a similar experience to presentations I would give in a professional setting.**

TF CP Q7	**Dining Center Equipment Improved Experience**	**Using the dining center equipment improved my experience in learning product development.**

Figure 14. 2024 Capstone Course (TF) Research and Laboratory Skills, for Full Statements (Table 3).

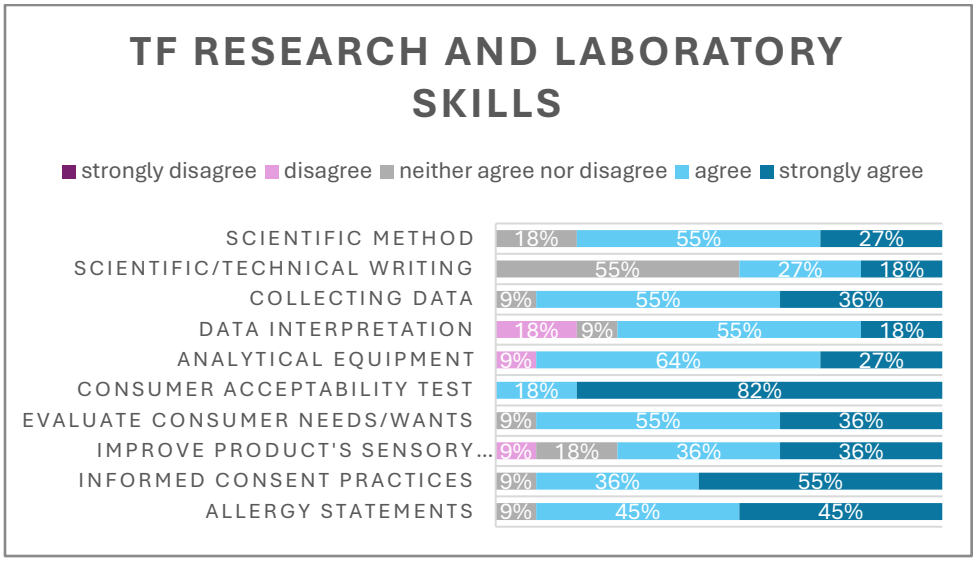


Figure 15. 2024 Capstone Course (TF) Food Production Knowledge, for Full Statements (Table 3).

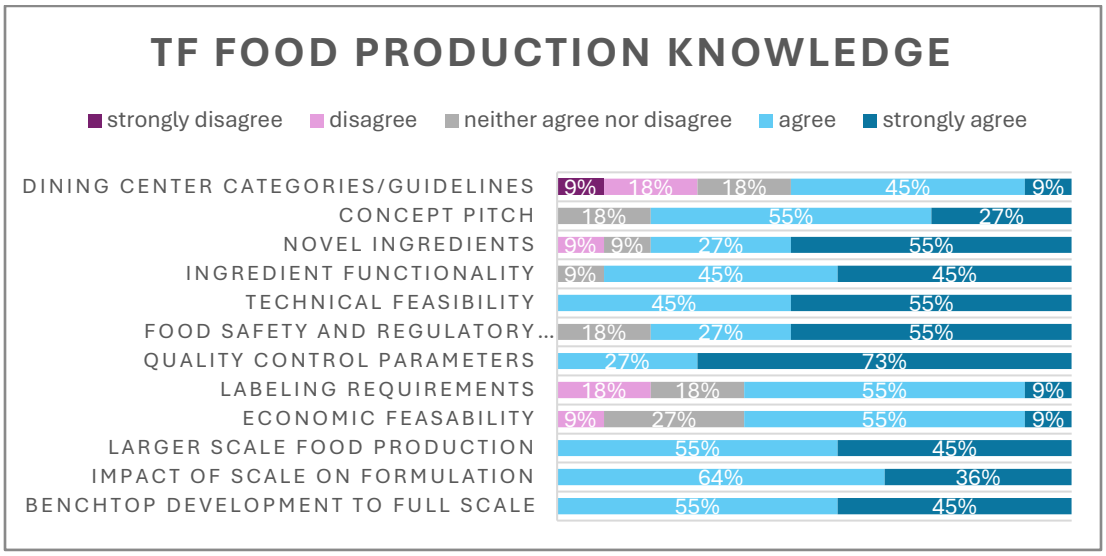


Figure 16. 2024 Capstone Course (TF) Interdisciplinary Aspects, for Full Statements (Table 3).

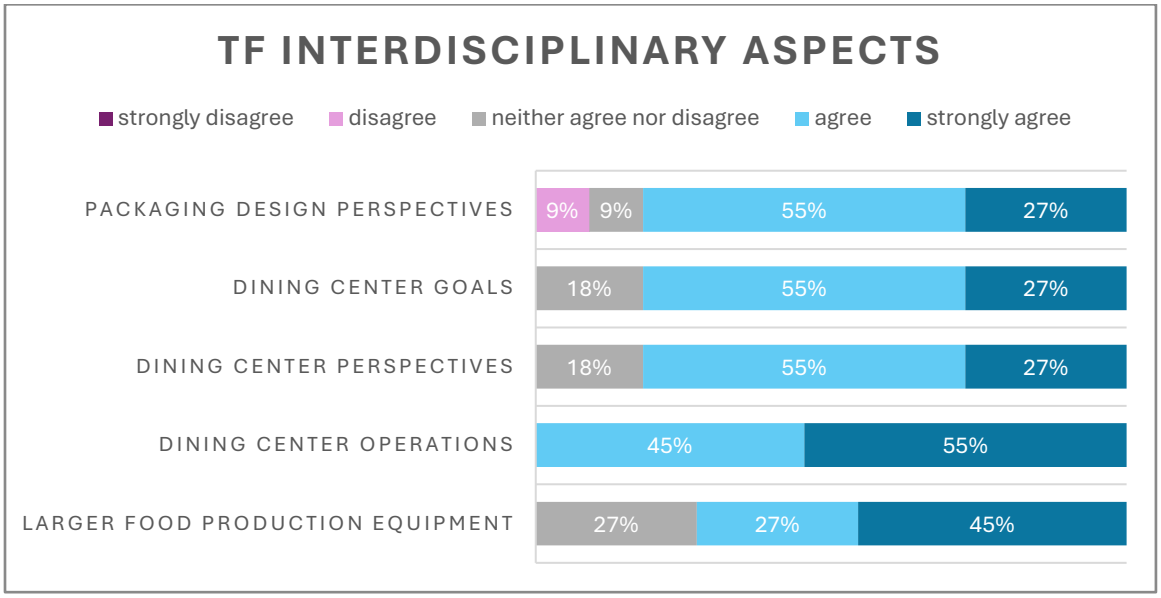


Figure 17. 2024 Capstone Course (TF) Soft Skills, for Full Statements (Table 3).

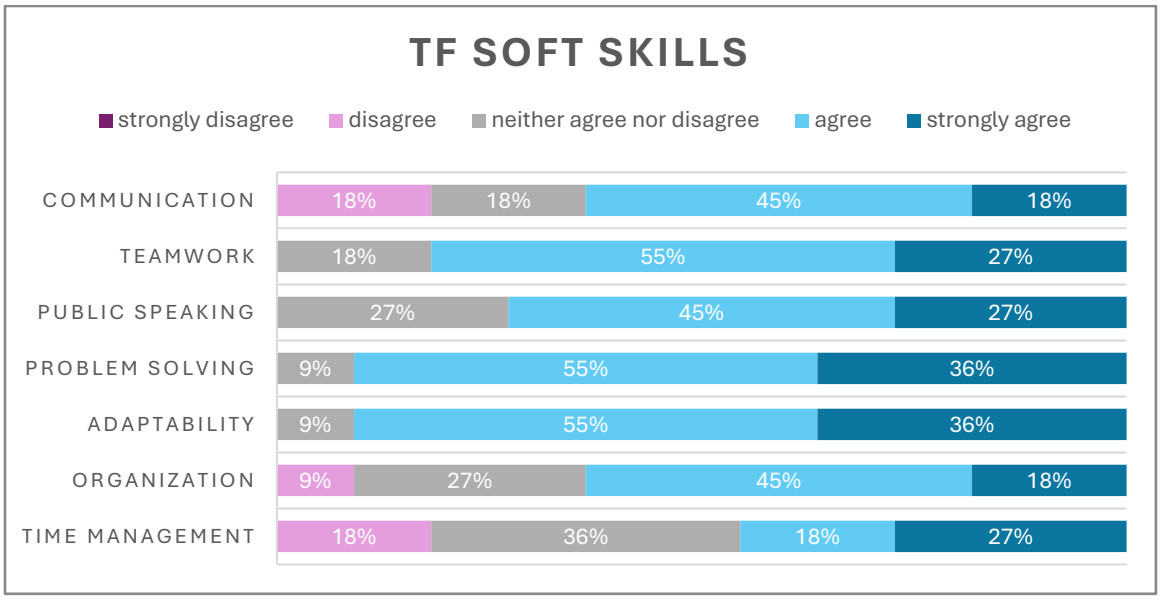
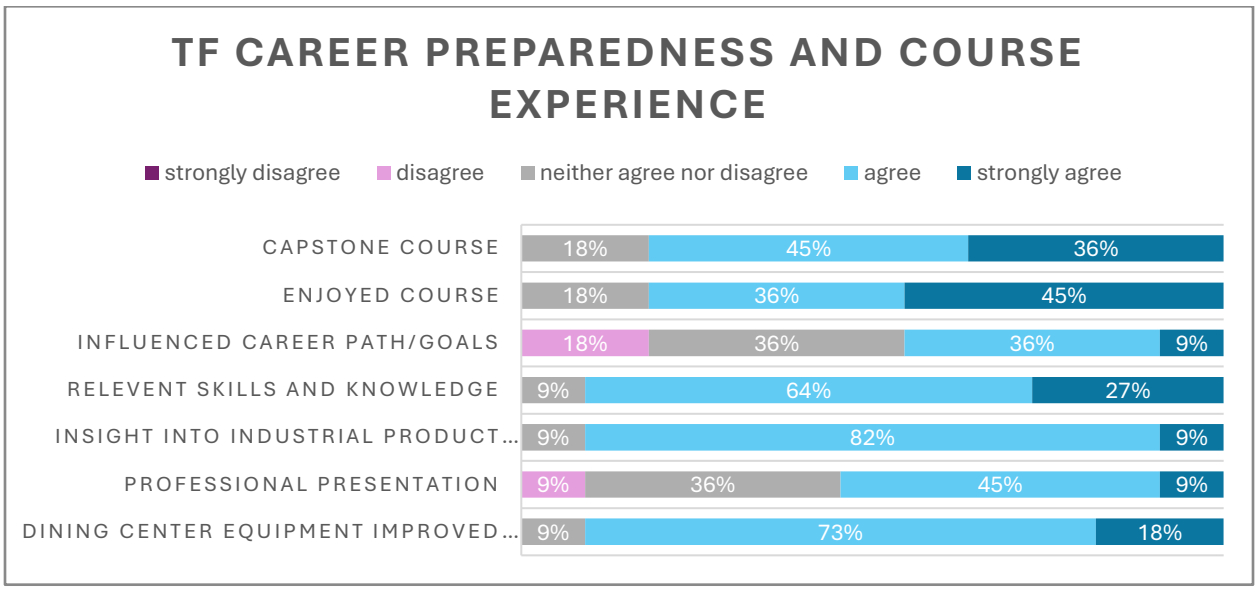


Figure 18. 2024 Capstone Course (TF) Career Preparedness and Course Experience, for Full Statements (Table 3).



RESULTS

Tangible Benefits

Over the three-year implementation period, the framework generated substantial tangible outcomes while demonstrating significant impacts on student learning across multiple domains. The project led to the successful development of 14 formulations/quantity production recipes (Table 4) that are now available in the "University" Dining Services recipe database (Computrition). Many continue to be served in the dining center on a regular basis. This work also led to several publications and presentations.

Publications:

1. FarmUS Recipe Book (was distributed to 40 university and community college dining centers and shared digitally with IFT Conference attendees and dozens of K-12 school foodservice organizations across the state) (example in Figure 2) https://drive.google.com/file/d/1Ilqf0C-RQ3htNh_97-G3Hroez3dGx_W9/view?usp=sharing (Getty & Whitehair, 2022)
2. Development and scale-up of gluten-free sorghum-based bakery goods for K-State Dining Services, DOI: 10.1016/j.jafr.2023.100840 (Cairns et al., 2023)

National Conference Presentations:

1. Formatting a product development capstone course for development of grain-based baked items for use in Kansas State University dining services (Getty et al., 2021)
2. Development and scale-up of the gluten-free sorghum-based bakery goods for K-State dining services (Getty, Whitehair, Brazington, et al., 2022)
3. Creating undergraduate research experiences in product development of grain-based food products for KSU dining halls (Getty, Whitehair, & Jones, 2022)

Figure 2: Tomato Basil Parmesan Sub Bun Recipe from FarmUS Recipe Book (Getty & Whitehair, 2022).

Tomato Basil Parmesan Sub Bun

Wheat-based

Yield: 48 each

Ingredient	Amount	Method
Tomatoes, Sun Dried	0.045 lb.	1. Coarsley chop tomatoes with knive or robot coupe. Hold for step 2.2.
Water Oil, Canola Tomato Paste Sugar, Granulated Salt Cheese, Parmesan, Shredded Basil, Dried Flour, Bread	0.444 lb. 0.090 lb. 0.076 lb. 0.030 lb. 0.015 lb. 0.123 lb. 0.009 lb. 0.787 lb.	2.1. Combine in mixer bowl on low. 2.2. Add chopped tomatoes from step 1 and mix with dough hook to 65 Deg. F on low speed.
Yeast, Instant	0.012 lb.	3.1. Add to mixer bowl, run on medium speed until internal temperature of 78-82 Deg. F. Note: the dough may take some time to reach the desired dough temperature. 3.2. Cover, let rest for 20 minutes. 3.3. Scale into 1.3 lb. rounds. Place 3x4 on greased 18x26x1 inch bun sheets. 3.4. Utilizing sheeter (settings may vary by model) process each 1.3 lb. lump into a 26-inch long loaf. 3.5. Place 3 loaves onto greased 18x26x1 inch bun pan. 3.6. Spray tops with non-stick spray. (You may cover and refrigerate overnight if prepping for a later use). 3.7. Proof until double in bulk. 3.8. Bake at 350 Deg. F (Conventional) for 15-20 minutes or until 200 Deg. F internal temperature.
Margarine, Melted	0.040 lb.	4.1. Brush over hot loaves 4.2. Cut each loaf lenthwise down center leaving hinged on one side. Then cut into six equal lengths.

Undergraduate Food Science Research Course Presentations:

1. Scale-up of Japanese curry buns for K-State dining services (Cairns et al., 2021)
2. Development gluten-free blueberry muffin for K-State dining services (Holmes et al., 2021)
3. Development and scale-up of peanut butter apple muffin (Martin et al., 2021)
4. Development and scale-up of the gluten-free savory breakfast waffle sandwich for K-State dining services (Vavra et al., 2021)
5. Development and scale-up of a gluten-free sorghum sweet potato muffin top for K-State dining services (Brazington et al., 2022)
6. Scale-up of sorghum energy bites for K-State dining services (Salmen et al., 2022)
7. Development and scale-up of a vegetarian lasagna using texturized soy protein for K-State dining services (Honor's Project) (Bhatt et al., 2024).

Table 4. Formulations Developed.

Sorghum	Wheat	Other
Savory Sorghum Waffles	**Tomato Basil Parmesan Sub Buns**	**Pizza Taquitos**
Chocolate Sorghum Cookies	**Peanut Butter Apple Muffin**	**Vegan Breakfast Bowl**
Sorghum Lemon Blueberry Muffin	**Japanese Curry Buns**	**Tofu Pho Bowl**
Sorghum Energy Bites	**Multigrain Sub Bun**	**Vegetarian Texturized Soy Lasagna**
Sweet Potato Breakfast Cookies	**Chocolate Chip Cookies with a Kick**	**Buffalo Chicken Meatballs**

Summer Internship

Three undergraduate students majoring in food science that had just completed their junior year participated in developing products. The three students expressed an interest in the project to the authors (Getty and Whitehair) and projects were selected for them. Formulations (from the senior-level capstone course) that were tested but were not scaled up included a breakfast casserole with wheat, an oat milk shake, vegetable-based crackers, and breakfast biscuit bar. The chocolate sorghum cookies, tomato basil parmesan bun, multi-grain bun, and whole grain chocolate chip cookies with a kick were all successfully scaled up as dining center recipes.

Product Consumer Acceptability and Physiochemical Properties

Examples of data from the project included consumer acceptability scores using a 9-point hedonic scale (1=extremely dislike and 9=extremely like). Physiochemical properties collected included color, volume, moisture loss, water activity, holding time-qualities, and reheat-ability. One goal of "University" Dining Services was to determine if a product could be frozen/refrigerated and reheated while maintaining its qualities to decrease waste and allow for advance food preparation, and on-demand heating. This concept provided another learning opportunity for students in the undergraduate food science research course as they were encouraged to experiment with freezing and reheating processes.

Using a 9-point hedonic scale, the sorghum waffle sandwich received scores of 7 and above for all attributes evaluated (acceptance, flavor, texture, aftertaste, and mouthfeel) (Cairns et al., 2023). The gluten-free muffins received scores of 7 and above in all categories except for texture (6.58) and mouthfeel (6.42) (Cairns et al., 2023). Figure 3 shows the volume of a gluten-free muffin during development (Cairns et al., 2023). Figure 4 was developed to provide a color scale for dining staff to use to determine if color was too light or dark (Cairns et al., 2023). The data collected showed that students were able to develop acceptable, desirable gluten-free products while using analytical methods during their participation in this undergraduate interdisciplinary research framework.

Figure 3. Lemon Blueberry Muffins Without Whipped Egg Whites (a and b) and With Whipped Egg Whites (c and d) (adapted from (Cairns et al. 2023)).

Figure 4. Gluten Free Waffle Color Scale (Light to Dark with Optimum Color Between Waffles 3 and 4) (adapted from Cairns et al. (2023)).

Student Learning Outcomes and Impact

Survey of Previous Capstone Course Years

Forty-one students took the capstone course with this interdisciplinary framework before the 2024 class. These students were mostly seniors majoring in food science. There were a few food science graduate students and a few undergraduate students majoring in baking science. All students were selected to be sent a survey. Survey links were sent to each of these past students with a 24.4% (n=10) response rate.

Responses for the previous year's survey were less positive than the 2024 survey and undergraduate research interviews. The average response percentages of strongly agree and agree responses for each category were 66% (research and laboratory skills), 73% (food production knowledge), 45% (interdisciplinary aspects), 68% (soft skills), and 67% (career preparedness and course experience/personal impact) (Figures 5-9). The previous year's survey was a survey of people who saw this framework in its earlier stages, and the framework's effectiveness increased over time, as evidenced by the more positive responses to the undergraduate research and 2024 surveys. Interdisciplinary aspects having the lowest average show that earlier in the development of the framework, students were not given equal opportunities to interact with dining center staff. This was improved in the 2024 class which observed a response of 84% for interdisciplinary aspects.

Some suggestions that were provided by respondents were to increase communication with the packaging design class, to have shorter homework assignments (and to focus more on product development than homework), and to increase the organization and guidance in the course. One respondent also mentioned that COVID-19 policies that were in place at the time impacted their course experience. There was also a respondent who credited their experiences in this course for helping them to get an internship at Kellogg's.

Interview of Undergraduate Research Course Participants

Of nine undergraduate research participants, seven agreed to be interviewed. The nine students were all food science majors with one student in chemical engineering later switching to food science. Three were sophomores and the remaining students were seniors. The average response percentages of strongly

agree and agree responses for each category were 79% (research and laboratory skills), 77% (food production knowledge), 76% (soft skills), and 71% (career preparedness and course experience/personal impact) (Figures 10-13). All averages were higher than those from the previous year's survey. The undergraduate research interview having a higher soft skill average could be due to the more independent and self-led structure of the undergraduate research class that requires students to develop skills such as time management, organization, and problem solving. This is supported by other feedback undergraduate research students gave. Multiple interviewees also brought up that this project was a great resume-builder that assisted them in obtaining their current job and improved their independent time-management and self-discipline.

Notable Quotes:

Aspects that were liked:

- "This class and the skills I learned from it were…a really great resume builder…I think this is part of the reason why I got my current job…Anything with R&D on it and showing that you almost led a project really looks really good…it shows you have those soft skills: time management, communication, you're able to adapt." - Interviewee 2
- "The time management…that really is something I was able to carry into my current job" - Interviewee 4

Suggestions for Improvement:

- "I would like to have been more organized from the beginning and have been able to have more time to run more trials and have had more time to collect more data." -Interviewee 1
- "I wish I had more opportunities for consumer feedback." - Interviewee 7

Survey of Fall 2024 Class

Eleven students took the senior-level capstone course in food product development in Fall 2024 with a 100% (n=11) response rate. The average response percentages of strongly agree and agree responses for each category were 83% (research and laboratory skills), 85% (food production knowledge), 84% (interdisciplinary aspects), 73% (soft skills), and 77% (career preparedness and course experience/personal impact) (Figures 14-18). The averages for this survey were higher than the undergraduate research interview responses in every category except for soft skills. These higher averages correlate to the framework's improvement over time as it was developed.

Packaging design interactions improved for the 2024 capstone course in comparison to previous years. Examples of packaging designs can be found in Figure 19.

Suggestions from respondents included requests for more structure/guidelines and interactions with dining center staff. This is likely because structure/guidelines were still being developed as 2024 was the first capstone class that worked to scale up their products in the dining center.

Figure 19. Packaging Designs from Fall 2024 Capstone Course (from left to right, designed by: Emerson Tarr, Kassidy Schuman, Kinsley Jordan, and Emma Sutherly).

DISCUSSION

The results demonstrate that this interdisciplinary framework successfully enhanced student learning across multiple domains. Viewed through the lens of Kolb's Experiential Learning Theory, students progressed through each stage of the learning cycle in ways that deepened their understanding of both food science and foodservice operations.

Concrete Experience Stage (CE)

The framework presented substantial, tangible experiences that were above traditional classroom activities. Students utilized real ingredients, commercial-scale equipment, and real operational constraints—experiences that are difficult to simulate in traditional laboratory settings. As one student noted in interviews, "Using the tilt skillet and convection ovens in the dining center made me realize how different large-scale production is from making a single batch in our lab." These authentic experiences created the foundation for meaningful learning by immersing students in the practical realities of food product development.

Reflective Observation Stage (RO)

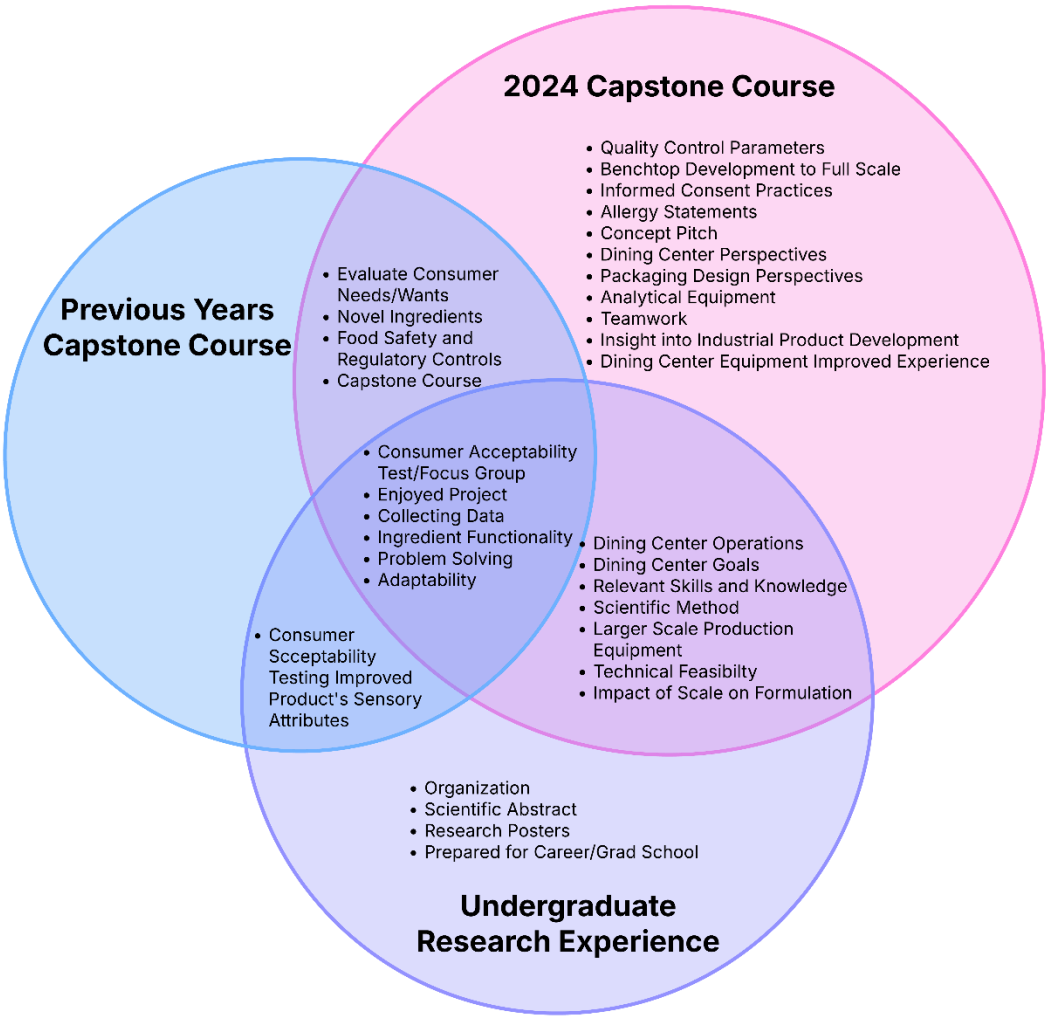
The framework provided possibilities for reflective observation through multiple formulation trials, consumer feedback sessions, and reviews by dining center staff. Students had to think critically about their work and look at it from different points of view. The high ratings students gave for developing problem-solving skills (88% agreed or strongly agreed) suggest they engaged meaningfully in this reflective process.

Abstract Conceptualization Stage (AC)

Students' development of abstract conceptualization was evident in their ability to connect food science principles to practical applications. Survey responses indicated strong agreement (85%) that the experience helped them understand how ingredient functionality affects large-scale production. Students learned to conceptualize solutions based on scientific principles— For example, understanding that an increase in gluten-free sorghum flour required modifications to hydration levels and mixing durations to attain the desired product structure. The combination of theory and practice demonstrates profound understanding rather than basic knowledge.

Active Experimentation Stage (AE)

Figure 20. Benefits that 80% or More Agreed or Strongly Agreed With.



The framework provided numerous opportunities for new product development. Students did not just follow the instructions; they improved the formulations based on what they had learned before and looked at different ingredients, and adjusted processing parameters. The iterative nature of product development—with multiple formulation trials followed by scale-up testing—allowed students to experiment with their evolving understanding. This active testing and refinement of ideas completes the experiential learning cycle and prepares students for the iterative nature of professional product development work.

Beyond Kolb's Framework: Interdisciplinary Learning Benefits

The interdisciplinary aspect of the experience offered supplementary educational advantages beyond those encompassed in Kolb's framework. Students learned a practical comprehension of the operational limitations in foodservice that food scientists must consider when developing products for institutional environments. Student feedback indicates that understanding equipment limitations, labor costs, and production scheduling constraints offers valuable insights that traditional food science coursework often

overlooks. This aligns with research on multi-professional collaboration in food education, demonstrating that the incorporation of varied professional perspectives enhances students' systems thinking and their ability to address complex, real-world challenges (Janhonen & Elkjaer, 2022).

CONCLUSIONS AND APPLICATIONS

Future Use of Course Framework

This case study demonstrates that collaboration between food science programs and campus dining operations can create valuable experiential learning opportunities for undergraduate students. Based on Kolb's Experiential Learning Theory, the framework gave students real-world experiences in product development, organized chances to think about what they had learned, a conceptual understanding of food science principles in real-life situations, and hands-on experimentation with formulations and processes. Student outcomes included enhanced research skills, food production knowledge, understanding of foodservice operations, soft skills development, and increased confidence in their career preparedness.

The course framework has evolved over the years since it was initially implemented. The feedback we received from students throughout each version of the course development has assisted in identifying improved methods and recommendations for future implementation. Consistent benefits identified included improved student problem-solving and adaptability skills, experience with data collection and ingredient functionality, hands-on consumer acceptability testing, and student enjoyment (Figure 20). Dining Services consistently received formulations/quantity recipes throughout the program, providing them with new products without increased labor needs.

Students gained more experience and benefited most from iterations of the program where they worked more closely with the dining center staff (undergraduate research course and the 2024 senior-level capstone course). Students of the 2024 capstone course, who took the product from an initial concept to full scale, received the most hands-on experience (Figure 20).

Moving forward this program would continue to benefit from including both the capstone course and undergraduate research course component. The capstone course would involve students meeting with dining center representatives, touring facilities, learning about available production equipment, and identifying menu goals and expectations. Students would individually conduct market screening research and present product concepts. Based on enrollment and dining center needs, appropriate concepts would be selected to move forward into development. Students would work in groups of 2-3 to develop initial product prototypes. Initial product prototypes would be reviewed by dining center staff and products would be selected for scale-up and recipe formulation in the dining center. Students would be regrouped, allowing everyone to be involved in the scale-up of one of the selected formulations. Scaled-up products would be put forth for consumer acceptability testing in the dining center. Once all data is collected, students will compose industrial-style reports and quantity recipes.

Product concepts that were presented but not selected for further development can be used by an undergraduate research course, dietetic interns, or other courses needing applied recipe development experiences in partnership with the dining center. Each student would be assigned a product, allowing them to be responsible for the time management, project planning, and organization required for scale-up of the product. Guidance would still be provided by the instructor, preceptor, internship director, or mentor, but the project would be more independently run by the student. Dining center staff would still actively engage and provide feedback. These students would have access to large-scale equipment for

scale-up and access to run consumer acceptability tests in the dining center. The data and experience could then be utilized for an abstract, poster presentation, or internship competency report.

In conclusion, this interdisciplinary framework addresses a significant gap in food science education by providing students with authentic, hands-on experience that bridges academic coursework and professional practice. By partnering with existing campus resources, dining services that already prepare thousands of meals daily—institutions can create robust experiential learning opportunities without requiring extensive external partnerships or additional infrastructure. The framework benefits both students, who gain practical skills and confidence, and dining centers, which receive menu innovation and student engagement. As the food industry continues to demand graduates with both technical competencies and professional skills, models like this that integrate experiential learning with interdisciplinary collaboration will become increasingly important in food science education.

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