

Interdisciplinary Capstone Experience for Master's and Doctoral Students in STEM at Kansas State University

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Abstract

Interdisciplinary research training is a critical aspect of the graduate students' experience, and may have an impact on their professional lives. Interdisciplinary research is also important for the United States' economic and technological competitiveness. This paper describes the implementation of a new two-credit interdisciplinary capstone course for teams of graduate students from different STEM disciplines working on interdisciplinary research projects at the nexus of Food, Energy and Water Systems (FEWS), and the experience gained with it. This capstone is required for the Rural Resource Resiliency NSF Research Traineeship (NRT) at our university. The traineeship focuses on engineering and socioeconomic innovations to create resilient food, energy, and water systems in semi-arid regions despite natural resources depletion. The traineeship integrates the disciplines of agriculture, engineering, and social science. In general, students who participated in the NRT capstone have appreciated the opportunity to practice real interdisciplinary work and develop their interdisciplinary communication skills. Capstone course objectives, structure, products, evaluation method and results are discussed.

Introduction

The importance of interdisciplinary training for graduate students has grown to become U.S. policy priority [1] [2]. Responding to that need, the United States National Science Foundation formed a Research Traineeship program, the NRT, to give graduate students in STEM interdisciplinary training and prepare them for the national workforce [3]. The NRT at our university prepares masters and doctoral students to solve the grand challenges at the nexus of FEWS, which are complex and interdependent, and require solutions integrating engineering, natural sciences, and social sciences. Only a small percentage of college students in the United States take an interdisciplinary capstone course [4], and interdisciplinary capstones are more prevalent at the undergraduate level [4]. At the graduate level, capstone courses are limited and varied [5] [6] [7]. Faculty from the colleges of Engineering, Agriculture, and Arts and Sciences at our university developed the NRT Capstone as a new part of the NRT curriculum in the fall 2020 semester. The NRT faculty team tailored the capstone requirements based on the time and resources faculty and students were able to dedicate to the capstone project. The NRT capstone is

a required two credit hour course and its curriculum builds on the knowledge that students gained from a prerequisite interdisciplinary system-thinking course. The first cohort of students completed the capstone in the spring 2021 semester. This cohort had three teams and each team had five or six master's and doctoral students. This paper describes the NRT Capstone course objectives, structure, products, evaluation method and results.

The interdisciplinary author team includes faculty, administration, and staff from the colleges of Engineering, Agriculture, and Arts and Sciences. One member is an external project evaluator. Several author team members have experience in undergraduate capstone courses in engineering, agriculture, and social science, and experience doing interdisciplinary research and working on interdisciplinary teams.

Course Objectives and Structures

Traditional curricula for graduate students often lack the training needed in interdisciplinary research to address current and future global grand challenges. The NRT at our university provides a strong interdisciplinary structure, and trains graduate students to work together on complex problems at the nexus of FEWS. The objectives of the NRT capstone are to train graduate students from different STEM disciplines to plan and implement strategies for solving complex problems; prepare students to work together across disciplinary boundaries; and prepare students to address unfamiliar problems outside their discipline. The NRT Capstone Course is a project-based, cross-listed course that integrates engineering, social sciences, and professional skills needed to work in interdisciplinary groups, with focus on hands on interdisciplinary research. The NRT capstone runs as a mix of lectures and team workdays. Students attended faculty-guided lectures designed to provide training in team communication, team collaboration, research, and final research product preparation. During team workdays, teams worked on their final research product; for all three teams, this was a draft journal manuscript. Course assignments included both individual and group assignments. Literature review, an individual assignment, counted for 20% of the grade. Project outline, a group assignment, counted for 10% of the grade, and the final product, also a group assignment, counted for 35% of the grade. The final presentation, a group assignment, counted for 10% of the grade and peer evaluation, an individual assignment, counted for 10% of the grade.

The Project outline was due in Week 6 so faculty (e.g., two different faculty members mentored each of the NRT teams) could provide teams early feedback on their research project. Students individually wrote a literature review relevant to the interdisciplinary research topic, which was due in Week 10. Faculty from the same discipline as the graduate student were responsible for grading it. For some research projects, the literature reviews were integrated into the final product; for one of the projects, which was itself a literature review, this was more of a challenge. On Weeks 2, 4, 6, 8, 10, 12, and 15, students attended team workdays to develop their final research product. Teams submitted, via Canvas Learning Management System, goals for the workday and following the meeting, submitted teams' accomplishments and any questions for their faculty advisors. Faculty attended some of the student workdays. Teams held workdays either in the classroom, another location on-campus, or virtually on Zoom/Teams. The team's

two faculty mentors graded the final capstone product that was due in Week 15 based on a rubric that assessed overall quality and interdisciplinary expertise. Teams presented their final research products during finals week, week 16. Presentations were 20 minutes with five minutes of questions and answers. Presentations were in person, masked and distanced, with some faculty attending virtually. All faculty graded the team final research product presentations based on a rubric. In addition, students completed peer review in week 15, in which they assessed the work of themselves and their colleagues. An assessment of “1” (weak effort) required a written explanation.

Capstone Course Products

Students selected the team’s NRT capstone research product from the choice board: research paper (conference or journal), research and extension report, NSF or USDA-style research proposal, or a community project. After careful consideration, all teams chose a research paper for their final product, and thus, had to write an interdisciplinary journal article. The team’s final research product followed the formatting and citations requirements for the selected journal, and drew on the interdisciplinary expertise of the entire team. It was expected that teams would complete their research project within one semester; however, only one team was able to complete the manuscript within the semester and published it soon after in *Frontiers in Water*. Another team worked this last academic year on a revised manuscript and submitted it to *Frontiers in Sustainable Food System* this summer. The third team has modified the target publication to a magazine article in the National or regional pork association, which is still in preparation.

Evaluation Method and Results

We surveyed the students about their experiences in the capstone course and got feedback about the team set-up, course content, faculty support, and what students gained. To this end, students completed an end-of-course survey. The NRT external evaluator developed this survey in April and early May 2021 in collaboration with the NRT team. She programmed the survey in Qualtrcis and shared a link to it with the NRT team, who shared the survey link with 16 students via KSU’s Canvas Learning Management System on May 13, 2021, after they completed their final presentations. The survey remained open until May 18, 2021 and fourteen students completed the survey. The NRT external evaluator analyzed both quantitative and qualitative data and then held a collaborative interpretation session with NRT team members involved with the course.

A main theme that emerged from survey feedback was how students valued working in interdisciplinary teams despite challenges, on the final project. Through these experiences, they could practice ‘real’ interdisciplinary work that involved things like ‘relating key variables from each field and discussing how results from different disciplines could be combined to produce an integrated product.’ A key takeaway for students was a new understanding about the value of and strategies for building relationships with teammates [8]. Students’ abilities in several research areas - *write a literature review, produce research products, work in interdisciplinary teams* - improved from ‘somewhat’ able before capstone participation to ‘very able’ after course

participation. As seen in Table 1, students’ greatest reported gain had to do with *working in interdisciplinary teams*. Course activities that student valued most were working with teammates outside their discipline, developing communication skills, and networking. Two challenging aspects of the course were: 1) working effectively with teammates and 2) some students would have liked to work on research topics that more closely related to their academic backgrounds.

Table 1: Gains in students’ research abilities (scale: 5=extremely able; 4=very able; 3=somewhat able; 2=a bit able; 1=not at all able)

Activity	Before participating in the NRT Capstone	After Participating in the NRT Capstone	Gain
Work in interdisciplinary teams	2.9	4	1.1
Produce research products	3.3	3.9	0.6
Write a literature review	3.6	4	0.4

Conclusions

The first cohort completed the NRT Capstone in spring 2021. The course combined theory and practice. The lectures provided students with the knowledge to conduct interdisciplinary research while the workdays provided students a place to practice interdisciplinary research. We are going to continue to learn and seek ways to improve the capstone experience for students. Thus far, we found that interdisciplinary communication skills and aligning team research topics with all students’ academic backgrounds are notable challenges and we expect to encounter in future semesters. We also found that even though the NRT capstone offered sessions about team collaboration, students still faced challenges with team logistics. Therefore, to better support the next cohort, in the spring 2023 NRT capstone course, the NRT faculty will offer more team building activities at the beginning of the semester. In addition, we found that even though the scheduled team workdays were useful, successful teams needed to meet outside of course time. We also found that one semester might not be sufficient to develop and submit a final research product for journal publication, especially if it includes laboratory experiments. Literature review papers and conference papers may be more suited to complete within one semester. Furthermore, team formation is critical to the success of the students. The NRT team formed the capstone teams with student input after considering interest in final products, and student timeline to graduation. It is also important for teams to work on a topic of interest relevant to their research and career goals, but it was challenging aligning team research topics with all students’ academic backgrounds. To this end, the NRT team is examining how to make interdisciplinary research an integral part of the graduate discipline. Finally, co-teaching interdisciplinary curriculum requires

communication and learning by the faculty, and requires them to step out of their teaching comfort zone.

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Dr Rebecca Cors is a scientist and program evaluator who works at the Wisconsin Center for Education Research. For the last 10 years, her work has focused on supporting program managers to study and improve training, education, and outreach programs focused on science and nature learning, and also on environmental sustainability. Before this, Dr. Cors studied and published research about how organizational learning and systems thinking strategies can improve natural resources management. This work was carried out primarily at the Wisconsin Department of Natural Resources and the Institute for Environmental Decisions at ETH Zurich, a contributor to the European Sustainable Phosphorous Platform.

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