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WIP: Designing a program for convergent research in Artificial Intelligence and Agriculture

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WIP: Designing a program for convergent research in Artificial Intelligence and Agriculture

Rapid global population growth and increased human consumption has put unprecedented demand pressure upon agricultural systems [1], [2], [3]. Meeting the challenges posed by weather, disease, and pests to meet this demand requires co-creating solutions across sectors that call upon skills from the domains of engineering, fundamental plant science research, and applied plant biology research through a robust convergence approach. Such an approach requires researchers to engage in boundary-spanning work that overcomes historical disciplinary silos and separation of knowledge, often necessitating the onboarding of advanced skills in metacognition, knowledge integration, and management of interpersonal dynamics. Current student training falls short of providing opportunities for academics to develop these convergence research skills [4], [5].

The National Science Foundation defines convergence as "driven by a specific and compelling problem" and showing "deep integration across disciplines" [6]. To achieve the latter, the fields of Integration and Implementation Sciences (I2S) and Science of Team Science (SciTS) have developed robust methodologies and tools [7], [8], [9]. However, for individuals to effectively integrate knowledge across disciplines, they must be given the opportunity and resources to invest in developing their own convergence capacity [10], [11], [12]. GRAD-AID for Ag, our National Science Foundation National Research Traineeship (NSF-NRT), aims to provide this training in the context of addressing the complex problem of sustainable agriculture through a hands-on, project-based learning approach. PhD students from engineering, bioinformatics, biomath, and plant and soil sciences work in cross-disciplinary teams to apply artificial intelligence and machine learning to plant science research to develop solutions that will increase the sustainability of row crop agriculture. In this paper, we will 1) describe the activities of the first year of this program designed to help students develop convergence research skills and 2) present evaluation data to demonstrate the effectiveness of these activities.

Convergence Training in GRAD-AID for Ag

GRAD-AID for Ag is a 5-year grant where two cohorts will participate in a 2-year training program in which students develop a convergent-translational research project in cross-disciplinary teams. This program was conceived to provide students with the skills and expertise to design and implement these projects. In this section, we describe the first 6 months of this program including how we curated a disciplinarily diverse cohort of students, implemented a 3-week Summer Graduate Bridge Program, and taught a semester-long capstone course.

Student recruitment

Convergence research is complex and time consuming. Its success depends on the ability of the participating researchers to navigate the uncertainty that comes with combining knowledge across disciplines both individually and as a team. This can be particularly challenging for early career researchers who are still developing expertise in their own disciplines [11]. While training and structure in a program such as this NSF-NRT can increase the likelihood of success in a convergent-translational team, students must possess the drive and motivation to overcome

inherent challenges in their work. The leadership team developed a rigorous process for selecting the fellows that evaluated students beyond just their academic success to encompass 1) their motivation and alignment with program goals; 2) perseverance, passion, determination, and resilience; 3) career goals and impact of the program on them; 4) qualitative measure of enthusiasm for the student by the rater. In addition to selecting students from a diversity of disciplines, a mix of current and prospective students was chosen to encourage peer mentorship.

Summer Graduate Bridge Program

GRAD-AID for Ag began with an immersive 3-week summer bridge experience where the nine fellows gained first-hand knowledge of the challenges faced by farmers and industry in the agricultural sector. Field experiences such as this provide opportunities for students to develop a foundation of community and shared knowledge that is key to subsequent brainstorming [13]. Building an intellectual community for effective convergence is essential in supporting strong team function from the beginning of the program [14].

The first week was spent visiting regional biotech companies, including start-ups, single-product focused research firms, and global agribusinesses ("industry week"). In their second week, the fellows visited farms and agricultural extension stations, learning first-hand about the issues facing growers and how they do or do not use data in their decision processes ("on-farm week"). In the final week, students were cross-trained on data analytics tools and basic plant biology ("Camp Converge").

The purpose of industry week was to introduce students to different local businesses that engage in agricultural research or support research with AI tools and allow the trainees to network with the hosts to ask questions and learn more about their businesses, particularly how they may be integrating AI into their research. The agricultural businesses engaged in all aspects of the research pipeline from micro-cap businesses engaging in basic research that are supported by the NC State Plant Sciences Initiative to multinational companies that engage in basic and applied research in multiple lines of business along with product marketing and sales.

The primary objective of on-farm week was to expose students to growers and the issues that they face. In addition, students were introduced to the work of agricultural research stations operated by NC State and the North Carolina Department of Agriculture. The primary activities of the week were to visit several farms in the "blacklands" area of NC, to visit research stations, and the Blackland Farm Managers Tour. There was also a kayaking trip for recreation and teambuilding. Lodging was in a central location for the week which allowed several members of the leadership team and students' advisors to participate with the students in a day or two of activities and share meals.

Camp Converge was a four-day workshop where students learned basic phenotyping using corn leaves collected at a research station during on-farm week and were introduced to several software applications for data analysis. It allowed the engineering and data science students who had no experience in basic biology protocols to learn basic lab skills and all students to learn about AI tools available at NC State and from local companies.

Exploratory Course

Onboarding the cross-disciplinary knowledge as well as the metacognitive and integrative skills that students need to complete a convergent-translational research project requires facilitated skills development [8]. Therefore, following the Summer Graduate Bridge Program, students in the NSF-NRT program enrolled in a semester-long exploratory course where they participated in guided exploration of team formation, disciplinary methods, and convergence research skills. The culmination of this course was a project proposal to address an industry or grower challenge using advanced data analytics and basic and applied plant science research. The students will spend the balance of their two-year fellowship working together on their project, culminating in dissertation chapters for each student. Over the duration of this course, students participated in classroom activities that demonstrate convergence competencies such as shared habits of mind, systems thinking, and interpersonal team skills through a series of guest lectures. Lectures on methods from I2S, SciTS, and Systems Thinking were combined with hands-on brainstorming sessions to develop projects in groups of three (one applied plant scientist, one basic plant scientist, and one data scientist). Additionally, disciplinary knowledge was explored through lectures given by each student's graduate advisor to demonstrate the methods their group uses and the types of research questions they explore.

Assessment and Outcomes

Student Recruitment

The NSF-NRT received 84 applications from 14 basic plant scientists, 29 applied plant scientists, and 41 data scientists. After initial scoring, 25 students were considered for the program. After discussion of each candidate by the leadership team, 3 basic plant scientists, 3 applied plant scientists, and 3 data scientists were selected. It was most difficult to find qualified basic plant science students. The final cohort included eight women and one man in the disciplines of Electrical and Computer engineering (2 students), Biological and Agricultural engineering, Bioinformatics, Biomath, Soil Science, Crop Science, and Genetics (2 students).

Summer Graduate Bridge Program

At this point, the evaluation was exclusively formative. In this evaluation, the evaluator fully participated in the experiences with the trainees as a participant-observer for the on-farm and industry weeks. Participant observation permits the evaluator to understand a program to a degree not possible from second-hand accounts, such as interviews [15, p. 23]. In addition to the evaluator participating in the activities and taking contemporaneous notes, trainees were also asked to respond to short daily surveys about each day’s activities and a longer survey at the end of each week in which they reflected on the full week’s activities. Students were also asked to reflect on the summer bridge experience during a focus group following the capstone course.

Industry week was fast-paced with students being introduced to the project, hearing from a panel of start-up companies, visiting nine local businesses over 3-½ days, and receiving professional development. While the purpose was to learn about how the companies use AI in plant science

research, most visits tended to focus on one or the other, indicating to the students that there are significant gaps that can be addressed with convergent research. Success metrics from this week included whether students reported ending the week with a better understanding of how companies apply (or do not apply) AI to plant science and if they left the week with additional convergence research ideas. Many students reported high levels of success on both of these metrics.

On-farm week afforded the opportunity for the students to see different approaches to farming, from one farmer leasing several hundred acres to family farms up to 8000 acres. These visits were evaluated based on student learning outcomes including 1) understanding the day-to-day challenges farmers face that may or may not be solvable using AI and 2) understanding the current ways that farmers use data to inform their decisions. Students reported ending the week with a better understanding of how different farmers do or do not use data and technology to make decisions about crop selection, fertilizing, weed and pest control, and the like. Students also learned about the interconnectedness of farmers and farming with agriculture-focused businesses such as seed producers and equipment makers. While not directly related to the desired learning outcomes, students learned about issues farmers face such as pests, weeds, fungi, and weather and how the farmers approach maximizing crop yield while minimizing costs. With one exception, the farm visits were instrumental in helping the students to understand the issues faced by farmers – particularly the engineering and data science students who did not have a lot of experience around crops and farming. Additionally, visits to the research stations showed students cutting edge agricultural research and how they partner with both NC State researchers and area farmers to use data to make informed decisions. Students also reported that the dormitory-style accommodations with communal meals during this week allowed them to get to know each other and their interests better, meeting the goal of building community and shared knowledge. Overnight visits from project leadership and the students' advisors allowed the students to get to know them informally and also occasionally provided guided reflection and brainstorming opportunities.

Camp Converge gave the engineering students in particular some basic plant research skills while introducing some AI tools. The students were left wanting more AI information and hands-on activities around using the various tools. The most valuable session was one discussing a particular data analytics tool.

The students were asked to reflect on the value of the summer bridge program following the exploratory course and after the students had selected their projects. The activities of industry week were directly related to one of the three projects while on-farm week informed the design of another project. Overall, the summer bridge was considered to be a valuable experience, particularly the first two weeks. The students were able to get to know each other and their interests and develop relationships which helped them in the process of group formation, but also in getting to know the other members of their cohort well whose expertise they could call on when necessary. The students did not find Camp Converge to be as directly beneficial to the design of their capstone projects. They suggested instead that the time would be better spent visiting the labs of the project team to get a better understanding of the research process.

Exploratory Course

A focus group was held with the trainees in lieu of a normally scheduled class period at the end of the semester. The purpose of the focus group was to 1) gather feedback about the organization and structure of the course; 2) reflect on the value of the Summer Bridge program in light of the experience in the course; and 3) gather feedback on group formation and the project proposal process. The students appreciated the professional development sessions on resumé and cover letter writing and informational interviews. They learned how to write a research proposal, which they found quite challenging. They felt well supported by the course instructor (who is also the project manager) in all aspects of the course and group formation. She was responsive to feedback and provided deadlines and milestones, a brainstorming session, and a collaborative planning contract to make them feel well prepared to work as a team. The process of identifying a project and forming groups was somewhat of a struggle. The students thought that the groups were formed too late in the semester, wishing they had come together in the first couple of weeks rather than halfway through. As they were writing their project proposals, they sought input and feedback from project faculty and their own advisors, which was not always timely, causing one team to go down an unproductive path before being forced to change direction late in the semester. Students suggested that a project mentor be assigned to each team to guide them through the research because none of their individual advisors is able to help with these convergent research projects. At the time of the focus group, the key concern for the students was how they would manage to fit their ultimate projects into their dissertations. This will be an ongoing focus of the evaluation as the students work on the projects.

Conclusions

While the first iteration of the student recruitment process, Summer Graduate Bridge Program, and capstone course proved overall successful, there are a few key areas in which the program will need to improve upon for the next cohort. The disciplinary diversity of the students and their eagerness to engage in the challenging process of convergence research provided a key foundation for the development of novel projects addressing key gaps in sustainable agriculture. This foundation was bolstered by the 3-week intensive Summer Graduate Bridge Program where students developed a shared intellectual space in which they felt comfortable brainstorming nascent research ideas and evaluating their potential contributions. Following this program, the exploratory course provided the structure students needed to develop these ideas into fully realized project proposals.

To facilitate the project development process, the Summer Bridge Program and the capstone course need to be adjusted to allow students more time for brainstorming and disciplinary learning. In future cohorts, student teaming will be explored early on in the exploratory course to build upon the experiences of the Summer Graduate Bridge Program. Additionally, more time will be provided for students to explore alternative team structures to ensure they are able to select the team that most aligns with their interests. This will also give the students ample time to elicit feedback from mentors and more senior researchers early on in the ideation process.

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