Work in Progress on a Case Study of Preparedness in Engineering for Agricultural Start-ups (PEAS)

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I am an engineer who loves to work with people, learn about new ideas and developments in my field, and spend quality time with friends and family. My goal is to inspire the next generation of engineers to be curious, excited, and passionate about engineering and life. In my free time I enjoy playing flag football, crocheting, cooking, and gardening.

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Dr. Perry is an Assistant Professor of Engineering Education in the Department of Civil & Environmental Engineering. His work contains a unique blend of engineering education and civil engineering projects. Dr. Perry's current work centers on understanding how students transfer their knowledge between engineering school and work. This is supplemented by his role in developing assessment techniques for two NSF-funded projects focused on the incorporation of virtual and mixed reality technology into civil engineering education. In addition, his past civil engineering research investigated the behavior of wood shear wall structures under seismic loading conditions. Dr. Perry's expertise in both the engineering education and civil engineering domains provide him with a unique skillset that drives his interests in learning and technical engineering work.

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Introduction

We are now entering a period called the fourth industrial revolution, where the world's growing population is resulting in the need for the agricultural industry to grow and adapt [1]. This revolution is calling for changes and advancement in precision agriculture and smart farming [2]. These needs have helped create the agricultural technology (Ag Tech) industry which either creates or repurposes technology to increase the benefit of agriculture.

As the ag tech industry grows, so do entrepreneurship opportunities. There is room to start new business ventures, build partnerships, and there is a market for innovative products. It is also a place for new business ventures, called start-ups, that are focused on finding a gap in a market and providing innovative solutions to problems [3]. However, for a start-up to succeed, multiple steps need to take place. A problem needs to be identified, research needs to be done and people need to be talked to, a product concept needs to be developed, the product needs to be tested, and customers need to be found [4]. It is during this time, while start-ups are struggling to get funding and solve the problem they have identified, that they also need technical support. To create viable products, technical expertise is needed, and this is where engineers can help.

Engineers are an important part of many start-ups. They provide the technical support and design skills needed to create the product [5]. Engineers are even more important in the Ag Tech industry due to the technology aspect entering a field, agriculture, that has not had many technological components in the past. Both engineers and engineering interns are hired by start-ups to help bring innovative solutions to market. However, even though entrepreneurship has become a topic of interest in academia in general, it is not always a focus in engineering programs. Thus, in order to make sure that undergraduate engineering students that want to work in the Ag Tech start-up industry are prepared, it is important to understand both if industry professionals believe engineering undergraduates are prepared to work in that area, and what academia can do to improve undergraduate engineering student preparedness.

Literature Review

Agriculture Technology

Agriculture is an important part of life in the US and beyond. The need for food is growing as the world population grows, thus calling for advances in technology to meet these needs. By 2050, we will need to produce 70 percent more food than is currently being produced [6]. In the last few decades, there has been a shift in focus from agriculture in general to Ag Tech (the 4th industrial revolution) [4]. Ag Tech "is the development and application of new technology, or application of existing technology from other sectors, to increase the productivity, profitability and sustainability" of agricultural production [1]. Farmers and agricultural supporting industries are looking at how to apply technology to agriculture [1]. These technologies are derived from,

but are not limited to, the fields of biology (e.g. RNAi, gene editing), data/software (e.g. AI, data management), hardware (e.g. robotics) or a combination of these (e.g. satellite-based-GPS controlled autonomous tractors planting GM seeds) [1]. Ag Tech is a growing area of research and development, with both entrepreneurs and investors playing a role in the industry [6].

Entrepreneurship

The concept of entrepreneurship has been around for a long time, bringing with it varied definitions and thoughts on what entrepreneurship entails. In this study, "[e]ntrepreneurship refers to all business ventures, new or old. It includes sole-proprietorship, small businesses, partnerships, firms, and corporations. It can be based on an existing idea or on a new idea" [7]. Hrytsaienko et al. [8] outlines the history of the entrepreneurship and provides a definition for agrarian (agricultural) entrepreneurship:

> Agrarian entrepreneurship is an initiative, independent activity of citizens and their associations, aimed at obtaining income at their own risk and for property liability in within defined organizational and legal forms operating in the agricultural sector of the economy [8, p.428-429].

Entrepreneurship is not a new idea in the agricultural sector, however studies in this area tend to focus primarily on entrepreneurial skills and behavior in developing countries [9]. The research also looks at entrepreneurial programs and their effects on both women and young farmers. Research has also found, however, that entrepreneurship in the agricultural sector can affect economic and rural development with social factors influencing entrepreneurship the most [10]. It should be noted that there is a lack of studies on entrepreneurship in the agricultural industry in the developed world and in the Ag Tech sector.

Start-ups

Even though there is a lack of research on entrepreneurship in the Ag Tech sector, Ag Tech start-ups have grown more than 80 percent each year since 2012 [6]. According to Kulik et al. [11, p.245] worldwide "there are currently more than 150 start-ups in the agrarian sector that have managed to form a large business with capitalization of more than 1 billion dollars."

Start-ups are new business ventures where the entrepreneur takes on risk, comes up with a business plan, and attempts to meet a gap in an industry. Start-ups tend to be created with the plan for them to grow very quickly, solve a problem with an innovative solution, and meet the needs of a wide market [5]. The initial group of people that create a start-up are called a product team. A product team at a start-up, made up of around three to fifteen people, tends to be made up of at least a product manager, a product designer, and a few engineers [5]. This group is needed to begin a start-up, figure out the design of the product, build the product, test the product, improve the product, and work to understand if the product is meeting customer needs.

Jing [5] points out that, though the role of engineers will vary depending on the product, they need to be involved and involved early to help with determining technical constraint, building constraints, and sometimes building the actual product. Roach and Sauermann [12] also state that start-ups rely on engineers to bring products to market and that there is little research on early employees of start-ups (e.g. engineers). While start-ups do struggle to hire talented engineers, engineers do still work at start-ups and sometimes use to take less pay in order to do so. While

there is research on founders of start-ups and what they need to have to enter the industry, there is limited research on what skills and training engineers need to have to work in the start-up industry and no research on engineers in the Ag Tech industry, in particular.

Engineering Education

In the last couple of decades there has been an increase in research on entrepreneurial instruction in education, in general, and in engineering education, specifically. These studies look at topics such as entrepreneurial education, start-ups, and educational incubators in multiple fields including Ag Tech for engineers and non-engineers [13],[14]. Research has also been conducted on how to build a program, or at least a course on entrepreneurship, for engineering students [15]-[18]. Furthermore, there has been research completed on how engineering students understand and feel about and participate in entrepreneurship [19],[20]. Still, the authors found that engineering students did not feel that entrepreneurship was being addressed in their studies, and furthermore, it was not a factor in deciding to go into the field of entrepreneurship.

In a recent study focusing on engineering alumni from an Estonian University, the authors found that entrepreneurship education did not have a significant impact on their entrepreneurial activities, a finding similar to the one above [21]. They also found, however, that even with less education on the topic than other disciplines, engineers were two times more likely than any other discipline to go into entrepreneurship. The authors further concluded that there must be factors, other than their education, causing engineers to go into entrepreneurship.

Work-Readiness/Preparedness

Engineers, as with all graduates, need to have industry specific skills and competencies in order to enter an industry such as Ag Tech start-ups. Prikshat et al. [22] provides a thorough summary of the literature on preparedness for industry. They found that in recent years, there has been a push for ‘work-ready graduates’ that can demonstrate competency in their fields and are able to navigate an ever-changing work environment. Graduate work-readiness, or industry preparedness, is defined differently in every paper on the subject, but for this study, it is defined as the skills or competencies that a graduate must demonstrate to be prepared to work in industry. Prikshat et al. [22] created a theoretical framework based on the study by Finch et al. [23] that posits that graduate work-readiness can be thought of using a ‘resource-based view’ approach. The skills or competencies that a graduate should exhibit make up resources that when balanced can produce a graduate that is prepared for industry. At this point, there is not enough literature on preparedness of graduate engineers, let alone engineers in the Ag Tech start-up space.

Problem Statement

There is a gap in the literature on what skills or competences engineers need to have to work in the Ag Tech start-up industry. This research will help to explore the perceptions of engineers and engineering interns regarding what constitutes preparedness or work-readiness in an industry that where there is both lots of opportunity for grow and historically lacked technological integration.

Theoretical Framework

After researching the topic of graduate readiness and looking at all available scales, Prikshat et al. [22] created a framework to look at graduate work-readiness. The framework is called the Work-Readiness Integrated Competence Model (WRICM). This model is not limited to a specific area of study, but rather encompasses the complexity of work-readiness for all graduates. The model includes four types of resources: intellectual resources, personality resources, meta-skill resources, and job-specific resources. Intellectual resources referred to both foundation skills (reading, writing, and numbers) and cognitive skills (critical thinking, problem-solving, decision-making and strategic thinking). Personality resources include innovation and creativity thinking skills, leadership skills, self-management skills, and the ability to follow through. Meta-skill resources include information technology, teamwork and political skills, communication skills, and system-thinking skills (seeing how things are interconnected and work within different systems). Lastly, job-specific resources refer to the basic skills or proficiencies and the transferable skills required to perform a role in a specific job context. The model also includes 10 competencies that map to the four resources. This WRICM model is used as the theoretical framework of this study and a diagram of the model is shown in Fig. 1. It was used in both the design of the interview protocol and the data analysis processes in this paper.

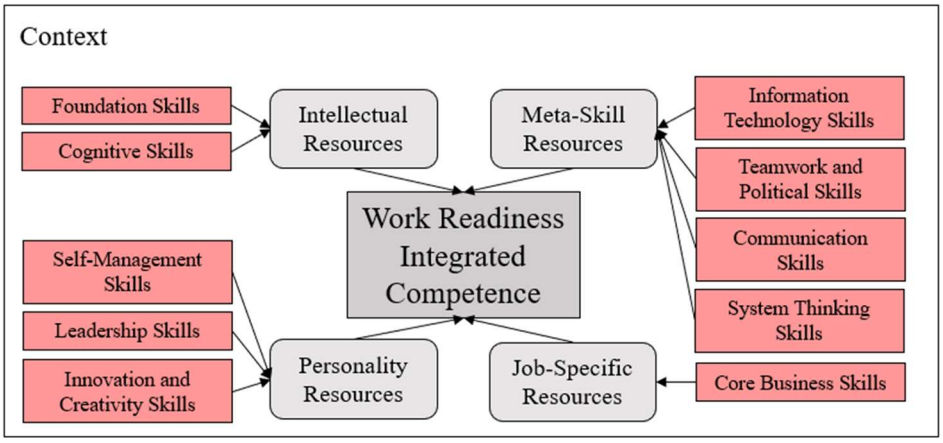

Fig. 1-Work Readiness Integrated Competence Model (WRICM) [22].

Purpose

The purpose of this study is to explore engineers' and engineering interns' perceptions of preparedness to work in agricultural technology start-ups in the Midwest through semi-structured interviews. The following research questions will be addressed:

1. What resources (intellectual, meta-skill, personality, job-specific) are perceived to be important for engineers and engineering interns to have in order to work in the agricultural technology start-up industry?
    a. Which skills are perceived as most important?
    b. Where do engineering students gain these skills from?
    c. Which of these skills are missing in the undergraduate engineering curriculum?

Researcher Positionality/Reflexivity

The first author is an engineer by training. I have both an undergraduate degree in civil engineering and a master's in environmental engineering. I have spent my whole life surrounded by engineers and engineering. I have, however, not spent a significant amount of time in the agricultural sector. These two facts, along with my enjoyment of learning and people, need to be considered during this study. I know that I value engineering and think other people should also, however I need to be objective in the questions I ask. I also know that my lack of experience in the agricultural sector could be a hindrance in this study. However, I have aimed to be reflexive in my work and transparent about my background throughout this study.

Methodology

This case study leveraged a qualitative study design. The case being looked at is bounded by the participants (engineers and engineering interns), industry (Ag Tech start-ups), and location (Midwest US). It was a qualitative study since semi-structured interviews, held over zoom, were used to collect the data. The interview questions were based on the resources listed in the WRICM model. Multiple questions were formed with each resource and the skills connected to it in mind. Participants were also asked about their background, degree programs, and how they would describe their job. Two examples of questions that were asked in the interviews were "What personality traits are needed in this industry?" and "What roles do teamwork and communication play in your job?"

The data from the interviews will be analyzed using thematic analysis using the resources from the theoretical framework as themes. This work-in-progress study will share preliminary results from a portion of the data analyzed.

Preliminary Results and Conclusions

Interviews so far have been with five engineers and engineering interns that work or have worked at different ag-tech start-ups in the Midwest. The ways in which the participants explained their job descriptions varied, though one participant jokingly described the range of their duties by saying it ranges "anywhere from hiring people and helping with fundraising, to taking out the trash can, and mopping the floor." This quote paints a picture of the wide and varied roles that engineers take on within ag-tech start-ups.

Initial findings also point to skills that participants felt that engineers and engineering interns needed in order to succeed in the industry. One participant said, "soft skills, and or the project management, or the business side that I think are critical." "They probably come with a little bit work experience, but I think I think those skills are just as important as technical skills." Another participant mentioned "Personally, I would want them to have a good math background, good software like good understanding of Python and I want them to have some experience with machine learning and then probably some knowledge of agriculture." Another said "I don't know how to describe it, but it's like being able to see a goal, and then figure out what steps you need to do on your own to get to that goal. You know, I think a lot of interns you give like one step to a good task, and they do it, and they and they did a great job. But then, if you have somebody

who can do the next thing and then do the next thing, and then do the next thing, or like, create a plan, and then just do the whole thing." A different participant summarized these ideas in this quote: "we've had interns that have lacked in both interpersonal skills as well as being able to break down a problem and and see it from different angles." Drawing from these quotes and others, participants value experience/background in agriculture, experience in programming, the ability to break down a problem, being able to communicate well, and strong interpersonal skills in their engineers or engineering interns. There are themes of communication, teamwork, and breaking down problems, all of which are classified as meta-skill resources.

When asked about what was missing in their undergraduate education, one participant mentioned the lack of a class on entrepreneurship and communication. Others mentioned that there was an opportunity for them to take more technical classes that would have been helpful, but they were not able to take them before entering the ag-tech industry. These ideas point to the need to share what the ag-tech industry is looking for in their engineers and engineering interns with students earlier in their academic journeys. Participants mentioned that there are tons of opportunities in the industry, however it is hard to find and hire engineers to work for their start-ups. Thus, there is a need to let engineers and engineering students know about the skills that are needed in the field. Overall, the findings of this work-in-progress paper and further research on this topic will provide a better understanding of the Ag-Tech start-up field and provide recommendations to the college of engineering at an R1 institution and beyond to ensure that engineering graduates can be prepared to enter the exciting and growing ag-tech industry upon graduation.

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