

Utilization of an interdisciplinary student design team to develop a modern grain entrapment simulator

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Abstract

Incidents of entrapment in flowable agricultural material (i.e. grain) have been on the rise as a result of increased on site storage of these commoditiesⁱ. Grain entrapments can occur when a victim becomes buried in material beyond the point of self-extricationⁱⁱ. Ohio currently ranks 7th in total number of these agricultural confined space incidents in flowable material, behind the states of Iowa, Indiana, Minnesota, Illinois, Wisconsin, and Nebraskaⁱⁱⁱ. There is no surprise that the frequency of entrapment is highest in the Midwest corn-belt, where a sizeable portion of agricultural commodities are stored.

A long-standing partnership has existed between the Ohio Fire Academy (OFA) and The Ohio State University's Agricultural Safety and Health (OSU ASH) program. Both entities recognized the need for a training unit focused on grain entrapment, but limited resources (i.e. funding, labor) delayed the construction of such a unit for several years.

An interdisciplinary student team was utilized in 2012 to design and fabricate a modern grain entrapment simulator to meet the needs of OFA and OSU ASH. This project served as a trial capstone experience for students enrolled the Agricultural Systems Management (ASM) program within the Department of Food, Agricultural, and Biological Engineering (FABE) at The Ohio State University. This project was conducted prior to a formal capstone course offering in the ASM curriculum. Four senior ASM and one Civil Engineering (CE) student enrolled in individual study credit hours as compensation for their efforts. This project was able to highlight the various strengths of the students to produce a device capable of providing training and awareness education to emergency responders, agricultural producers, and industry professional.

Introduction

The first installment of an Agricultural Systems Management (ASM) capstone design course was scheduled to begin in the 2013 spring semester. Located within the Department of Food, Agricultural, and Biological Engineering (FABE), the ASM program traditionally recruits students from rural communities and large towns with an interest in production agriculture.

A group of four ASM students expressed an interest in completing a capstone type experience during autumn 2011. These students came from various backgrounds and collectively had experience working on farms, experience with volunteer fire departments, connections to the grain industry, and strong fabrication skills. The grain entrapment simulator appeared to be a perfect match for students with these skill sets. An obvious void of this preliminary student team was extensive computer design knowledge.

Engineering instructors who work with student teams have likely encountered the "let's just build it" team during their career. To provide a structured approach to the design portion of

the project, a fifth student with extensive computer design knowledge was recruited to be part of the design team. This student was a Civil Engineering (CE) major with similar skill sets and interests to the ASM students. It should be noted that this student was chosen by convenience, as he was a student worker in the FABE department. Choosing a student with similar background experience and a supporting knowledge set (e.g. computer design skills) contributed greatly to team cohesiveness and ultimately the success of the project.

The workload set forth by the academic team for the students began with an existing 40-foot long semi-trailer and tasks were to complete the following; determine arrangement of grain handling components, design specific components such as a folding mechanism for the 20-foot high grain leg, install a safe walking-working surface around the components, fabrication, and installation of components with safety and function at the forefront.

Capstone Course Process

Offering a senior capstone course is not a novel concept in most disciplines. Senior-level capstone courses have been implemented in an effort to bring the practical side of engineering design into engineer-related curricula^{iv}. A set of pedagogical guidelines proposed by Breen and Durfee served as a tool for designing the Agricultural Systems Management (ASM) capstone experience described in this document^v. The three main pillars of facilitating a successful interdisciplinary capstone, as presented by Breen and Durfee are;

1. Expectations must be clear: Students that are unclear of the requirements face a major impediment to their success.

2. Workload must be reasonable: Depending on the duration of the course(s), tasks and deliverables should be consistent with the allotted time.

3. Students should have a choice in how tasks will be accomplished: As described later in this document, students with a desire to see a project through to completion are the most valuable stakeholders.

During the first face-to-face meeting between students and academic advisors, a communication protocol was established for efficient transfer of information. Over the course of a 10-week quarter¹ beginning in January 2012, the five-member student team met with their academic advisors on a weekly basis to discuss design of the training unit, potential features and functions, methods for communicating with industry partners (i.e. sponsors), and scheduling a face-to-face meeting with industry representatives. The communication protocol consisted of open communication among the student team members throughout the week, identification of individual leaders for specific tasks, email communication with academic advisors, and guidelines for communicating with the industry partners. Once it was determined which components could be available through the industry donors, a sketch of component configuration was created. Figure 1 below shows this rough sketch that served as the first effort for the students to organize their design ideas on paper.

¹ The Ohio State University transitioned from 10-week quarter terms to 14-week semester terms, effective August 2012. The trial ASM capstone project described in this document was conducted over two 10-week quarters, where as students have enrolled in one 14-week semester for the ASM capstone course offered spring 2013.

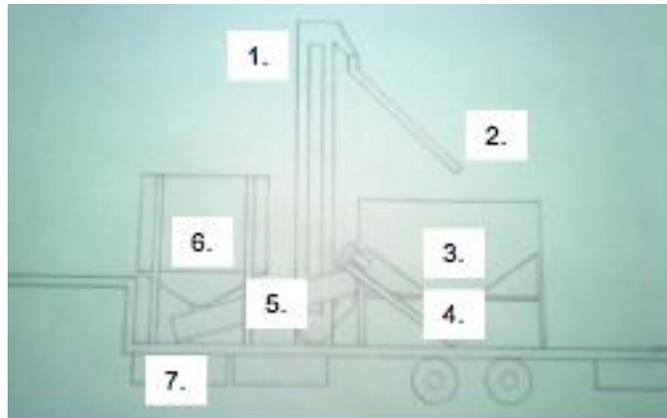


Figure 1. Hand-Drawing of Component Placement on Trailer

Utilizing Fig. 1, a written description of component placement, and verbal communication from the other team members, the Civil Engineering team member created a computer rendition using SolidWorks software, that is shown in Figure 2.

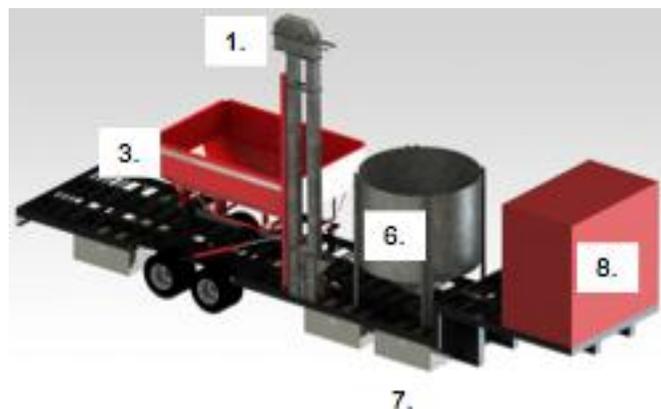


Figure 2. SolidWorks Model of Component Placement on Trailer

Description of Components

The following is a brief description of the components shown in Fig. 1 and Fig. 2 including each component's function and rated capacity.

1. Grain Leg (Elevator): Designed to elevate the grain, allowing it to free flow into storage vessel. Rated at 950 bushel per hour (BPH) maximum capacity; reduced to approximately 640 BPH (33% reduction) in an effort to reduce dust emissions.
2. Grain Discharge Shute: Allows grain to be directed into either storage vessel.
3. Gravity Storage Box: Common agricultural grain storage vessel designed to transport grain from harvester in the field either directly to storage or to a larger transport vessel (i.e. tractor trailer or truck). The capacity of this vessel is 190 bushel, and common on farm gravity boxes (i.e. grain wagon, grain cart) can be as large as 2,000 bushel.
4. 4-inch (diameter) Transfer Auger: Used to transfer grain from the gravity box to the grain leg, which can either be reclaimed into the gravity box or transferred to the grain bin. Powered by a 1 horsepower motor, maximum capacity is 450 BPH.

5. 10-inch (diameter) Drag Chain Conveyor: Poly paddles are pulled across the flat bottom of the internal housing and ‘drags’ grain towards the grain leg. This component was NOT installed due to the time required to manufacture a specialized conveyor of this small scale. A 6-inch transfer auger was installed in its place.
6. Hopper Bottom Grain Bin: Grain storage vessel that allows for easy cleanout when emptying the vessel. The capacity of this vessel is approximately 200 bushel, and common on farm grain bins range from 3,000 to over 100,000 bushel capacity.
7. Chrome Tool Storage Boxes: Based on feedback from OFA (fire service members), provisions for six storage boxes were included in the design of the unit.
8. Custom Storage Box: This 8-foot wide, 7-foot tall, by 4-foot deep storage container was built to store items too large for the chrome tool storage boxes.

Once the tentative design plan and SolidWorks model was solidified, a meeting was held with industry representatives during February 2012. The feedback received from the industry partners was then incorporated in to the design plans. This meeting included partners from grain handling cooperatives, equipment manufacturers, academia, and the fire service. A consensus building approach was utilized to gather feedback, synthesis the information, and incorporate changes into the design. The student team then spent the next 6-months fabricating the training unit.

Team Dynamics and Managing Conflict

As noted in the literature, teams that function cohesively tend to work more efficiently and produce a quality end product^{vi}. While this is an easy goal to set at the beginning of a project, the reality is that conflict is inevitable. A unique dynamic of this student team was that each student knew each other on a personal level. The advantage of this team aspect included informal dialogue on a regular basis within the student group. Members had an understanding of each others strengths and weaknesses before the project even began. One disadvantage that was observed through the course of the project consisted of members getting easily frustrated with one another. Issues that might normally be concealed among team members, who are not close acquaintances, come to fruition more quickly among groups that are close on a personal level. Even through some slight adversity, students were able to handle themselves professionally and gain valuable conflict mitigation skills through the difficulties experienced with this project.

Stakeholder Input

The success of a project begins with a group of motivated stakeholders who understand the scope of the project and have the desire to see it through to completion^{vii}. While all stakeholders must communicate to ‘stay on the same page’, the student team provided the initial motivation and labor force needed to start the project in a positive direction. It is worth noting that the student team members were not required to complete a capstone course, but enrolled in an individual study course to engage in this project. Personal accountability was crucial since there were no formal assessment tools used in the evaluation of student achievement. The desire to ‘leave their mark’ by representing their academic institution through creation of a safety tool to be used for training and educational awareness served as enough motivation for students to complete the project.

Incorporation of industry professionals on an advisory team provided a valuable perspective regarding commerce and contributed balance to the academic team. In addition to regular verbal communication with the students and periodic input provided at the weekly meetings, a face-to-face meeting was scheduled early into the project. The purpose of this face-to-face meeting was to build consensus among industry partners, students, and academic advisors. The student team used a feedback form in an effort to quantify certain aspects of discussion. Items were presented to the industry professionals using a five point Likert scale. Examples of select data captured from the professionals are presented in Table 1.

Table 1. Examples of Feedback Received from Industry Advisory Team Members (n=9)

Item Description	Median Score*	Comments (Quantity)
1. The current design of the trailer will work well	5	Initial design is a great start
2. The 7-foot bin should be flat bottom (instead of 45° hopper)	2	30° (2), 45° (2)
3. The auger used to transfer grain from the gravity wagon to the grain leg should be 4-inch (diameter)	5	[Specific company] can donate if needed
5. Catwalk is only needed around TWO sides of the bin and gravity wagon	3	Around all sides (2), This is yet to be determined
9. The trailer decking [material] should be expanded metal (instead of wood)	4	Diamond plate on deck (2), Steel non-skid for safety (2)

*Median score of 5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree, 1=Strongly Disagree

Following a general interdisciplinary team approach described by Kansas State University, the establishment of a faculty/staff team also proved vital to the success of the project^{viii}. The faculty and staff team included the academic department administrator (e.g. department chair). The leadership and engineering knowledge of the department chair supported the skill sets of the remaining academic team.

Student Feedback

An online survey tool was implemented to capture feedback from the student team, six months after the completion of the project. Items were presented to the students using a four point Likert scale. Available space was given following each item, in an effort to gather detailed insight the students had regarding any particular items. A summary of the data captured from all five-student members is presented in Table 2.

Table 2. Six-Month Post-Project Feedback Received from Student Team Members (n=5)

Item Description	Median Score*	Abbreviated Comments
1. This project was a good application of skills I learned thru internships and personal experiences.	4	N/A
2. This project was a good use of skills I learned in my major area of study [at college].	3	N/A
3. This capstone project was a positive conclusion to my collegiate career.	3	I would not have done any other capstone project.
4. The face-to-face meeting with industry partners was a good learning experience.	4	N/A
5. Leading up to the face-to-face meeting..., our student team was forced to research details of the project that we might have otherwise left out.	3	[Investors] don't want to invest in a project when the team [is not prepared].
6. Working with stakeholders was often frustrating.	4	You're not going to [please everyone], but you need to take their ideas into consideration.
7. Despite any frustrations, the experience of communicating with stakeholders allowed me to gain skills that I use in my current career.	3	When it came to communication, I was always nervous, but now I do it on a daily basis.
8. The ability to work as a team and manage conflict was a valuable learning experience.	3	Learning to [work through conflict] in a professional manner was very valuable.
9. Having a student with computer design skills was extremely valuable to the success of our team.	4	We would not have been able to do half [of what we wanted] without the computer design [student].
10. The use of an interdisciplinary team (i.e. ASM and Engineering) would allow for integration of different skill sets to create a good capstone experience.	4	[Will] depend on the [individual] students.
Other General Comments: I feel as though I gained [knowledge] through this project that I might not have otherwise done in my college career. The earlier these projects get started, the more organized they will be. Overall, this is probably a [more complex] project than [most students] might attempt. Groups should be formed the spring semester before summer break, before their senior year.		

*Median score of 4=Strongly Agree, 3=Agree, 2=Disagree, 1=Strongly Disagree

A good range of data was observed in 60% of the items, where responses ranged from a low of 1 (strongly disagree) to 4 (strongly agree) on the Likert-scale. The students unanimously agreed on the value of the stakeholder meeting (item 4), working with stakeholders could prove difficult (item 6), and that the use of an interdisciplinary team could allow for a good capstone experience (item 10).

Conclusion

Based on this experience, the consensus building process will be recommended to future capstone course instructors, if it is feasible within the scope of the project. The process, and difficulties that came with building consensus to create an end product had a positive impact on the student's experience. The frustration experienced by students during negotiations and the necessity to compromise provided effective real-world experience that will enhance the student's capabilities to deal with stressful situations during their professional careers. As noted in Table 2, a student indicated that communicating with stakeholders was difficult, often building anxiety and making the student nervous. However, that same student also signified that this type of communication with superiors occurs on a daily basis.

This capstone experience taught the academic advisors that having a specific end goal in mind is advantageous, but a concise project with realistic deliverables is crucial. Most academic advisors will have many other responsibilities, and need to assist the students with setting realistic goals, on a reasonable timeline in an effort to avoid setting the students up for failure.

The authors of this document acknowledge that reviewing literature and researching capstone projects implemented by other academic programs and institutions can provide insight into the scope and difficulty of high caliber capstone projects. The project timeline for this project consisted of a proposed 6-month frame (January thru June), but aspects such as project design, coordination with component manufacturers, and fabrication added 3-months to the project completion date. The student team members prolonged starting their new professions for one month to continue work on the project. One additional student team member provided the last two months of fabrication and installation to finalize the project.

A project of this magnitude was a significant undertaking for a capstone course, and the authors realize this scale of project may not be feasible for most programs. The scope of this project included design, coordination with industry partners, fabrication, and installation of components on a 40-foot semi-trailer, and proved unrealistic in the allotted time frame. The dedication and follow-through of the student team eventually lead to the final product. Without establishing a protocol for concise and open communication and dedication of the student leaders, the project would not have reached completion. The mutual respect among students and advisors contributed to the cooperation of all parties and ultimately the success of the entire team. The Grain Comprehensive Agricultural Rescue Trailer (Grain C.A.R.T.) was dedicated to the Ohio Fire Academy at the 50th Farm Science Review in London, OH on Tuesday September 18th, 2012. The final product, as presented at the ceremony is shown in Figure 3 below.



Figure 3. Grain C.A.R.T. at Dedication Ceremony

Acknowledgements

The Grain Comprehensive Agricultural Rescue Trailer (Grain C.A.R.T.) was built by students of The Ohio State University, dedicated to the Ohio Fire Academy for the continued education and prevention of agricultural injuries and fatalities. In honor of the Food, Agricultural, and Biological Engineering (FABE) student design team, their advisors, and founding industry sponsors:

Student Team; Steven Bostelman, Dustin Elder, Jonathan Francis, Kyle Lahna, and Michael Damschroder

Academic Advisors; Dee Jepsen, Scott Shearer, Dewey Mann, Kathy Mann, and Kent McGuire

Industry Advisors; Andy Bauer – Heritage Cooperative, Albert Gross, Heritage Cooperative, Dave Torsell – Urbana Fire and Rescue Service, Scott Walker – Ohio Fire Academy, Gerald Robinson – Ohio Fire Academy, Greg Pontius, Scott Sims – Sims Construction, and Cheryl Storch – Custom Agri Systems

Founding Industry Sponsors; All-Phase Electric, Andersons Grain, Bauer Basics, Cargill AgHorizons, Custom Agri Systems, Deerfield Farms Service, Francis & Shipley Farms, Gingway Products, Greg Pontius, Heritage Cooperative, Honeyville, Metal, JD Equipment, Land O'Lakes, LoadOut Technologies, Mennel Milling, Rainbow Industries, Sims Construction, Unverferth, and Worthington Industries.

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