



Multidisciplinary Capstone Design Experiences: Students' Perspective

Cole Shannon

South Dakota State University alum that recently graduated in May of 2022. I currently work at Danfoss Power Solutions in Ames, Iowa as a tactical buyer on their supply chain team. I currently live in Madrid, Iowa which is my hometown and the place that I grew up in.

Patrick David Lovrien

I graduated South Dakota State Spring of 2022 with a degree in operations management. As well as minors in engineering management and management. I am currently working as an Environmental, Health, & Safety Lead.

Bret Barnett

Currently playing baseball for South Dakota State University. Graduating in 2022 with a degree in Operations Management.

Carrie Steinlicht (Senior Lecturer)

Ekaterina Koromyslova

Dr. Ekaterina Koromyslova is an Associate Professor in Operations Management. She teaches several courses, including Operations and Supply Chain Management, Engineering Economic Analysis, and Research Methods in Management. She has several years of industry experience as an analyst-consultant for manufacturing companies and as a leading manager in supply chain and logistics. Her research interests are in engineering education, including learner-centered teaching strategies, inductive teaching and learning, and development of students' professional skills.

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Abstract

It is common practice for authors to study engineering education projects where authors propose a theoretical framework for a teaching approach, collect and interpret data and students' feedback, and report findings through the prism of their understanding of theory and implications. The approach taken in this paper is different. This paper is prepared by students who participated in a multidisciplinary capstone project, and it presents first-hand highlights of the student-participants' perspective of their experiences as a response to multidisciplinary teaching interventions.

The paper emphasizes the importance for college graduates to develop multidisciplinary collaboration skills and competencies for successful employment. A summary of various approaches practiced in higher education to provide opportunities for multidisciplinary learning, including capstone projects, is outlined in the literature review.

The paper describes goals, objectives, and outcomes of a project assigned to a multidisciplinary capstone team. The authors outline organization of the multidisciplinary student collaboration in the project, team structure, project activities, and communication and teamwork practices. Students' learning experiences, including benefits, challenges, and lessons learned are discussed in the paper, presenting different points of view from different disciplines.

Relevance of multidisciplinary teaching for student career goals and value for their professional development are discussed in the paper. The authors provide suggestions for improvements and advice to instructors and peers for improving multidisciplinary learning experiences at the college level.

Introduction

Multidisciplinary collaborations are important for several reasons. First, it improves learning and student engagement. As stated by Drake and Reid, after reviewing numerous studies, "interdisciplinary approaches can lead to increased student engagement and motivation, less absenteeism, and better attitudes towards school [1]." The second reason that multidisciplinary collaboration is important, is that it simulates the working environment of a real company. According to Qattawi, Alafaghani, Ablat, and Jaman on the capstone course that they initiated, "The capstone course is a one-semester course (16-weeks) aimed to prepare the engineering students with the required design skills in an environment that simulates the real-world problem while offering mentoring and feedback [2]." Multidisciplinary collaboration can offer an opportunity to work on real-world problems before getting out into the real-world. The simulation of the working environment can also help with communication skills since some students get little practice on that skill while in school. In industry, professionals must communicate with people with different backgrounds and multidisciplinary collaboration can help develop those communication and working skills.

There are several published studies that examine multidisciplinary capstone experiences for undergraduate students for improving professional skills. The authors of this paper are students who participated in a multidisciplinary project. This paper offers a unique perspective and the first-hand experiences of these students engaging in a multidisciplinary capstone project. This paper aims to give insight into multidisciplinary projects that is different from the research currently presented. The authors describe the actual project and how it offered opportunities to develop professional skills, including their own thoughts and experiences, frustrations, and discoveries with multidisciplinary projects, as well as describe their own progress toward better professional skills. In the end, the authors will show how well the project was able to enhance students' professional skills and prepare the students for their careers.

Companies want individuals that work well with different groups. They also want workers that are well-rounded and that includes the ability to work in groups of people that have different backgrounds and education. Students have little opportunity to develop their skills in working with teams made of different groups of people during their schooling. Much of the coursework separates individuals into groups based on major and/or college. There are few opportunities to interact with other disciplines outside of general coursework. One opportunity is through internship. Working in groups made up of different disciplines is something that happens a lot through internships. During an internship, students work on tasks that involve interacting with different people. The authors have seen the industry needs of multidisciplinary collaboration firsthand. Attributes related to multidisciplinary work are seen as some of the most sought-after skills that an employer looks for on a resume. Based on a survey by NACE, skills like the ability to work in a team (86.3% of respondents), communication skills-written (77.5%), leadership (72.5%), and communication skills-verbal (69.6%), these were ranked 2, 5, 6, and 7, respectively [3]. Then, according to statistics taken by the Foundation for Young Australians, certain team-based skills are growing in the proportion of jobs requesting those skills. Skills like team management (46%), multi-tasking (45%), and organizational skills (44%) are right near the top of that list and will most likely continue to increase [4]. The more global industry becomes the more those team-skills and communication skills will become important. Working in teams made up of different disciplines is something that happens daily in industry and through internships, students work on projects and everyday tasks that involve interacting with different people. The authors, who are undergraduate students, have seen the industry importance of multidisciplinary collaboration firsthand. Multidisciplinary projects help to prepare students to effectively work with different people with different backgrounds in the real-world and industry.

Literature review

There are many researchers that have studied multidisciplinary projects and their effect on student learning. All these researchers began these projects with the intent to improve/develop skills needed in future places of work for their students. Those skills included communication, teamwork, idea collaboration and more. Even students, who were being surveyed on what made a good project, know that certain skills are useful in making projects work. In a survey done by researchers at Loughborough University, students answered that individuals, teams, processes, project, and product all played an important role in determining a successful project [5]. Communication is a highly valued skill in workplaces and in everyday life [6]. Communication remains one of the focal points of multidisciplinary projects and the next studies that are

reviewed kept that in mind. They all seemed to have the same goal of preparing students for the workforce by trying to improve these skills.

Metropolia University of Applied Sciences in Finland, a multidisciplinary university in Canada, a multidisciplinary project by Stevens, Carmen Stevens and Stevens using 3 different classes, York College of Pennsylvania, Nanyang Polytechnic, and the University of Houston all conducted multidisciplinary projects and documented their findings [7], [8], [9], [10], [11], [12]. At Metropolia University of Applied Sciences in Finland, researchers conducted a study on the effects of the required multidisciplinary project for their university. Student diaries were studied to get an idea of what the students thought of multidisciplinary projects. They concluded that the students were engaged in the project work but lacked motivation due to the collaboration aspect of the multidisciplinary project [7]. In another multidisciplinary project at a university in Ontario, Canada, a group of engineering students and a group of business students collaborated to gain skills when working with people of a different discipline. This multidisciplinary project was also pitted against a single-cohort group to analyze the effectiveness of the multidisciplinary group. Through pretest and posttest analysis, researchers found that the interest in entrepreneurship grew more in the single-cohort, but the likelihood of having a successful and productive project in the single-cohort was greater than the likelihood in the multidisciplinary cohort [8].

Other studies of multidisciplinary projects seemed to be very similar to the one experienced by the authors of this paper. A systems engineering capstone project was set up with three different majors from 2 universities with a total of 12 students on the team. They were tasked with designing a dual-use ferry and the researchers concluded that the project was a success, because the students were able to gain experience with engineering design, systems engineering, and communication [9]. They were able to gain experience on several skills that are needed in a real work environment. Another similar project dealt with designing an FSAE car. The difference between this project and that of the authors was that this one had three groups of all engineers rather than a mix of students from more differentiated majors. This project was conducted by York College of Pennsylvania, and they concluded that it was a successful project for both students and faculty members. They also commented that students showed growth in skills that they will use well in the workplace [10].

These next two projects really provided great insight on the success of their projects. One was a very successful project and the other reported poor outcomes with multidisciplinary projects. In the project held by Nanyang Polytechnic, they sensed a demand from the biomedical industry for work-force ready students, so they created an integrated curriculum with multidisciplinary components to aid in that demand. They were provided feedback from their industry sponsors on the success of their integrated curriculum who showed satisfaction in the students they were now employing. They also noticed that their employment rate improved in 2016. The students also reflected positively on the curriculum and now a 12-month integrated work-study program is being implemented to take the multidisciplinary project a step further [11]. At the University of Houston, they have had their share of problems with their multidisciplinary projects such as individual grades, class participation, and project completion. They had to find solutions to these problems to better help students develop into work-place ready students. They ended up coming up with several solutions to their problems including dividing the class into smaller groups and

doing projects out of their labs instead of from real companies. The three courses involved in the capstone class couldn't agree on the allocation of resources and it was determined that the class size was just too big. If they were to continue with smaller groups, it would just be best for them to do it in their own departments. This was an example of the multidisciplinary project teams not working and as such the course was disbanded and the capstone projects fell back onto the three departments individually [12]. All these researchers reported having some success in their projects, except the University of Houston who, as stated before, ended up disbanding their multidisciplinary project teams. For the most part, all other researchers described the multidisciplinary projects as being able to instill those workforce and industry skills needed.

A lot of researchers used surveys as a way of measuring their success. They would get responses from students and participants so that they could get feedback on how the students felt about working on a multidisciplinary project. In a study done during one of the summer schools in Wales, U.K., the researchers survey indicated that students rated all questions on the question above neutral (3.5) meaning they were more than satisfied with the project. The lowest scored question asked whether the information being taught would be useful in a future career field. The mean was above the neutral rating. Researchers learned through this survey that multidisciplinary projects are useful and have positive outcomes for the students [13]. Another way to measure success used by the researchers was a rubric. Rubrics, however, were regarded as difficult when running a multidisciplinary project. So, researchers at Rowan University decided to make a rubric that could help with evaluation of students and the multidisciplinary projects. Instructors were asked to use the rubric and then fill out a survey on how helpful the rubric was. These researchers found that on a scale of 1-4, 4 being the highest, the mean for every question on the survey was close to that highest mark of 4. All questions were rated in the 3.3-3.9 range [14]. These two studies clearly showed how the survey in students and employers and rubrics evaluating student performance can be a useful tool for evaluating project success and effectiveness. Surveys and rubrics, however, may not capture rich data on the successes and failures of multidisciplinary projects. Additional insight can be gained using different research methods in hopes to obtain more rich data.

A review of literature has shown that there are virtually no papers or research projects from a student perspective. All the above have been conducted and written by instructors, teachers, or professionals. This paper is written to give a look directly into what three students felt about their capstone project and working on a multidisciplinary team. This study, from the account of students, presents the perception of the effectiveness of multidisciplinary capstone projects on the development of team-based skills.

Description of the capstone project

The Capstone Project was designed as a project that revolves around the concept of multidisciplinary work between different majors. This project would allow students to collaborate across disciplines to satisfactorily complete/achieve the necessary goals. It also would simulate collaborative work typically found in a business setting between engineering, marketing, and operations functions.

The project that was presented to each of the students was a collaborative project that would help to improve competition results for the NFPA Fluid Powered Bike competition. In this project there were three different disciplines/classes that would participate in the project. The different disciplines were marketing, agricultural & biosystem engineering (ABE), and operations management (OM). Each of the different disciplines were charged with handling different aspects of the project. The marketing students were charged with finding markets in which the fluid powered bike could possibly enter. The OM and ABE students would be working together on assembling the bike. The ABE students were charged with more hands-on assembly, as well as designing the parts of the vehicle. The OM students were charged with project management and general support. This was supposed to be more than project management including manufacturing costs based on market figures.

The project team was recruited from students that were in capstone courses for each of their own majors. The ABE students were each assigned to the project by their senior design professor. The OM students each chose to take on this project after a description of the project and its details were proposed. In the marketing capstone course, the students were divided into groups to present separate proposals to the NFPA team. The NFPA team would provide feedback on the plausibility of each idea and review the submitted proposals.

The initial meeting was between the OM students and the OM instructors to go over what was expected from this project as well as iron out details of the multidisciplinary project. This meeting was before classes had started as the OM students would have to be enrolled in a special topics course in order to participate. The details as to what kind of work would be done as well as the writing of a paper were also discussed in this initial meeting. Later, there was a meeting of the members of the NFPA team which would be made up of the OM and ABE students. This meeting introduced the concept of the vehicle, how it worked, as well as introductions between the two discipline groups. The meeting with the ABE team also included the ABE professor, who would be directly helping as well as supervising the project. Once each of these meetings had occurred and the NFPA members had met, the NFPA team attended a meeting with the marketing group. The initial meeting with the marketing team had the NFPA members and the marketing group go over the bike with the professors in attendance. Details of how the bike worked were shared with the marketing group so that they may better be able to provide possible marketable ideas. The concept of how the marketing group would be interacting with the NFPA team was also discussed to establish proper lines of communication. Because there was a need for communication between three different discipline groups, a project management plan was needed for how the OM students would manage both marketing and the NFPA team.

Organization of the multidisciplinary student collaboration in the project

As the project started, roles for the students began to be assigned. The OM project instructor informed the OM students that she would like to see them use the Agile Project Management methods to manage the project. She then gave the three OM students a crash course on SCRUM and Agile. Using SCRUM Agile Management all students on the NFPA team would be at the same level with the expectation that everyone will do equal work and would also volunteer to do work when they felt it was within their skillsets. This was all based around the OM and ABE students working together. The original plan called for two ME and one EE student to

participate. However, they did not end up being on the team. This left the engineering resources stretched and stressed because they would have to learn and cover all the diverse techniques that were used. Microsoft teams was used as the SCRUM board where the team assigned individuals their tasks and had them sign up for things during the biweekly status report meetings. The marketing class was outside of the agile management cloud and therefore was involved through communication between the one project manager and their professor.

The structure of the project was constantly in flux as it developed and as the dynamic changed, the team began to fall apart. The OM students would work to keep things on schedule, log items such as work hours, and complete status reports for the group. It was beginning to become more and more obvious that the team was not going to be able to complete milestones on time. Things were always “in the works” but they were never getting done on the ABE side. The OM students had no organizational power given to them by the professors and the ABE students only saw them as equals and so there was no way to correct the poor progress without getting the professors involved. As the project continued it wasn't until most of the way through the semester that it was clear that there was one member who was holding up the progress. To correct this problem the three OM students met with the OM and ABE instructors. They discussed the issues and the problem actor. The solution to fix the team dynamic was to continue the project without the problem actor.

The new plan called for having a single point of contact within the OM team over the whole team to increase accountability of the team. The OM students were also now asked to work much more closely with the ABE students. The OM students were asked to start doing some of the tasks related to the bike. They would attend shop work, contribute where possible on engineering related tasks, and ask questions to make sure that the ABE students were continuing to make the required progress. The communication also changed. The OM and the ABE instructors asked one of the OM team members to step up as the single point of contact. The goal of this is to help clear up the confusion of the communications between all groups. These changes addressed several of the collaboration issues and the team finished the first semester of the project strong. Many of the milestones were achieved and initial results were favorable. At the time this paper was written, the team was entering the second semester of the project.

Learning experiences discussion

The OM students gained several firsthand learning experiences on the multidisciplinary team. Most of the OM students time was spent interacting with the ABE students as well as three of the instructors for the courses. Students in the OM and ABE groups integrated into one group for the project and were overseen by the various instructors. The OM students also worked with the marketing class to give them meaningful feedback about their ideas they presented to the ABE, OM, and instructors. All feedback was given by the OM students and was sent to them via email to be redistributed by their professor. Communication was by far the most important skill that was refined during this project. Everyone involved was able to see the importance of communication and how quickly it can breakdown.

All projects have their challenges; ours had plenty of them along the way. Communication was difficult and troublesome at all levels. The project had several issues with communication with

the instructors as there were four different instructors from three different disciplines who did not seem to be communicating amongst themselves as they should have been. This led to unanswered or open questions from the OM and ABE students to the instructors. Within the agile management group (OM and ABE students) there were issues with asking for updates on the project and not getting good feedback or no results at all. This also plays into the issues with motivation. The OM group was motivated to complete everything that would be required of them. This was not a shared trait with the ABE team. This is because the OM students volunteered to participate in this multidisciplinary project. The ABE students had been assigned to the project and were not excited about it. The OM students gave them all the tools they needed as well as all the support to easily complete the project. But after the corrective action meeting it was obvious there were prevalent motivation issues. The OM students had done everything within their power to ensure that they had external motivators and support. The external motivation issues are easier to fix, internal motivation is difficult problem to correct. In addition to a lack of internal motivation there was quite a lot of confusion that caused issues for the project from the very start. There seemed to be incredibly high expectations from the instructors. The confusion only got worse as the project went on. It seemed that every two weeks the project was changing more and more. When a person is told they are not doing well every two weeks and is constantly being told they are doing something wrong, without know what, it is not exactly shocking to see them lose their internal motivation.

When asked to “Provide honest feedback on the capstone experience”, the students involved responded with the following comments.

OM Student 1: In this project, I got experience on how much being off track can really begin to slow down the progress of a project. So, learning how to not only be able to play a little bit of catch up, but also having to deal with a project that is behind was a new learning experience. I also think that learning how to adapt to situations that happen unexpectedly will be something that I will really be able to use in my career.

OM Student 2: During this project I gained a lot of experience and knowledge that I did not previously have. I learned a lot about project management and leading a group of ABE engineers. There were some different things that happened during the project that really got my brain working and gave me some difficult problems to find solutions to. I think that what I learned through this project will really help me with my career goals.

OM Student 3: The skills that I gained were how to correct and realign a project that has gone off track. Additionally, I learned how important it is to make sure that all groups have the same scope. Scope creep was prevalent in this project, and I see why it is important to control it before it happens. Overall, the project was just a great way to get more experience using my skills.

Marketing Student: This project was a very interesting idea but was gone about the wrong way. I really enjoyed learning the processes and interactions economics employees and engineers use in a real-world simulation. I did feel communication was very lacking, as we got put in the dark at the end of September. However, I think all the professors involved need to fully understand the assignment, and what each group is doing. For example, the business economics professor did not understand how hydraulics work, making it easy to make non feasible designs.

Further, the engineering kids are doing this as a challenge, which would make it way less enticing to listen to business kids' ideas about designs. To combat this, I feel as though a noncompetitive project would be of greater benefit, and more realistic. The project is an overall very beneficial project but must be changed to be of value to students.

ABE Student 1: I liked the idea of having multiple majors interact with one another in a large project to gain experience towards what the career field will be like. However, throwing six individuals into a project outside of their zone without much guidance on a starting point would not be my first choice. My main grievance is that when presented the project, many claims were made of having other majors who are more to the project join: mechanicals for bike design, electricals for programming and wiring. Those claims were dropped and never touched again. We were then given project managers, and three of them. I think there needed to be some more direction from the beginning of what was to be expected of the project managers as they were not sure where they should've been placed in the project. I believe so many bodies were thrown at this seem to be last minute endeavor to cover up for the lack of preparation for this project.

ABE Student 2: This project has shown some challenges and asked a lot from our team. I would have liked to dedicate more effort towards this project, but I simply do not have the time that it demands for. It is an interesting competition and has had its enjoyable problem-solving aspects. But for the most part, it feels as if we have done just enough to get by. On a positive note, I believe we have grown in teamwork and communication, and have learned to find motivation when there was little to begin with.

ABE Student 3: I believe that our project is going smoothly now. Right away we had some troubles getting motivated, but now we are sitting very well. Overall, I feel that the experience has been very helpful in learning how operations work in the real world. We have made a good team, with the OMs helping with the paperwork and contacts side, and the engineers being able to focus on the design features. I am appreciative of the work that the OMs have been putting in, taking some of the load off has helped us to be able to keep working.

Overall, the Operations Management students were able to gain good experience on project management as well as leadership. The most important thing that all these students gained were an ability to identify and correct projects that had begun to go off course. Additionally, the OM students were able to see the value of this experience. But this was not the common feeling that was shared by all the involved students. The marketing students had a great deal of confusion. They were left in the dark time and time again. The professor as well as the students did not have a working understanding of the physics of hydraulics and thus had no idea if the ideas, they came up with, were feasible or not. The ABE students felt a similar way as the marketing students, lost and without direction. They were promised that there would be more engineering students on their team that would have diverse roles and skills, when they were unable to get this, the task at hand became too large. On the positive side the ABE students have been able to recognize the value of the team and the different ways that non-engineering team members would be able to help them to reduce their load and supplement their work.

There were several observations made by the students about this collaboration project. When asked about some of their observations regarding the overall multidisciplinary course and how it could possibly apply to their future careers, the OM students had this to say.

OM Student 1: For me, being able to experience what it is like to deal with other departments or groups is very valuable. Since some people may not have the same background, being able to work together and navigate different managing tactics is a very useful skillset. As a project manager, having to keep track of the state of the project and assignments you gave to others is a crucial part to the success of a project. So having to see where different parts of the project stood and having to communicate with each of the multidisciplinary groups was a good experience to have.

OM Student 2: This project for me was very relevant to my career goals because of the profession that I am trying to pursue. I want to be in a manufacturing plant working with different groups of people to solve problems. My current career goal is to get in at a manufacturing plant to work in a supply chain department. I have already started helping in a supply chain department and I have gained insight into the skills needed to perform those jobs every day. This project and being a project manager will help me to achieve those career goals.

OM Student 3: This project was relevant to my career in several ways. It gave me quite a lot of leadership and communication practice. The environment that the project was in is great to be able to try things and fail without any real-world consequences. My career end goal is to be a plant manager within the aerospace manufacturing industry. There are a million different types of people and engineering disciplines within this industry. If I would like to one day lead within a diverse multidisciplinary industry, I need to have plenty of experience to ensure I am proficient and effective.

Even though the project was valuable experience, the overall experience could still be improved in ways to get even greater results from the project. One of the first things that became apparent was a problem with communication with the instructors. At the beginning of the project, there was confusion about the expectations and what the project structure would be. In the future, better communication between the different instructors of the multidisciplinary project would help to clear up this confusion. Though allowing for the project team to control most of it is good for experience, it made for a lot of confusion as the project team really had no direction and was lost at the beginning.

Bi-weekly check-ins with the instructors was another thing that we believed could have been of benefit to the project team. By having these bi-weekly check-ins, we could make sure that the project was being done in the way that was expected rather than having to guess. The people that would be in attendance in these check-ins would be the members of the project team (ABE students, OM students, Marketing if needed), and the instructors for each of the various groups. With each of the instructors at these check-ins, we would be able to have formal scope documentation, which could help eliminate or minimize any kind of scope creep that occurs pulling the project getting off track. Given how early in the project scope creep happened, having the check-ins with the instructor could have averted problems. Overall, the main improvements that would be recommended are clearer communication with instructors, having a structured

system that would help with accountability, and to have instructors and students be more hands on with first time projects such as this one.

Summary

The project at the beginning was very confusing and in a constant state of change. There have been several positives and negatives associated with this project. Everyone who has been involved in this project has worked to improve their skill whether they realize it or not. The project overall has been a success when measured from start to finish as we ended where we wanted to. The drawbacks of course are the struggles along the way and that it took far more work to get there because it took months to get the end goal figured out while trying to keep all the stakeholders happy. However, the students involved in the multidisciplinary project felt like they gained valuable knowledge and skills that will not only help them academically, but also prepare them for their new careers. This project did show signs of improvement to student learning and to student's career readiness. The importance of multidisciplinary projects is clear, and the student authors feel that the project was an overall success.

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