



Students' Experiences with an Open-ended Client Project in a Graduate Course

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Reuben F. Burch V received his Ph.D. in Industrial and Systems Engineering from Mississippi State University in 2014. He has also received a Master of Engineering Management in Industrial and Manufacturing Systems Engineering from Kansas State University and a Bachelors of Science in Computer Engineering from Mississippi State University. Dr. Burch's work history largely consists of research and development in the virtual reality space where he consulted for NASA, Naval departments from multiple countries, and the Department of Defense and Energy. Recently, his Research and Development (R&D) expertise has expanded to include logistics and industry. He currently serves as a faculty consultant and logistics and technology advisor for numerous universities and multiple Fortune 100 companies around the world. He is also an elected official for a small municipality in western Tennessee where he works with local entrepreneurs to build a better ecosystems for creativity with the goal of growing a stronger community and workforce. Dr. Burch's primary research interests center around human factors, ergonomics, and future generations of technologies. He is particularly interested in the design of and human interaction with rugged mobile tools, robotics, and contextual awareness within the industrial workplace. Other work includes studying the current demographic shift in the global workforce and what new expectations from a self-actualized generation of workers mean for the future of all industrial technology. Dr. Burch has a number of publications regarding ruggedized handheld devices in the industrial work environment and has filed a number of potential new intellectual properties and inventions as part of his research.

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Introduction

Much research by the engineering education community concerning student projects has focused on undergraduate students' experiences with open-ended client projects, for instance, in capstone design courses. Comparatively fewer studies have examined graduate students' experiences. Projects with real clients provide benefits for both the students and the company. Students gain experience applying the course content, have the opportunity to build skills for solving unstructured problems, and gain exposure to potential employers. Client companies can leverage the advanced capabilities of graduate students to address business challenges and have the opportunity to interact with and evaluate potential recruits.

The successful integration of open-ended client projects into a graduate course poses challenges for all parties involved. Assessment of students' experiences with such a project can guide future decisions about the structure of projects that best meets the needs of students, clients, and faculty. This paper presents the results of a study of students' experiences with an open-ended client project in a graduate course. The study participants are master's, doctoral, and advanced undergraduate students enrolled in graduate courses at two different universities. The content of the two courses was similar, and participants at both universities completed the same project with the same industry client. Data about students' experiences were gathered using two surveys, one during the project and one after project completion.

The surveys measured several dimensions of students' experiences. Specifically, they measured students' confidence in their own abilities relative to course content, confidence in the abilities of their teams as a whole, and attributes of projects and client involvement that students find important. Student responses were analyzed to gain insight about the following questions:

- How does students' confidence in their own abilities change during the project?
- How does students' confidence in team abilities change during the project?
- What characteristics of client projects are most important to students? Characteristics include the level of direct client involvement with the team, perceived impact of the project on the company, and availability of real or realistic data.
- How does the fact that the project is for a real client impact levels of stress about the project and the degree to which the project is rewarding for students?
- Do these observations differ between on-campus and off-campus (distance learning) students?

The paper describes opportunities to use the survey findings to inform graduate course design and project selection.

Literature Review

Open-ended problems, also referred to as ill-structured problems, are characterized by several attributes^{3,7,9}. Such problems have multiple possible solutions and approaches. This stands in contrast to well-structured problems with a single "right" answer that are more typical of

textbook engineering assignments. Open-ended problem context and requirements may be revealed over time through questioning, and the problem description may have missing, conflicting, and/or extraneous information. The goals of solving the problem may be uncertain, and solutions may be evaluated using multiple criteria. As a result, students may be required to use judgment and justify assumptions to proceed with analysis.

Open-ended problem solving is an important skill for engineers. Among the most common ways that open-ended problem solving is incorporated in the curriculum is through capstone design experiences. Although ubiquitous in undergraduate degree programs^{2,8}, capstone design has also been included in master's degree programs, sometimes in place of the thesis⁴ or as a non-thesis option for students on an industry-oriented career track⁶. Typically these capstone experiences integrate technical skills from multiple classes, and in some cases, they span multiple semesters.

The literature on undergraduate capstone design offers insight into important factors for a successful industry-based project². Attributes of effective client projects include the involvement of a company liaison who interacts regularly with students and participates in evaluating students' project performance. Student accountability to the client is important. Real-world problems have been associated with increased student commitment to the project in comparison to instructor-created problems².

Although industry-academic research collaboration and industry-based capstone experiences are widespread, we found little guidance in the literature about strategies for incorporating an open-ended client project within a single graduate course. This paper describes the experiences of two faculty members at different institutions, one industry partner, and our students with such a project. In what follows, we discuss the ways that the project was integrated into our respective courses, summarize findings from student surveys, and offer insights and lessons learned.

Study Context and Methodology

We briefly describe the courses in which the project was used, the perspective of the industry client, and the design of the student surveys.

Kansas State University

The first course included in this study was a graduate-level course in logistics engineering at Kansas State University. A total of 52 students took the course either on-campus or via distance education. Of these, nine were pursuing the M.S. in Operations Research (three on-campus, six distance); 12 were pursuing the M.S. in Industrial Engineering (all on-campus); 25 were pursuing the Master of Engineering Management (all off-campus); five were advanced undergraduates pursuing the B.S. in Industrial Engineering (all on-campus); and one was pursuing a degree outside the industrial engineering department. An undergraduate-level knowledge of linear and integer programming was a course prerequisite. The course covered logistics systems applications of operations research, particularly network flow models, shortest path problems and algorithms, and vehicle routing problems and heuristic solution methods.

All students completed the same industry project, which constituted 25 percent of the grade for the course. The project was conducted in self-selected groups of between four and six students.

The client liaison presented the project to the class in person, and students were given a two-page description of the problem as well as a rubric outlining deliverables. Teams prepared written interim and final reports and a final oral presentation. During the course of the project, the instructor and client liaison published answers to students' questions in a frequently-asked questions document available to the class. The client liaison and another representative from the company reviewed students' final reports and helped to evaluate final presentations.

Mississippi State University

The second course included in this study was a graduate course on network flows and dynamic programming at Mississippi State University. The enrollment consisted of eleven students: six on-campus Ph.D. students, three off-campus Ph.D. students, one on-campus M.S. student, and one on-campus advanced undergraduate student. Students were expected to have a working knowledge of linear programming. The course focused on the theory and application of three network flow problems: the shortest path problem, the maximum flow problem, and the minimum cost network flow problem. Students were taught how to solve these problems by hand using well-known algorithms, how to implement these algorithms in computer code, and how to interpret problem solutions. Students were also shown how to derive the correctness and computational complexity of the algorithms they learned.

All students completed an end-of-semester project worth 35.7 percent of the total grade, but students were allowed to choose the project topic. Most of the students in the class chose a project that related to their doctoral research. One self-selected three-person team chose to complete the industry project, for which they were required to prepare a project proposal, a final project report, and teaching materials that they could use to teach their client about one aspect of network flows. Students were given a two-page description of the project and the same frequently-asked questions document given to the Kansas State University students. In addition, the client liaison gave an in-person presentation about the project and answered questions.

Industry Client

The logistics-based industry partner in this study sought to engage in a graduate-level course project for several reasons. First, the company is interested in project-based learning experiences. Project-based learning, or PBL, in the classroom is a concept that has been in practice since its initial suggestion by John Dewey in 1897 when he promoted "learning by doing"¹. For industry, when learning by doing is executed correctly in the classroom, those students who "solve authentic problems and produce results that matter" are extremely attractive as future hires⁵. Expectations from competitive companies are such that new hires must be capable of entering a work culture and producing immediately as personnel resources continue to be reduced while production output anticipations are ever on the rise. PBL at the college level is one method in which organizations can evaluate potential future hires in lieu of internships or cooperative education opportunities. Project deliverables based on real industrial needs provide insight into students' abilities to solve issues similar to what they may face during an actual career. For instance, project output within a classroom provides insight into students' problem solving capabilities as engineers; their creativity and ability to think outside of the normal boundaries of workbook definitions; their ability to lead, take direction from, and interact with their peers; their professional motivations; and their personalities.

Along with the standard PBL experience, two other aspects of this study were of great interest to the partnering organization: 1) graduate student capability during operations research-based PBL and 2) open-ended problem solving for an industrial opportunity within the graduate students' field of study. Students working in the logistics and transportation space may experience these types of industrial problems and so preparing them by using open-ended projects in the classroom warrants consideration from those who define the engineering curriculum. Industry and academia should grow their partnership as the teaching paradigm shifts to a more hands-on, trial and error learning model.

Survey Design

Students' experiences with the industry project were assessed using two surveys, both administered electronically. The first survey was distributed during the project and the second approximately one month after students had completed the project. Survey items addressed several variables of interest, including students' confidence in their own abilities and those of their teams, as well as attributes of projects and client involvement that students find valuable. Students were also asked to indicate for which degree program they were taking the course and whether they were enrolled on-campus or via off-campus distance learning. The study protocol and survey instruments were reviewed by the Institutional Review Boards of both participating universities. Survey instruments are available upon request from the authors.

Results

Findings from both the survey administered during the project and the one administered after the project are grouped based upon the five key areas of interest:

- Student confidence in themselves
- Student confidence in their teammates
- Important client project characteristics
- Stress and reward associated with real client projects
- On- and off-campus observations

For the first survey completed during the project, a total of 34 students responded; 33 of these were from Kansas State University and one was from Mississippi State University. Of these students, three were taking their respective class as part of their bachelor's degree and 31 were taking it for their master's degree. For the second survey, a total of 19 students responded, 17 from Kansas State University and two from Mississippi State University. Of these students, three were taking their respective class as part of their bachelor's degree, 15 were completing their master's, and one student was pursuing a doctorate.

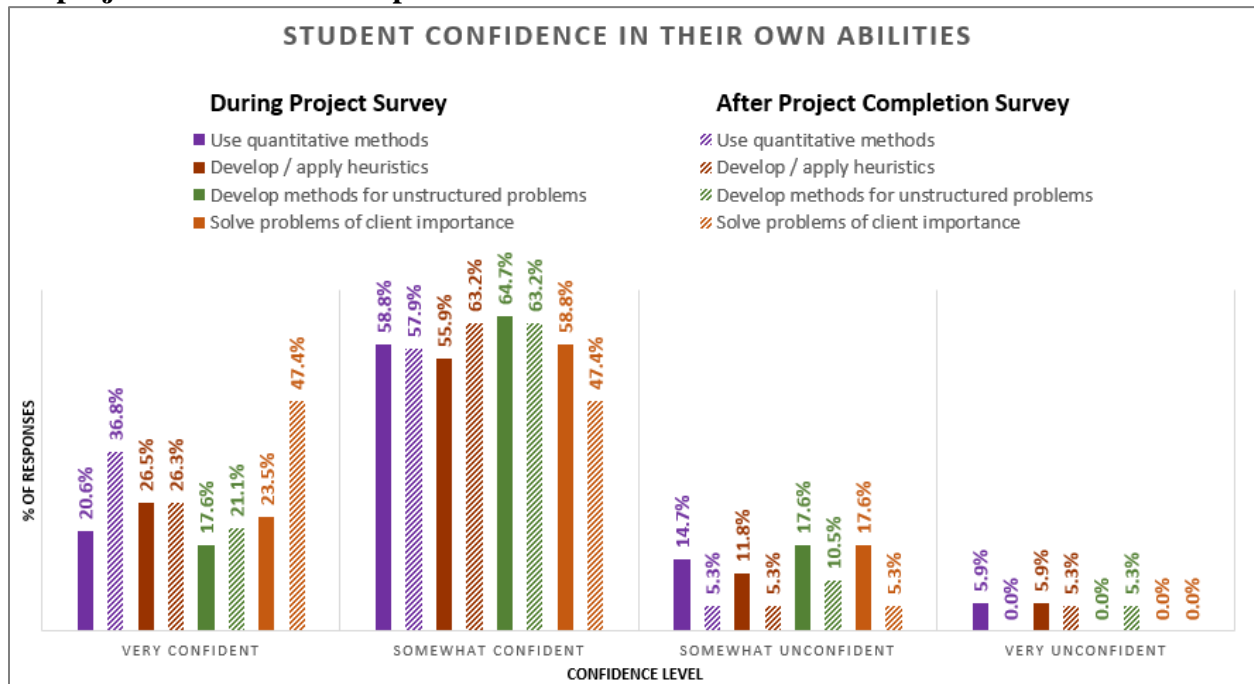
Student Confidence in Themselves

The first area of interest was how students' confidence in their own abilities changed during their completion of an open-ended client project. Students assessed four skillsets associated with the open-ended client problem, and responses were analyzed to gain insight into areas of perceived strength and weakness. The aggregated response totals are illustrated for all respondents in Figure 1. Regarding the students' confidence in their abilities, 'Somewhat confident' was chosen most frequently and 'Very confident' second most (or tied for the second most) frequently for all four ability areas:

1. Using quantitative methods to model a logistics problem,
2. Developing and/or applying algorithms and/or heuristics to solve a quantitative logistics problem,
3. Developing a method for solving an unstructured problem, and
4. Solving problems that are of importance to an industry client.

The second survey asked about the students' confidence in the same four abilities upon completion of the project. Aggregated results for each skillset are shown in Figure 1 alongside the responses for the same ability in the first survey. 'Somewhat confident' was chosen the most for all four of the ability areas with the exception of the ability area: solving problems that are of importance to an industry client. In this ability area, the proportion of 'Very confident' and 'Somewhat confident' selections were tied at 47.4%. This ability also saw a marked increase in the fraction of respondents who were 'Very confident' in their ability between the two surveys. In fact, the percentage of students responding 'Very confident' after the project compared to the percentage giving that response during the project increased for all skill areas except for developing and applying algorithms or heuristics, for which the values were almost the same.

Figure 1: Students' confidence levels in their abilities to solve open-ended problems during the project and after its completion

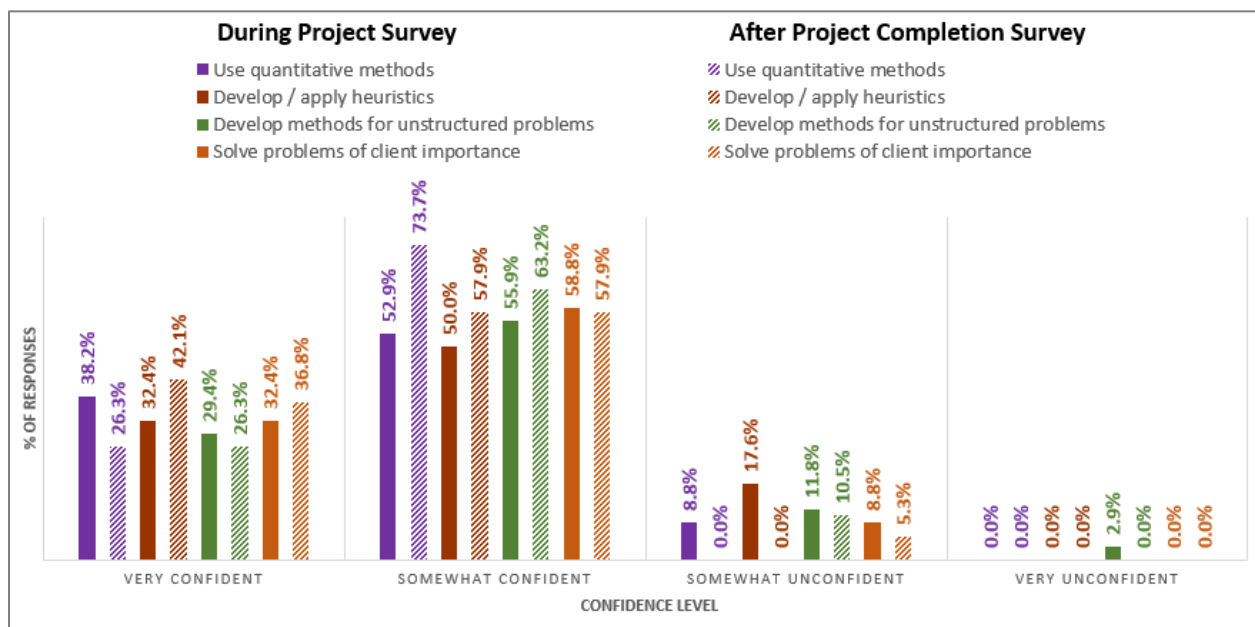


Student Confidence in Their Teammates

The second study area of interest focused on confidence about the same four ability areas. However, students were asked about their confidence regarding the abilities of their team as a whole. These survey responses regarding students' confidence in their teams' abilities were aggregated and totals are displayed in Figure 2. The main selection made for all four ability confidence areas was 'Somewhat confident' with 'Very confident' getting the second most responses.

The second survey focused on students' confidence in their teams' abilities upon completion of the project, and aggregated results are presented in Figure 2 alongside those from the first survey. Again, all four ability areas received mostly 'Somewhat confident' selections with 'Very confident' getting the second most. In comparison to the first survey, a larger percentage of students responding to the second survey were either 'Very confident' or 'Somewhat confident' in their teams across all skill areas. The percentage that chose 'Very confident' showed mixed results, however, with this fraction increasing in the areas of developing and applying algorithms or heuristics and of solving problems of client importance, but decreasing somewhat in the other two skill areas.

Figure 2: Students' confidence levels in their team members' abilities to solve open-ended problems during the project and after its completion



Important Client Project Characteristics

The next series of survey questions specifically addressed the client's role in project delivery, the industrial data and scope characteristics, and industrial job opportunities including student evaluations. These questions were asked in both surveys, but we observed minimal differences in responses between the first survey given during the project and the second survey given after project completion.

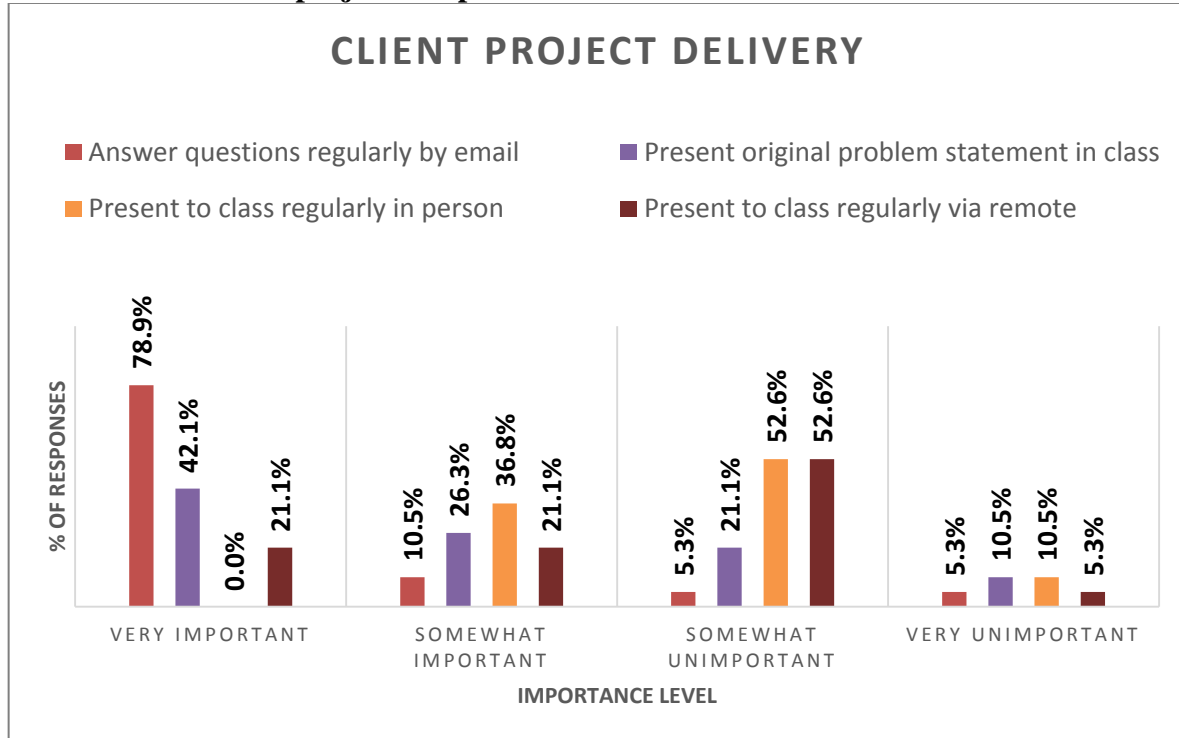
Figure 3 summarizes responses from the post-project survey where students were asked about the importance of the following delivery mechanisms by the client:

1. Being available to answer questions regularly by email,
2. Presenting the original problem statement to the class in person,
3. Presenting to the class regularly in person, and
4. Presenting remotely to the class regularly.

Students identified regular client availability via email as a critical attribute, with 78.9% indicating this was 'Very important'. Regarding the value of a client presenting the original

problem statement in class, 42.1% selected that this form of communication was ‘Very important’, 26.3% ‘Somewhat important’, and 21.1% ‘Somewhat unimportant’. Over half of the students (52.6%) selected that a regular client presence in the classroom was ‘Somewhat unimportant’ followed by 36.8% selecting ‘Somewhat important’. Selection varied only slightly when considering a client presence in the classroom via remote or distance communication. Over half (52.6%) selected that a remote presence was ‘Somewhat unimportant’ followed by a tie for ‘Very important’ and ‘Somewhat important’ (21.1%).

Figure 3: Importance of project characteristics specific to client delivery and communication after project completion



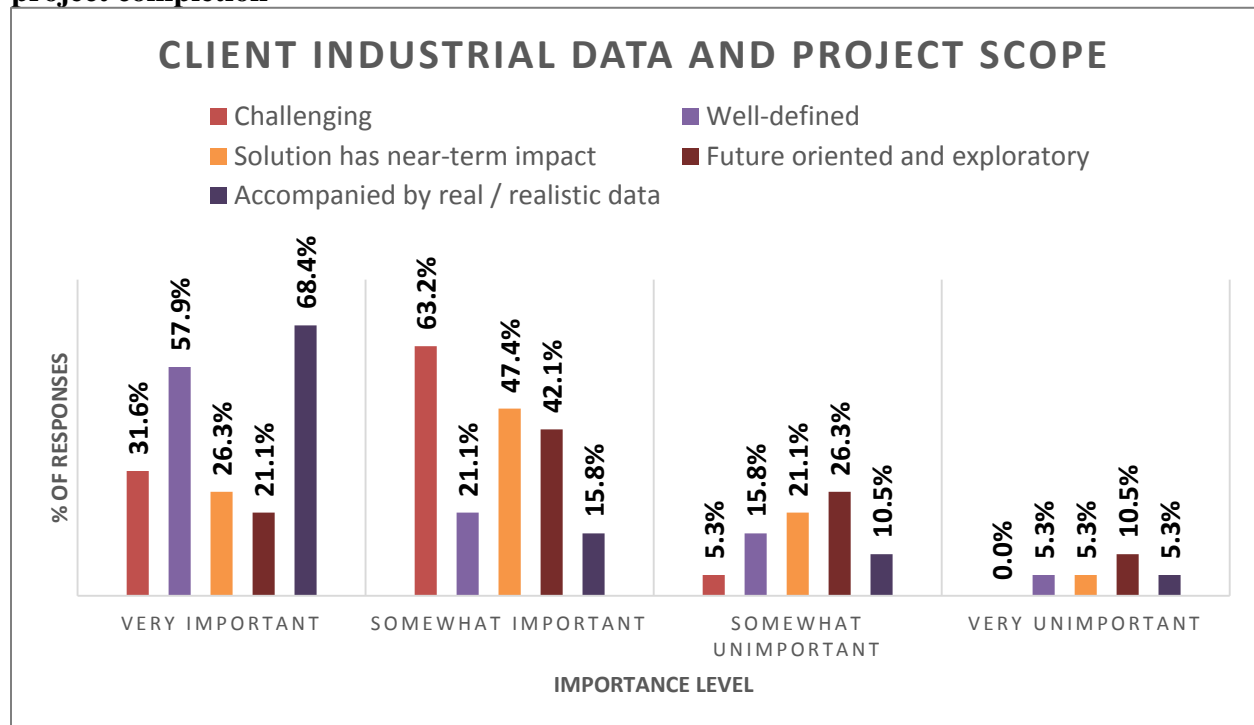
The industrial data and scope characteristics were analyzed next within the survey and focused on the importance students placed on whether the problem presented by the client is:

1. Challenging,
2. Well-defined,
3. Capable of having an impact in the near term when solved,
4. Future oriented and exploratory in nature, and
5. Accompanied by real or realistic data.

The student responses to these five data and scope related survey components were captured after project completion and are summarized in Figure 4. A challenging client problem was largely regarded as important with multiple ‘Somewhat important’ (63.2%) and ‘Very important’ (31.6%) selections made. A problem that is well-defined also received multiple important selections with ‘Very important’ (57.9%) and ‘Somewhat important’ (21.1%) chosen the most. A problem with a near-term impact received mostly ‘Somewhat important’ (47.4%) and ‘Very important’ (26.3%) votes. A similarly split response was seen in the student response for a client problem that was future oriented and exploratory with ‘Somewhat important’ (42.1%) and

‘Somewhat unimportant’ (26.3%) chosen the most. The last question explored the importance to students of real or realistic data, with a significant majority of respondents (68.4%) indicating that this was ‘Very important’.

Figure 4: Importance of project characteristics specific to industrial data and scope after project completion



The last questions in this series sought students’ perspectives on the importance of connecting the project to industrial job opportunities, including client participation in project evaluations. Results from the second survey are aggregated in Figure 5 with respect to the following three attributes:

1. Providing a problem that has yet to be solved by the client’s company,
2. Providing a problem that tests student ability as a potential future hire for the client’s company, and
3. Participating in evaluating project deliverables.

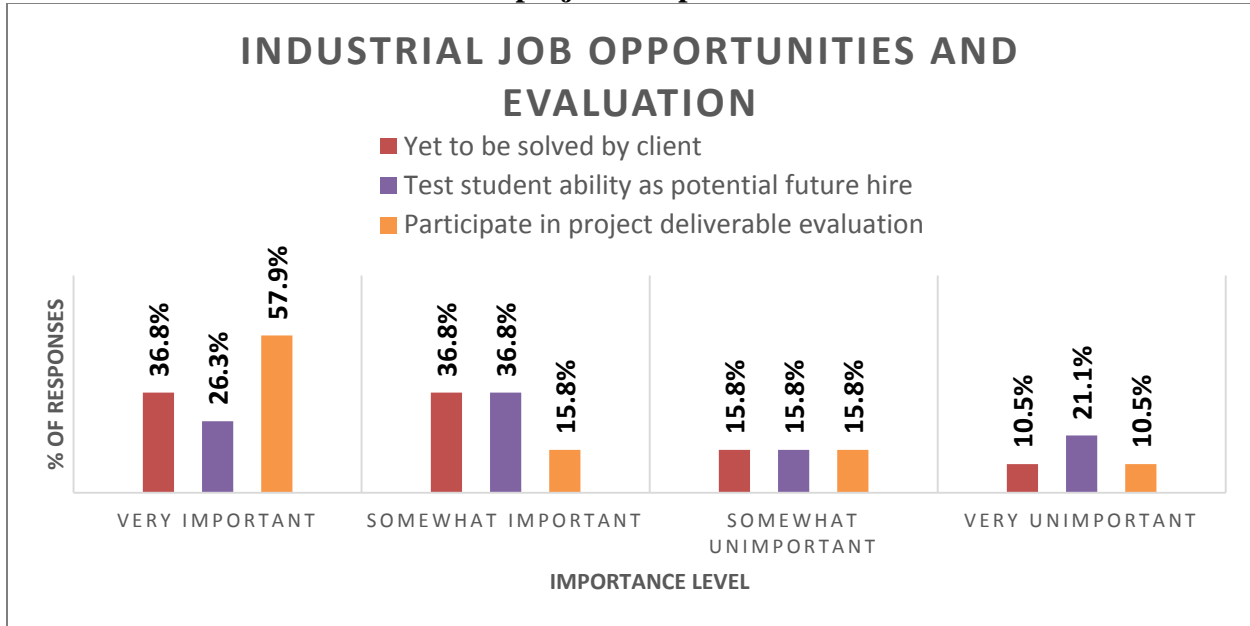
Providing students with a problem that had yet to be solved by the company was largely positive but importance varied. Students equally answered (36.8%) that this aspect was either ‘Very important’ or ‘Somewhat important’. Providing a problem that tested students’ ability as a potential future hire was similarly valued by the students, with ‘Somewhat important’ (36.8%) selected the most followed by ‘Very important’ (26.3%). Student participants also emphasized the importance of client presence during project delivery evaluations, with 57.9% indicating that this was ‘Very important’.

Stress and Reward Associated with Real Client Projects

The student participants were asked two open-ended questions regarding their experience while completing the industrial problem as a class project. The first question asked the students to

describe what they enjoyed most about the class project, while the second question inquired about what they liked least.

Figure 5: Importance of project characteristics specific to industrial job opportunities and student evaluation involvement after project completion

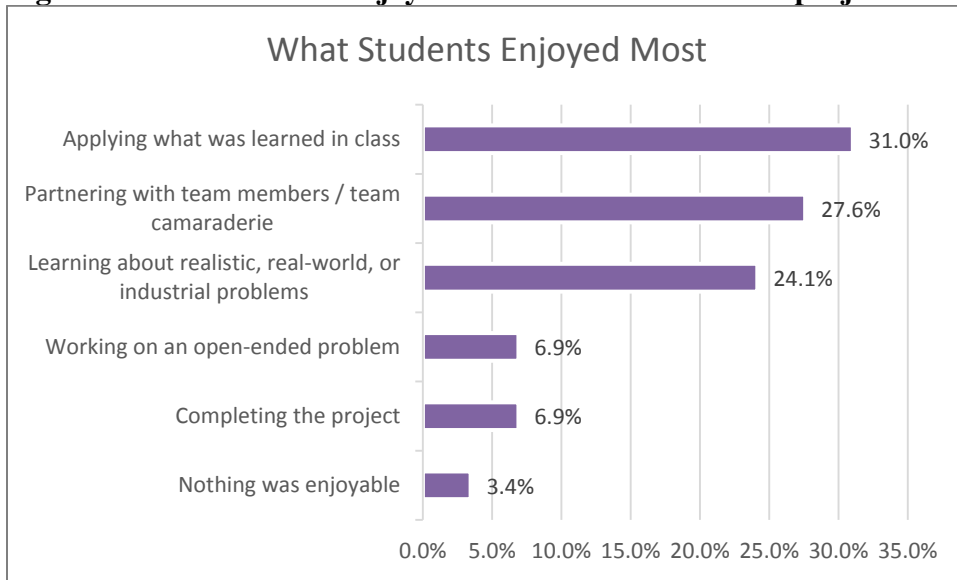


Of the 34 survey respondents to the first survey, 29 answered the open-ended question regarding what they enjoyed most. Responses were summarized into six categories, shown in Figure 6:

1. Applying what was learned in class,
2. Learning about realistic, real-world, or industrial problems,
3. Working on an open-ended problem,
4. Partnering with team members and team camaraderie,
5. Completing the project, and
6. Nothing was enjoyable.

The most-referenced answer category was the challenge of applying what was learned in the classroom to the problem (31%). One student stated, “Being able to apply theoretical classroom learning to a real problem and produce a result,” was what they enjoyed the most about the project. The second most-referenced answer category revolved around team experience and camaraderie at 27.6%. A response in this category described how the experience allowed the team to evolve and expand their knowledge together: “Seeing how the team came from not knowing much to having two great working models to present and also learning how to tweak models as things evolve.” Nearly one-fourth of the responses referenced learning and working on realistic, real-world, and industrial-based problems. One student response stated, “Learning what type of real world problems exist and gaining confidence that when encountered [they] can be solved using techniques you have learned in class.”

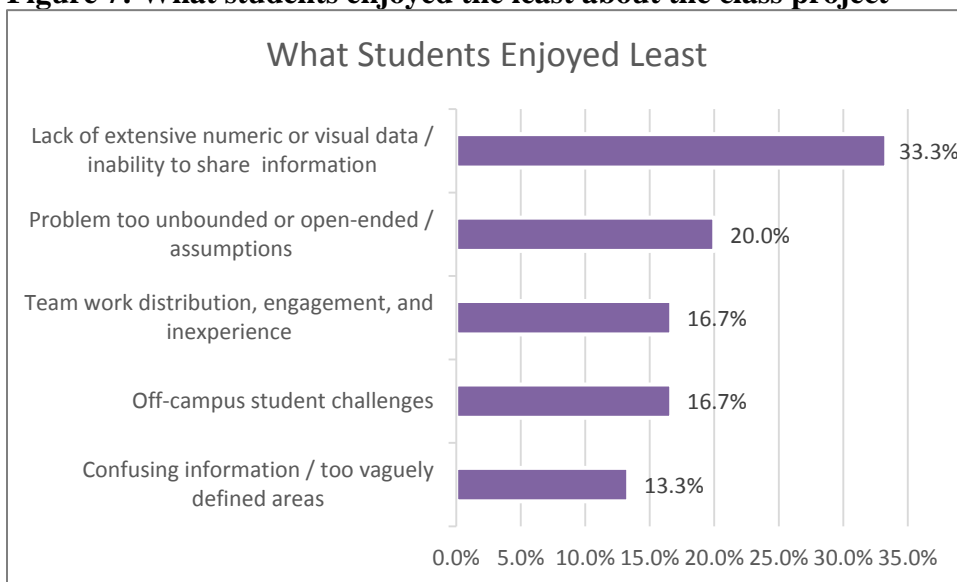
Figure 6: What students enjoyed the most about the class project



The second open-ended survey question regarding stress versus reward asked the students what they least enjoyed about the project. Of the 34 survey respondents who finished the first survey, 30 answered this question. Their responses were summarized into five answer categories, shown in Figure 7:

1. Lack of extensive numeric or visual data and gaps created by inability to share proprietary information,
2. Problem too unbounded or open-ended, requiring students to make assumptions,
3. Confusing information or too vaguely defined areas,
4. Team related items like work distribution, engagement, and inexperience, and
5. Off-campus student challenges.

Figure 7: What students enjoyed the least about the class project



The largest number of open-ended student comments (33.3%) identified the lack of data and gaps in information due to the company’s proprietary information. One student stated: “Writing deliverables and doing work in general isn’t fun, but that’s hardly unique to this project. I think the biggest thing that could be better is the data. I would love more and more realistic data.” The answer category with the second most responses (20.0%) related to the problem being too unbounded or open-ended thereby requiring significant assumptions. One answer explained the issue as “too subjective and the team needed to make a large amount of assumptions.”

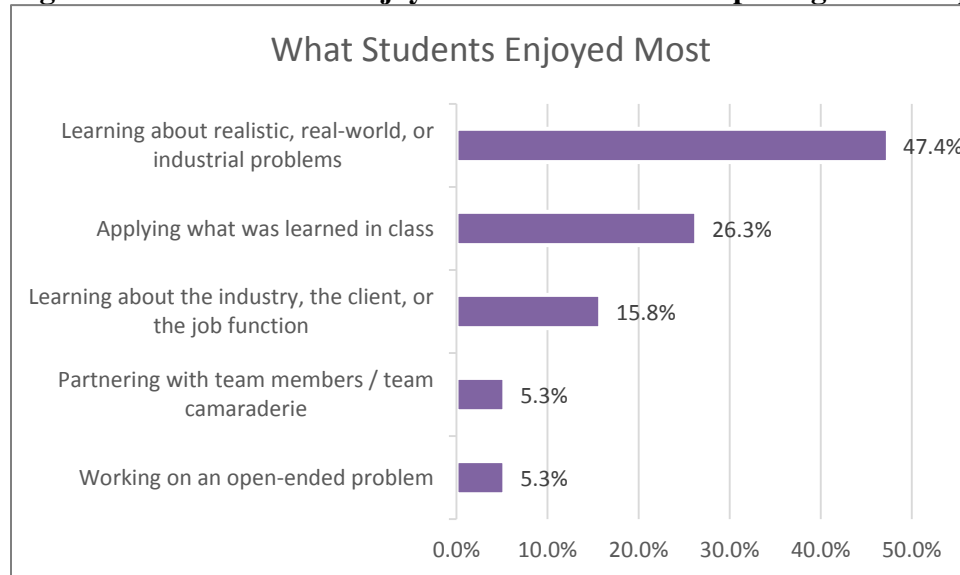
As with the first survey, the second survey asked two open-ended questions regarding what students enjoyed most and least about their experiences after the project ended.

All 19 of the survey respondents answered the open-ended question about what they enjoyed most. Their responses were summarized into five answer categories, as shown in Figure 8:

1. Learning about the industry, the client, and the job function or role required within industry,
2. Partnering with team members and team camaraderie,
3. Learning about realistic, real-world, or industrial problems,
4. Applying what was learned in class, and
5. Working on an open-ended problem,

Nearly half of the students identified learning about and working on realistic, real-world, and industrial-based problems as the most enjoyable part of the project. One student answered, “This project gave me a real life application to the material that was being covered in the class. This real life application allowed me to see the usefulness of the material as well as to better understand it.” The second most identified answer category (26.3%) was the application of what was learned in class for the real-world problem. One explanation detailed: “I could see how what I was learning [would] apply in the reality. Many of the courses that I took seemed uninteresting because it was difficult to see how the subject could be applied in the reality.”

Figure 8: What students enjoyed the most about completing the class project

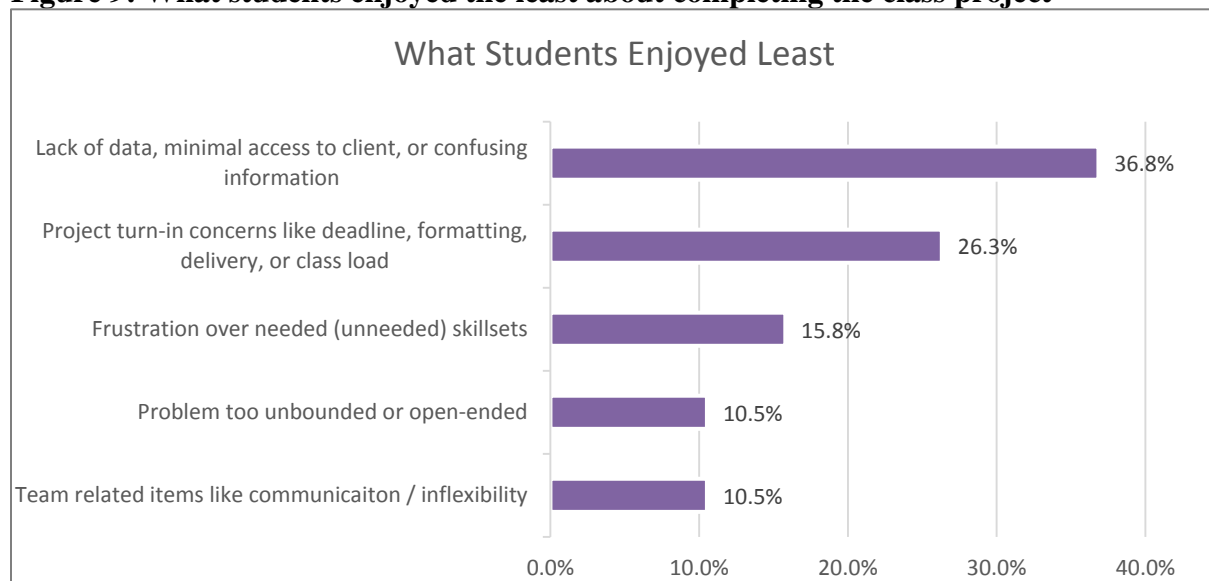


Students were also asked to describe what they enjoyed least upon completion of the class project. All 19 survey respondents who finished the survey answered the open-ended question. Their responses were summarized into five answer categories, shown in Figure 9:

1. Lack of data, minimal access to client, or confusing information,
2. Project turn-in concerns like deadline, formatting delivery, or class load,
3. Frustration over needed (unneeded) skillsets,
4. Team related items like communication and inflexibility, and
5. Problem too unbounded or open-ended.

The answer category that contained the most open-ended student comments regarding what they least liked about the project upon its completion was similar to the first survey. Over one-third of the students stated that lack of data, minimal client access, or confusing information about deliverable expectations was the biggest issue. One student voiced his/her frustration in the following comment: “The least enjoying part of the project is that the data from questions and answers could have been made available more efficiently. This is really in regards to what questions were answered and the time frame the information was available for the groups.” Project turn-in concerns like deadline expectations received the second most student comments (26.3%). One student specifically addressed the time needed to complete the project; “I didn't enjoy not having the time to put the effort that we needed to truly give our best recommendation. This project took a lot more time than originally expected and I didn't set up my semester to allow for this much time.”

Figure 9: What students enjoyed the least about completing the class project



The second survey asked additional questions regarding the relationship between the student teams and the client as well as the stress that comes with working on real-world problems versus typical class room projects. The survey participants were given an open-ended survey question to answer exactly what they would like to see done differently regarding the student team and client relationship. Their responses were summarized in the four answer categories below, which are visualized in Figure 10:

1. More forms of active feedback or direct contact between client and project teams,

2. More definition and data prioritization at the beginning of the project,
3. Client involvement in project team formation, and
4. No change needed.

Over half of the responses made it clear that more consistent communication and more options for communication between the project team and the client were desired. One student suggested, “Offer maybe a Q&A conference call once a month or every other week to begin the project and offer that human interaction to help reduce any confusion with people. I felt like some of the answers given in the email didn't always get answered right away.”

Figure 10: Student recommendations for improved client and project team interaction

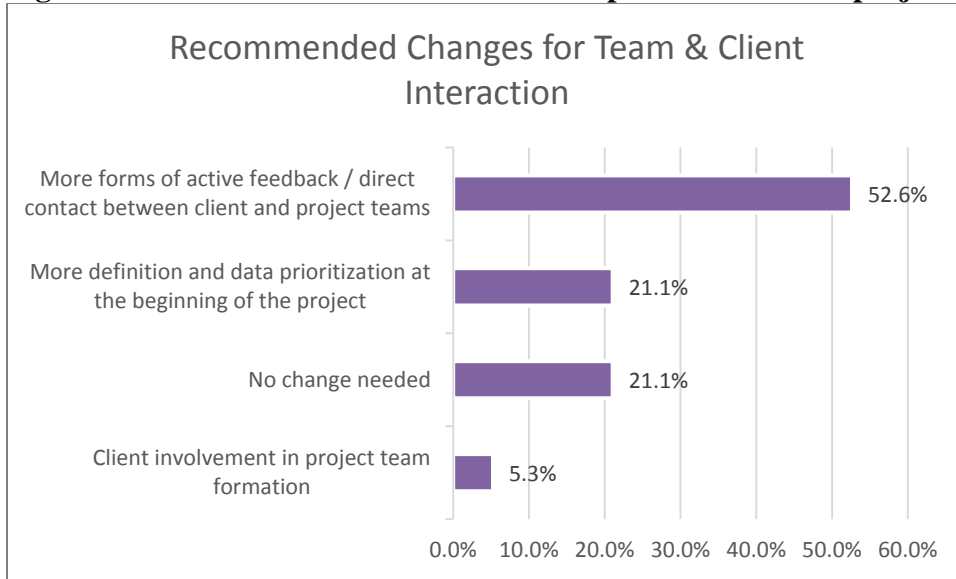
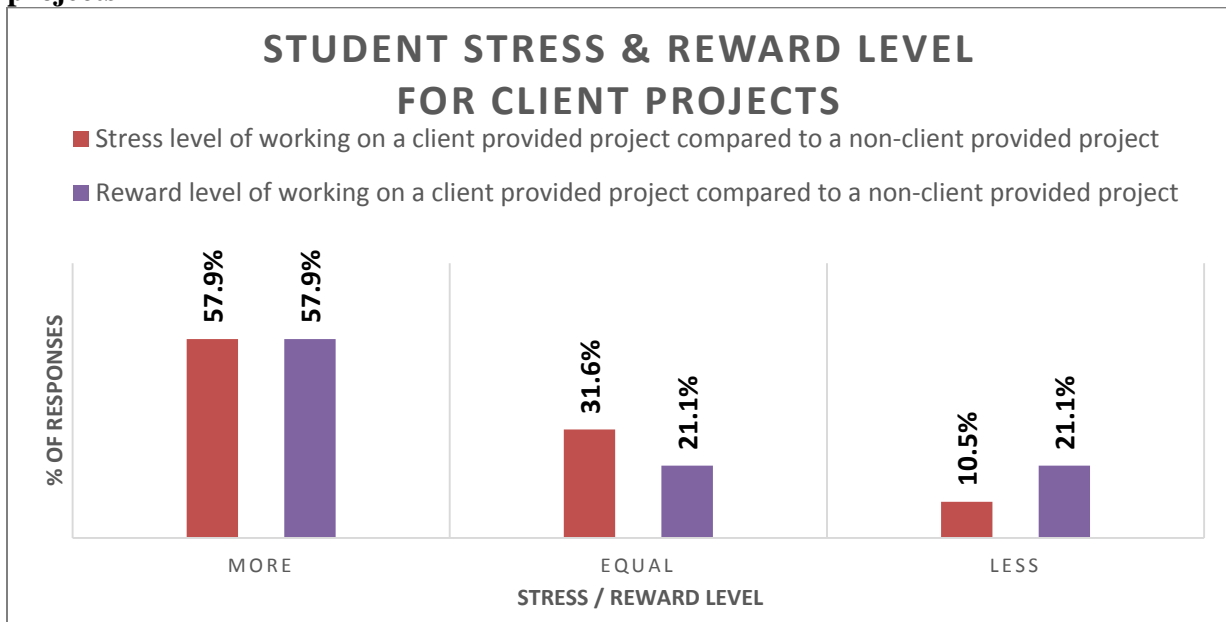


Figure 11: Student perceived stress and reward levels associated with client provided projects



The second survey then asked the student participants to consider the stress and reward levels when working on a project supplied by a client versus a typical class project with no client connection. The answers for both of these questions have been aggregated in Figure 11. The first question specifically asked about the project stress level, for which 57.9% students selected 'Client project more stressful' when contrasted to a non-client project. The second question was similarly constructed but instead asked about students' perception of the reward associated with working on a client project versus that of working on a non-client project. Here, 57.9% of students selected 'Client project more rewarding' when compared to a non-client project.

The last question asking for student feedback on the client-based, open-ended project was in open-ended form and sought their advice for what they would tell a future team working on a similar client problem. Of the 19 students who completed the second survey, 18 answered this question. The responses to this open ended question were summarized into five categories:

1. Start the project early, ask questions, stay structured, and keep deadline,
2. Use "out of the box" thinking and patient exploration,
3. Pick a tool and commit, stay familiar with needed skills,
4. Define group roles and communicate effectively, and
5. Unsure

Nearly 40% of the students agreed that good project advice revolved around starting the project immediately, asking questions early, managing the work and staying organized, and paying close attention to deadlines including not procrastinating. One student explained the issues facing his/her team: "Know in advance that you are going to need to work the entire semester to reach your end goal. We pushed the project off as it had the latest deadline. Which is what we are taught in all of the other classes we have taken to this point. But these projects need to be worked on regularly such that you are always moving forward."

On- and Off-campus Observations

The composition of project teams varied, with some including only on-campus students, some including only off-campus students, and some including a mix of both on- and off-campus students. To gain insight into the impact of group composition on students' experiences, students were asked to indicate whether their teams included on- and/or off-campus students. Of the 34 students who completed the survey during the project, nine students were on teams with only on-campus students, 17 students were on project teams with only off-campus members, and eight students were on project teams comprised of both on- and off-campus students.

When asked about the effectiveness of team communication during the project, most students reported positive interactions as 50% selected that communication was occurring 'Very effectively' and 44.1% selected 'Somewhat effectively'. When responses were broken out by groups with only on-campus, off-campus, or mixed project team members, there were no notable differences in the results.

With respect to dividing project responsibilities among team members during the project, the responses were similar with 47.1% selecting that task division was 'Very effectively' occurring and 35.3% indicating that it was 'Somewhat effectively' occurring. When the responses to this question were broken out by team composition, project teams consisting of only off-campus students had four or the six 'Somewhat ineffectively' responses. Figure 12 aggregates survey

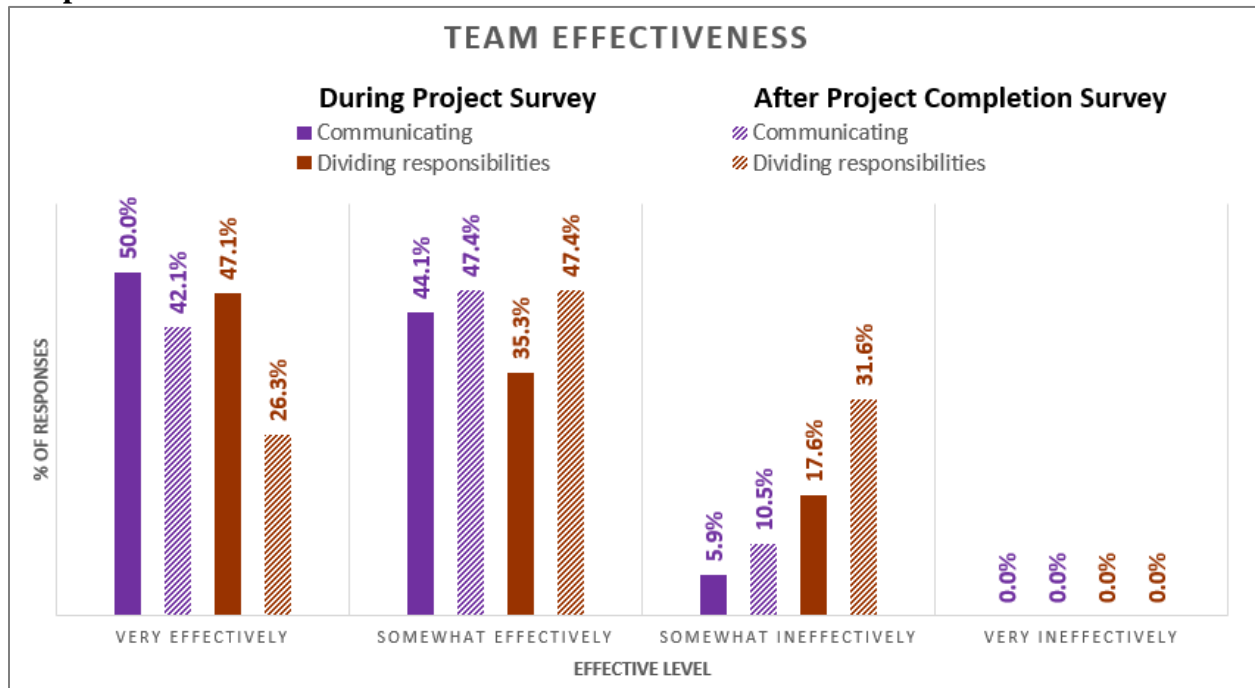
responses for this question as well as the previous question regarding effective team communication.

Among respondents to the post-project survey, seven students were on teams with only on-campus students, 10 students were on project teams with only off-campus members, and two students were on project teams comprised of both on- and off-campus students. Among all respondents, we observed a moderate decrease in self-assessment of effectiveness in both communication and division of responsibility after project completion in comparison to the first survey. This may be attributed to the stress that some teams identified in meeting final deadlines.

When asked about overall effectiveness of team communication upon completion of the project, 42.1% of the students reported positive interactions by selecting ‘Somewhat effectively’ while another 47.4% reported ‘Very effectively’. When responses were analyzed by team composition, there was a slight difference with students in on-campus only groups more likely to indicate that communication was very effective and those in off-campus only groups more likely to indicate this was somewhat effective.

We also analyzed students’ assessment of effectiveness at dividing project responsibilities after project completion. ‘Somewhat effectively’ was selected most often with 47.4% of the students picking this option. Further analysis by team composition revealed no notable differences in the results. Figure 12 aggregates both sets of survey responses for this question as well as the previous question regarding effective team communication.

Figure 12: Student perception of their team’s effectiveness during the project and after its completion



Discussion and Conclusions

The students' responses offer insight into their experiences with this open-ended client project and suggest areas of consideration for graduate course design. Students appreciated the relationship between the open-ended client project and the type or structure of problems they would be expected to solve in industry, but the open-endedness also caused frustration and stress. This was true even among students in professional master's degree programs who are currently working in the engineering profession.

Related to resolving project uncertainty, the availability of real or realistic data emerged as an important attribute from the student perspective. Likewise, the availability of the client liaison to answer questions was identified as important. This observation is consistent with literature on the importance of client engagement in undergraduate capstone design projects. Neither of the universities in this study included a site visit as part of the project, but doing so could help students better understand the problem and engage with stakeholders at the company.

Client participation in project evaluation was viewed as important by students, also consistent with the literature on undergraduate capstone experiences. From the industry partner's perspective, this participation was extremely valuable. The client representatives read and heard presentations on nearly a dozen different solutions to the same problem. A consistent theme in the client remarks was that each team offered at least one unique insight, consideration, or approach to the problem. At the same time, common elements emerged across all solutions that pointed to areas of critical concern.

From the instructor's perspective, we offer several observations to those who may consider implementing a similar project in a graduate course. First, this project required more effort than a typical instructor-defined or student-defined project. There is value in gaining more exposure for oneself to industry problems and certainly in providing students the opportunity to pursue open-ended applications of the course material. Yet this can be difficult in the span of the semester when students are still mastering the material itself.

For the instructor of a course with a combination of graduate and undergraduate students or even master's and doctoral students, industry projects can be complementary to research-based projects. Both provide an open-ended experience, and offering a choice between the two enables students to tailor the project to their professional goals. On the other hand, choosing one project for the entire class can be an advantage for the instructor and for the client. The instructor does not have to keep up with multiple projects and can become more familiar with the single project, making it easier to help students with problems. The client also benefits from seeing the problem and potential solutions from multiple perspectives.

For the instructor of a course that spans multiple degree programs, such as engineering management, operations research, and industrial engineering, it may be appropriate to form teams that include at least one student from each degree program. The students bring complementary expertise in project management, modeling and algorithms, and process improvement that can strengthen the team.

The sample size for this exploratory study limits our ability to generalize to other classes, institutions, or client projects. In particular, the number of students who participated in the project at Mississippi State University is very small, precluding comparisons between institutions. However, the survey results highlight several of the benefits and challenges of client projects in graduate courses and provide guidance for other instructors to consider in their graduate course design.

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