Peer Project Management for Capstone Design Teams

Abstract

The mechanical and mechatronic engineering programs at California State University Chico conclude with a robust, externally funded, two-semester capstone design experience. Students in both majors work in interdisciplinary teams on year-long design projects sponsored by industrial partners. Project teams are assigned a faculty advisor whose role [1] is multi-faceted, but does not include day-to-day project management or responsibility for project success.

Design projects in industry typically have an assigned project manager (PM) with responsibility for overall project success as well as a lead role in initiating, planning, executing, monitoring, and controlling the project. The PM is typically compensated at a higher rate than other members of the team and often has a supervisory or managerial role over them.

There are three primary hurdles to implementing an industrial model of project management in an educational setting. All project team members are peers; none are additionally compensated for PM duties; and none have a supervisory role over the others. The Capstone Design Program at California State University Chico has implemented three alternative models of project management for capstone teams over the past five years. This paper details the various approaches and examines four different metrics to assess the effectiveness of each.

Background

Capstone design programs, where senior engineering students work in teams on design projects sponsored by external partners, are quite common in today's engineering programs [2]. Based on review of the pedagogical literature, management of these design projects is an important and at times problematic issue for these team-based projects. Several papers [3-5] report observed project management issues and corrective measures, such as implementing milestones, formal design reviews, and Gantt charts into the capstone curriculum. Lawanto, et.al, [6] examine student self-regulation while working on capstone desıgn projects, and suggest that team strategies require a high level of student involvement and effort. Vavreck [7] identifies key skills needed by project managers and describes the integration of them into an existing capstone course. Porter, et.al, [8] have implemented a mandatory technical project management course aligned to its capstone senior design course.

But there does not appear to be significant study of peer project management for these design teams, where a student member on otherwise equal footing with the rest of the team assumes the role of project manager. Many questions come to mind, such as; what are the advantages of this approach; what are the pitfalls; are projects, and project teams, more or less successful with a peer project manager; are team dynamics better or worse; how should the student PM be chosen; how should the student PM be evaluated? This paper explores these questions and attempts to quantify outcomes realized while transitioning to a peer project manager model.

From this program's inception and up until five years ago, there was no model for project management of capstone design teams. The subject was taught in the class, with instruction detailing what project management is and generally how project management is done. Specific topics included processes for initiating, planning, executing, monitoring, and controlling projects. Specific tools, such as Gantt charts [9], PERT charts [10], status reports, and dedicated project management software were also presented. But there was no real discussion on the project manager, and the typical model used in industry for managing projects. Nor was project management within the team discussed in any detail. Student teams were left to manage themselves and determine their own methodology of shared responsibility.

Four and three years ago, the industry model of project management was introduced to the class. The profession and potential career path for engineering professionals were presented, along with special training and certifications available in the field. Student teams were allowed to optionally self-select a member to assume the role of PM or to manage themselves within their own methodology. During the past two years, the industry model of project management was more heavily emphasized and student design teams were required to self-select a member to assume the role of project manager. The three different models, which will be used for comparison of outcomes, are summarized in Table 1.

Table 1– Models of Project Management

ID	Years	PM Model
Cohort A	Fall '12- Spring '13	None
Cohort B	Fall '13- Spring '14 Fall '14- Spring '15	Option to self-select PM
Cohort C	Fall '15- Spring '16 Fall '16- Spring '17	Requirement to self-select PM

Metrics

Four different metrics exist longitudinally across the period of study. The first is peer evaluation data that is collected at the end of the project period. The second is a group's assigned grade for *Overall Project Quality*. The third is individual student grades for *Contribution to the Project*. The final metric is a recent survey specific to peer project management that was sent to every member of every class for the period of study. The details of the metrics and their results are summarized in the following sections.

Peer Evaluations

At the end of the project period, students confidentially evaluate their teammates and themselves by selecting a Likert [11] scale response to a series of statements; they also answer a final question. They are asked if they *Strongly Agree, Agree,* are *Neutral, Disagree,* or *Strongly Disagree* with the statements listed in Table 2.

Table 2 – Statements for Peer Evaluations

Q1	The group member did his/her "fair share" of the project work
Q2	The group member attended scheduled group meetings
Q3	The group member was a "team player" and worked well with other group members
Q4	The group member contributed significantly to the overall success of the project

The four statements were developed at the program's inception and have been used consistently since then with no perceived reason to change. Though no rigorous analysis has been performed, the instrument is perceived to have been successful at determining individual student participation. The final question has changed over the period of study. From fall '12 until spring '16, the question asked "*If I were awarding a grade for Project Contribution, the group member would receive a…*" (choice of *A+, A, A-, B+, B, B-, C+, C, C-, D+, D, D-, F*). Starting in fall '16, the final question was changed to "*If had $1000 to award to the team, and was told to distribute it to the members based on their overall contribution, I would award this team member $_____.*" Due to the differing question, and its unlikely correlation to the impact of peer project management, its results have not been included.

Student responses were scored *Strongly Agree* = 5, *Agree* = 4, *Neutral* = 3, *Disagree* = 2, and *Strongly Disagree* = 1. The total number of responses for the three cohorts was A = 222, B = 585, and C = 768. B and C are larger populations due to the data covering two academic years. The increase from B to C corresponds to enrollment growth in the program. The responses for each question were averaged for each group and are shown in Figure 1.
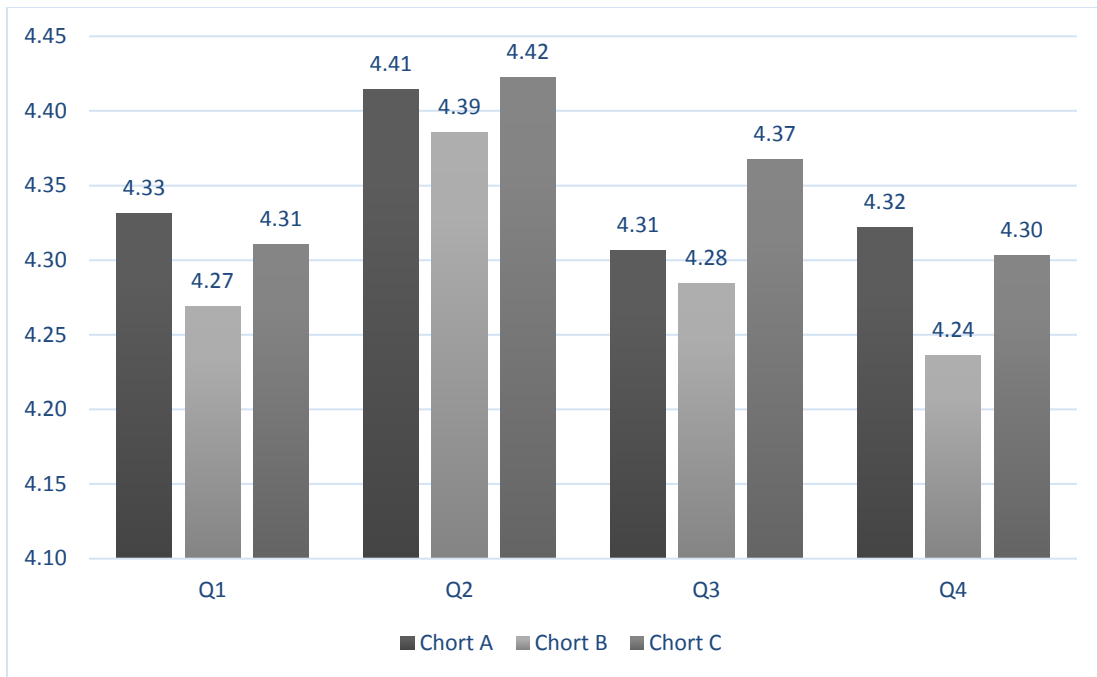

Figure 1 – End of Term Peer Evaluations

The data show that Cohort C (with a requirement to self-select a project manager for the design team) had better overall outcomes on two of the four questions with regard to peer evaluated student performance. Another interesting observation of the data is that Cohort B was consistently evaluated lower than Cohort A. Conclusions are difficult to draw based on the data, but it at least suggests that describing in detail the role of project managers in industry, and then not following through and requiring teams to adopt that model, resulted in lower overall peer evaluations.

Overall Project Quality

At the end of the term, each project team's faculty advisor assigns a group grade (same grade for all team members) for *Overall Project Quality*. The assessment is for the quality of the design solution relative to the difficulty of the project. Due to many faculty's variants on grading schemes, the capstone program has adopted a grading scale of grade points. All student work throughout the year (reports, presentations, posters, individual contribution, etc.) is graded numerically based on the scheme shown in Table 3.

Table 3 – Letter Grades to Grade Points

A	A-	B+	B	B-	C+	C	C-	D+	D	D-	F
4.0	3.75	3.3	3.0	2.7	2.3	2.0	1.7	1.3	1.0	0.7	0

Grades for *Overall Project Quality* were averaged for the entire class for each year. The total number of students for the three cohorts was A = 57, B = 138, and C = 161. B and C are larger populations due to the data covering two academic years. The increase from B to C corresponds to enrollment growth in the program. The average grade point score for *Overall Project Quality* for each group is shown in Figure 2.
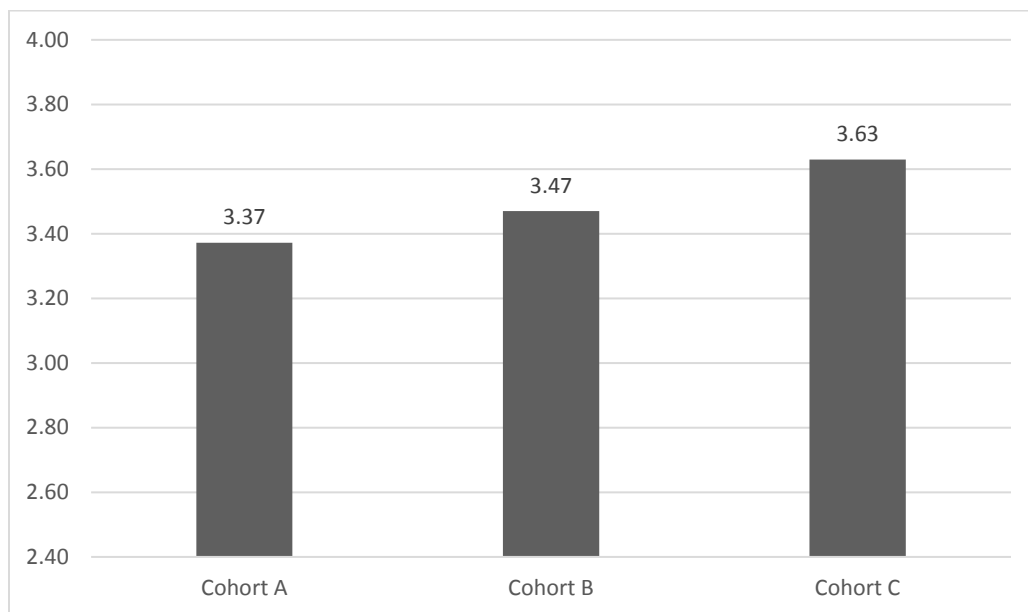

Figure 2 – Grade Points for Overall Project Quality

The data show that Cohort C (with a requirement to self-select a project manager for the design team) had the highest average grade for *Overall Project Quality*. In addition, the data for Cohort B was higher than Cohort A, suggesting that at least presenting the role of a project manager to the class is correlated with improved project quality. Due to the similarity of results, a t-Test [12] was performed at the 95% confidence level to determine if the differences between the cohorts is statistically significant. The results are summarized in Table 4, where a P-Value < .05 indicates that the results are unlikely to have occurred due to sampling error or chance and are therefore significant.

Table 4 – Statistical Analysis of Overall Project Quality Data

Comparison	P-Value	Statistically Significant
A to B	0.389	No
B to C	0.017	Yes
A to C	0.012	Yes

The data do show with high confidence that Cohort C demonstrated the highest overall project quality, but the increased performance of Cohort B compared to Cohort A is not demonstrated with high confidence.

Contribution to the Project

At the end of the term, each faculty advisor assigns each group member an individual grade for *Contribution to the Project*. The assessment is based on peer evaluations and the advisor's observations of the student's performance over the course of the project. Grades for *Contribution to the Project* were averaged for the entire class for each cohort and are shown in Figure 3.
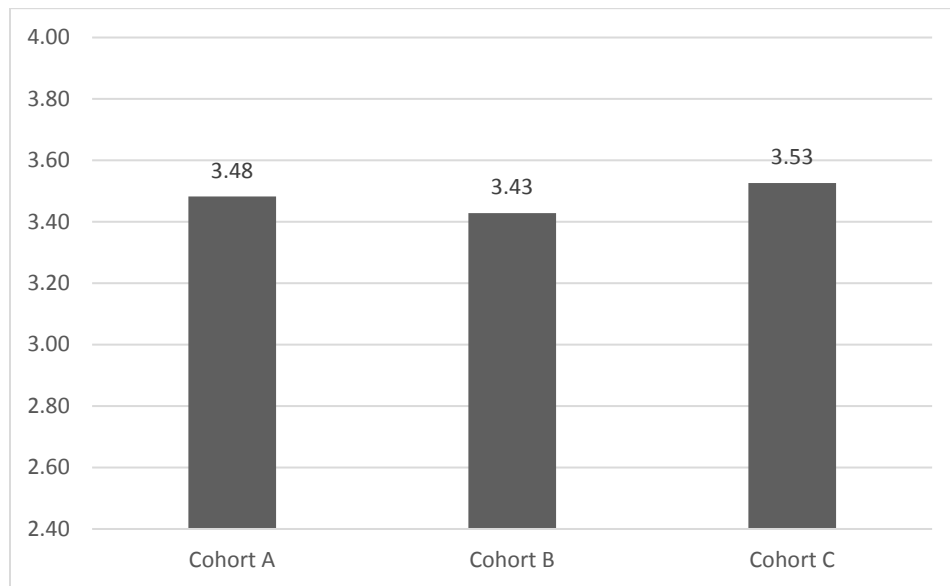

Figure 3 – Grade Points for Contribution to the Project

The data show a minor variation over the three cohorts, with Cohort C (with a requirement to self-select a project manager for the design team) slightly higher than the other two models. But the data appear quite similar, and the results of a 95% t-Test, shown in Table 5, confirm that the results are likely inconclusive.

Table 5 – Statistical Analysis of Grade Points for Contribution to the Project

Comparison	P-Value	Statistically Significant
A to B	0.650	No
B to C	0.691	No
A to C	0.250	No

Recent Survey of Program Graduates

All students from the five years considered for this review were recently invited to participate in a brief survey regarding project management of their capstone design teams. The survey link was sent to their university email address, which is permanent for graduates (but does not ensure that they still monitor the account). The first question simply asked the year they completed the program, and their response was used to assign them to either Cohort A, B, or C. The second question asked whether or not a member of their design team was formally named as the project manager. The remaining questions asked if they *Strongly Agree, Agree,* are *Neutral, Disagree,* or *Strongly Disagree* with the statements shown in Table 6.

Table 6 – Statements for Recent Survey of Graduates

Q1	Overall, I would consider our capstone project to be very successful
Q2	Overall, team members got along well and worked well together
Q3	Our design team had a "slacker" whose contribution was significantly less than the other team members
Q4	Having a project manager contributed significantly to overall project success (leave blank if your team did not have a designated PM)
Q5	There was easy, mutual agreement as to who would be the project manager of our capstone team (leave blank if your team did not have a designated PM)
Q6	Looking back, I think that having a team member act as project manager is a key element of success for capstone design teams

The survey was returned by 73 out of 356 graduates from the program's last five years for an honestly surprising response rate of 20.5%. The total number of respondents for the three cohorts was A = 13, B = 22, and C = 38. Recalling that Cohorts A and B were not required to self-select a PM for the project team, the percentage of respondents indicating that their team did so is shown in Figure 4.
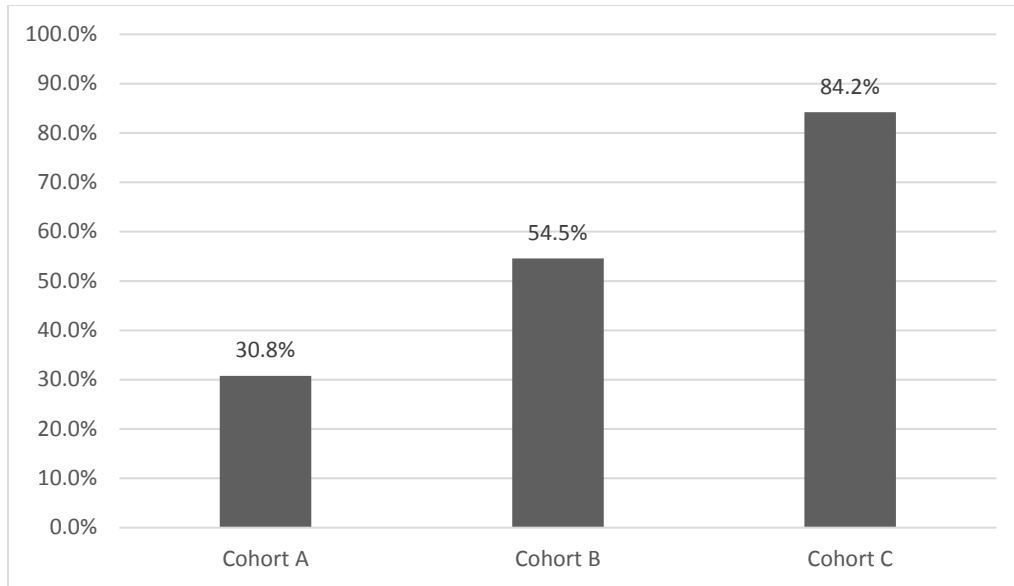
Figure 4 – Percentage of Teams with Self-Selected Project Managers

It is not surprising to note that introducing the concept of a team selecting a PM, as was first done with Cohort B, resulted in a higher percentage of peer project managers in that group. It is somewhat surprising to note that almost a third of teams in Cohort A did so, with no mention of the option to the class. Finally Cohort C was expected to report 100%. An inference may be that, while teams were required to identify one, they didn't actually function in that way.

Data for the six questions are summarized in the two figures below. Student responses were scored *Strongly Agree* = 5, *Agree* = 4, *Neutral* = 3, *Disagree* = 2, and *Strongly Disagree* = 1. The scores for each question were averaged for the population being considered. The results are first grouped by cohort as defined in Table 1 and are shown in Figure 5.

Responses for question 1 (student assessment of overall project success) are higher for Cohorts B and C, indicating a benefit to introducing the industrial model of project management to the class. It's worth noting that while likely not statistically significant, Cohort C (required PM) scored slightly higher than Cohort B (optional PM).

Question 2 (harmony within the team) interestingly scored highest for Cohort B. This is a possible indication that not forcing the group to select a PM may result in improved dynamics within the team.

Question 3 was added with the intent of discovering whether or not a peer project manager can be effective in motivating the team member often referred to as a "slacker;" one that does not contribute significantly, does the minimum to get by, and rides the coattails of his/her teammates to a passing grade in the class. The data first show that a team slacker is a fairly common occurrence. The data also suggest that some level of project management within the team (Cohorts B and C) may reduce the prevalence of slackers on capstone design teams.
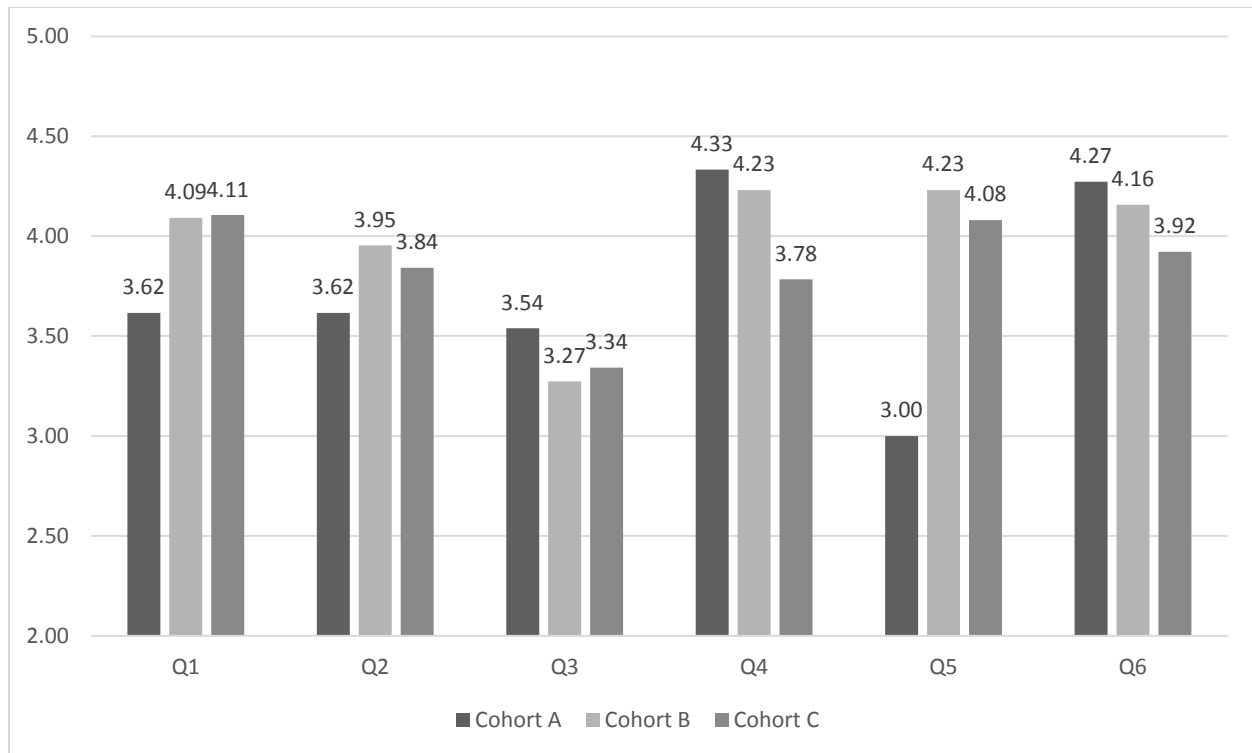
Figure 5 – Likert Responses by Cohort to the Survey Questions

Question 4 (the presence of a PM contributing to project success) was presumably only answered if the respondent's design team had someone in the role of project manager. Interestingly, the highest result comes from Cohort A (but is based on only 6 respondents). Also of interest is that the lowest result comes from Cohort C with a robust 37 respondents. A possible interpretation is that forcing the group to self-select a PM may negatively impact the perceived value of having one.

Question 5 (ease in selection of the PM) was also presumably only answered if the respondent's design team had someone in the role of project manager. The low result from Cohort A may not be statistically significant with only 6 respondents, but the data from the other two cohorts (50 respondents) does indicate an easier process if it's not forced on the team.

Question 6 (having a PM contributes to overall project success) first of all indicates a very high correlation among all three cohorts. It is notable however that the least agreement comes from Cohort C who were forced to self-select one for the design team.

The survey results were then grouped without regard to cohort but instead as to whether or not the respondent's team utilized a peer project manager. Of the 73 total respondents, 48 indicated that their design team utilized a PM while the remaining 25 did not. As expected, the majority (32) are from Cohort C, but Cohorts A and B also had 4 and 12 respondents respectively indicate that their team utilized a PM (refer to Figure 4 for the percentage breakdown). The responses to questions 1 through 6 were once again scored *Strongly Agree* = 5, *Agree* = 4, *Neutral* = 3,

Disagree = 2, and *Strongly Disagree* = 1. The scores for each question were averaged for the population being considered. The results are shown in Figure 6.
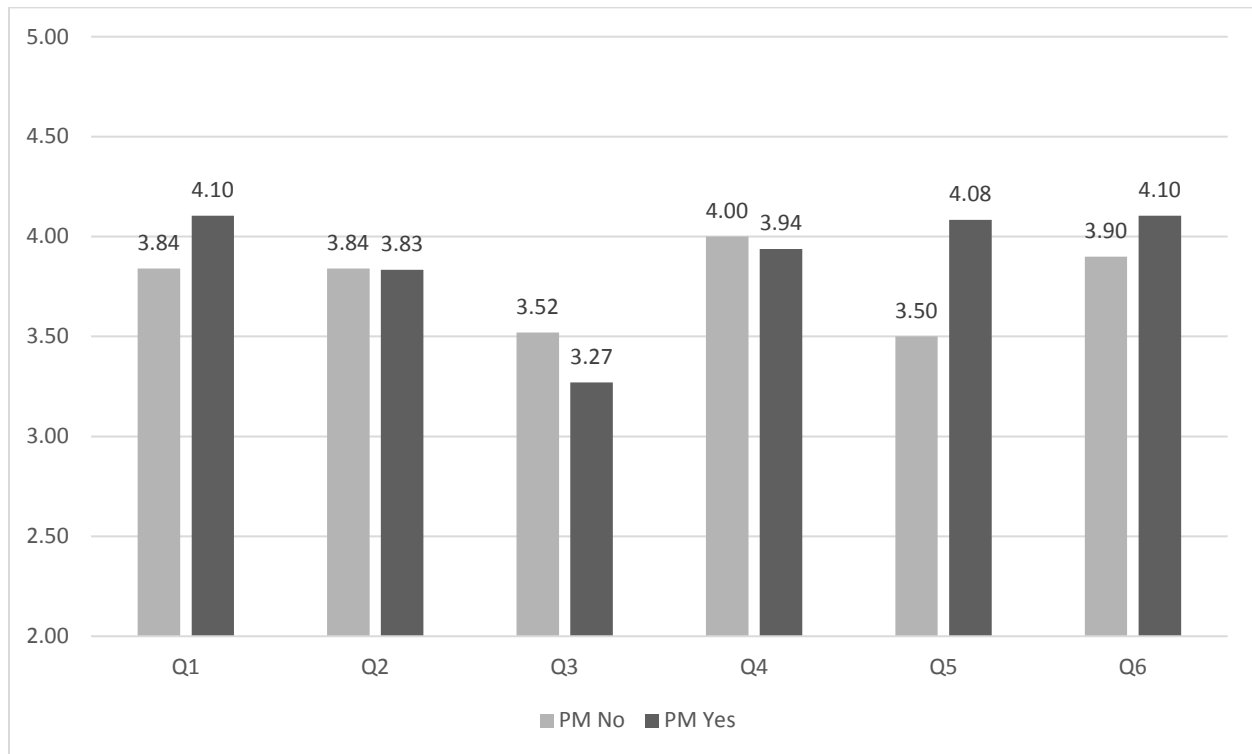

Figure 6 – Likert Responses by Presence of a Peer Project Manager

Responses for question 1 (student assessment of overall project success) are notably higher for groups that utilized a peer project manager and also indicate an overall high level in their self-assessment of project success. Results for question 2 (harmony within the team) were essentially identical between the two populations. The outcome of question 3 (the presence of a slacker on the team) does suggest that having a peer project manager on the team may be an effective means of motivating otherwise unmotivated students.

Moving on to questions 4 (the presence of a PM contributing to project success) and 5 (ease in selection of the PM), respondents were instructed to leave the question blank if their team did not have a designated PM. However, for both questions, 8 of 25 respondents who reported that their team did not have a peer project manager still chose to answer the question (the questions were answered by all 48 respondents who did indicate a PM).

Data from the PM group indicate a relatively high agreement that a peer project manager is a contributing factor to project success, and also that it was a relatively smooth process to select one. Data from the non-PM group are difficult to interpret, but perhaps something may be gleaned from the relative low score for the ease of identifying a PM.

Question 6 (having a PM contributes to overall project success) provides some interesting insights when the data are parsed in this way. As discussed earlier, the results generally indicate

a high correlation between the presence of a peer project manager and project success. It is noteworthy that of the 25 respondents who reported that their team did not have a peer project manager, 20 (80%) chose to answer the question. And their responses do indicate a relatively high level of agreement that a PM contributes to project success, even though their capstone design team did not utilize one.

Comments from Program Graduates

A final question in the survey offered respondents the opportunity to provide additional comments. A surprisingly large number (40 of 73) elected to provide some sort of written comment. The comments are of particular interest as they come from working engineers, some of whom have been in industry for as long as five years. Selected responses have been sorted into the generally positive, the somewhat critical, and others that may be of general interest.

Generally Positive Alumni Comments

- *I believe the Project Manager "position" helped keep tasks in sight and scheduling reflected real-world goals and missed deadlines. Utilizing programs such as Asana or Microsoft Project was good preparation for real-world project management software that is used in larger corporations*

- *I think the experience the project manager gets is very valuable.*

- *Not only is having a project manager crucial to the success of the project, being the project manager was valuable experience that translates to on the job success years later.*

- *I was the Project Manager, while it was difficult at times I learned a great deal from it and feel like the experience has definitely benefited me in my career.*

- *The capstone project was a highly significant part of my engineering education and has played a key role in my career. The opportunity to work on a team of student engineers designing, and building a tangible deliverable with the challenges of team dynamics, supply chain logistics, deadlines and budget gave me experience I could share with direct effects in my first interviews.*

- *If a project manager is chosen well, the team will enjoy the benefits. If not, then everyone generally shares the role, even if a designated PM has been selected.*

- *While it worked out for our team during the course, a Project Manager has been very beneficial to have in a working environment. Having additional experience in that position would have been useful for the times when there isn't one available.*

- *Having a project manager allows other members to focus on their intended roles without having to worry about logistics, scheduling and sponsor contacts.*

- *Even though we didn't have a formal project manager we figured out our strengths and we had one person who contributed a lot to the report and schedule, one that did most the design, build and testing, and one that helped with building and testing. A project manager might have been able to motivate the "two slackers" on the team to make them contribute more and enforce their tasks. Instead the 3 project contributors took over the slackers' tasks to ensure the team goals were met.*

- *Having a qualified project manager that is willing to put in the time would have made the difference between having a good idea that doesn't work out or get completed on time and having a complete working solution at the end of the project.*

- *I believe and project that has a core team larger than 2 requires a project manager. This eliminates the risk of assuming that another team member will complete a task. Communication is easily missed without an organized leader*

- *In my opinion having a student designated as the project manager is very important for 2 main reasons. #1 it is an extremely valuable learning experience for the project manager that directly correlates with the real world work force. #2 it gives the students a chance to split up tasks that may be undesirable.*

Somewhat Critical Alumni Comments

- *Our elected project manager did not have a strong enough personality to be a strong leader. Luckily all members worked well together and the need for an overseer was not crucial to project success.*

- *I believe having a project manager who would properly do their job would have contributed to the success of being project manager. However in my experience the project manager took the title and did not act as a manager. This left another group member to fill the role and created animosity between certain group members. However, overall I enjoyed the experience and appreciated all the help given by the faculty.*

- *I think leaders naturally emerge over the course of the project, who may or may not be the designated project leader. I don't think our designated leader was really the one leading our group.*

- *We had a PM who caused division and shut down ideas that were not his. It was despite this that our project succeeded. I think a PM is important to a project, but there needs to be a better process for their selection.*

- *Seemed like the project manager had extra duties as far as planning but didn't seem to increase overall project success.*

- *Having a strong, agreed upon project manager is critical to the success of a team. In our project, there was disputes over who the PM was which resulted in competing ideas. This ultimately caused our project to fail.*

- *Having/Being a project manager added a weird dynamic to the team when they had no real power over the team.*

Alumni Comments of General Interest

- *I was the project manager for our capstone project, but also was the control system engineer. I think it can be difficult to be both as effectively as it is to wear just the PM hat. Of course this depends on the individual, and if they have any project management relevant experience. I had taken a class with "Captain Morgan" in project management, but most engineers do not take a class in project management. How can an engineer know how to run a job if he has no experience running the job? Maybe engineers need an elective in project management / sales engineering, to further broaden the doors for employment.*

- *Our team had one person who was very difficult to deal with and one person who did nearly nothing. However, at my new job the exact same scenario has been happening. So overall, I would say the Capstone teams have been an excellent preparation for the real world. Especially government jobs...*

- *Though we did not have a designated PM, myself and one other student in the group acted and co-PMs. I handled the mechatronic side of the project and he handled the mechanical side of project. The two of us would collaborate on final design choices as we had technical skills the other did not have. We never officially assigned these roles. He and I just took them on and no one else in the group complained. This was very beneficial for our project due to the nature of our team members and the project we were working on.*

- *Four of us worked really well together and got work done smoothly. There was just one member that did not contribute effort or knowledge to the team. Overall we had a good team, just not a great solution for the project. Did not feel like we needed a PM.*

- *Our team was a little unique in that we never "officially" named anyone lead PM, but it kind of worked out to the point where everyone had mutual respect for each other and were willing to comply with their peer requests (the PM). Without a rank hierarchy it relies on mutual respect.*

- *The team had a mutual understanding that we all had to do our part in the areas that we exceled in in order to complete the project. We did have 1 member who did not do their part and the rest of the team had to pick up the slack. However having a project manager may be a benefit when the team is new in order to delegate work and to make sure that the group members are completing their tasks.*

- *Our project did not have a lead project manager but having someone whose main job was keeping the project on pace to finish elements of the project in a timely manner was a great asset.*

- *My capstone project greatly increased my confidence going into the workforce and also equipped me with powerful experience that I could use for my resume. I look back on my senior year and am proud of what I accomplished. Thank you Dr. Watkins for providing us with such a great and challenging program.*

Conclusion

This paper presents a significant amount of data gleaned from the past five years of a capstone design course that implemented three distinct models of project management for student design teams. Taken in whole, the data support the conclusion from earlier literature that project management is an important aspect of capstone design projects. The data also show that naming a peer project manager from within the team is correlated with improved peer evaluations and overall project success. The data additionally show that student impressions after the fact consistently support project management as an important aspect of project success, whether or not their particular design team utilized a peer project manager.

The data are less clear about the different approaches between Cohort B (option to self-select a PM) and Cohort C (requirement to self-select a PM). Peer evaluations and project quality (as assessed by the faculty advisor) both report better outcomes for Cohort C. But alumni survey data show slightly better outcomes for Cohort B with regard to teams working well together, the presence of a peer PM contributing to project success, and the ease in selecting the peer PM.

A final conclusion from the data has to do with underperforming students on the team, or "slackers," as they are commonly referred to. Cohort A (no model for project management) displayed a higher incidence of slackers, as did teams without a designated project manager.

Returning to the questions introduced at the beginning of this paper, and considering written comments from alumni:

- *What are the advantages of this approach?* Improved project quality and success, improved peer evaluations, a significant learning experience, and the ability for students to know their role and be able to focus on it.
- *What are the pitfalls?* Difficulty in selecting the student PM, undermining team dynamics, and poor outcomes as a result of selecting the wrong member of the team to be the PM.
- *Are projects, and project teams, more or less successful with a peer project manager?* The data indicate that they are, but alumni comments reveal that is not universally so.
- *Are team dynamics better or worse?* Better if a peer project manager is identified, but potentially not as good if the team is forced to select one.
- *How should the student PM be chosen?* This question is left unanswered, as the data do not suggest a clear path forward on this issue. Future work is recommended on the topic.
- *How should the student PM be evaluated?* Alumni comments suggest issues with ineffective peer project managers. Though not presented here, the program performs peer evaluations at the mid-term of each semester. It is suggested that each team's PM be carefully reviewed at this time, with corrective action taken as needed.

Going forward, this program will continue to utilize the model of requiring teams to identify a project manager. To improve the model, plans are in process to provide additional instruction and support specifically for PMs as a separate cohort. Additional evening class meetings are planned just for the student PMs. Local alumni, whose primary job is project management, are being sought to serve as resources and mentors, and offer first-hand examples of effective management tools and techniques. A follow-up survey is planned after the changes have been fully implemented.

References

1. Watkins, G., "*Best Practices for Faculty Mentorship of Capstone Design Projects*, Proceedings of the 2011 ASEE Annual Conference, Vancouver, British Columbia
2. Howe, S., Poulos, S., & Rosenbauer, L., *The 2015 Capstone Design Survey: Observations from the Front Lines*, Proceedings of the 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana
3. Wilson, S., & McIntyre, M., *Revitalizing A Capstone Design Sequence With Industrial Project Management Techniques,* Proceedings of the 2010 ASEE Annual Conference & Exposition, Louisville, Kentucky
4. Wilson, S., Cambron, M, & McIntyre, M., *Assessing and Improving a Capstone Design Sequence with Industrial Project Management Techniques,* Proceedings of the 2011 ASEE Annual Conference & Exposition, Vancouver, British Columbia
5. Allenstein, J. T., & Whitfield, C. A., & Rhoads, B., *From the Industry to the Student: Project Management of an Industry-sponsored Multidisciplinary Capstone Project,* Proceedings of the 2012 ASEE Annual Conference & Exposition, San Antonio, Texas
6. Lawanto, O., & Cromwell, M., & Febrian, A., *Student's Self-Regulation in Managing Their Capstone Senior Design Projects,* Proceedings of the 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana
7. Vavreck, A., *Project Management Applied To Student Design Projects*, Proceedings of the 2002 ASEE Annual Conference, Montreal, Canada
8. Porter, J., & Zoghi, B., & Morgan, J., *Integrating Project Management Into The Capstone Senior Design Course,* Proceedings of the 2002 ASEE Annual Conference, Montreal, Canada
9. Clark, W., Polakov, N., Trabold, F., *The Gantt Chart: A Working Tool of Management*, Ronald Press Company, 1922
10. Malcolm, D., Roseboom, J., Clark, C. and Fazar, W. "*Application of a Technique for Research and Development Program Evaluation*," OPERATIONS RESEARCH, Vol. 7, No. 5, September–October 1959, pp. 646–669
11. Likert, R., *A Technique for the Measurement of Attitudes*, Archives of Psychology, 140 (1-55) 1932
12. Glidden, C., "*How to Design and Evaluate Research in Education,*" Psyccritiques 38.10 (1993): 1125.