

Using Graduate Assistants as Project Advisers for Externally-Sponsored Capstone Design Projects*

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Capstone design is an opportunity for students to apply their newly obtained knowledge in a real-world setting. Oregon State University's School of Mechanical, Industrial and Manufacturing Engineering provides students with choices of internally (originating from within the department offering the capstone course) and externally sponsored projects and uses an assessment system based on written reports and the quality of the deliverable (e.g. prototype). Providing different projects for each group of students has made tracking and managing the progress of each project difficult. The large amount of work required to provide the necessary support for students has historically fallen to faculty. However, recently, much of this work has been shifted to graduate student assistants. The graduate students serve as technical advisers, project managers, centralized communication hubs, and report graders. When compared to faculty, graduate students tend to be more accessible to students, project sponsors, and instructors; they seem more motivated to provide high quality results, they provide comparable levels of student assessments, and they are easier to hold accountable. For many graduate students, the capstone projects are extensions of their research. Concerns over graduate student inexperience are resolved by having a faculty member available for support as necessary. Several tiers of graduate advisers are used and are illustrated through case studies. The first tier uses graduate students simply as report graders. The second tier adds project advising. The third tier adds responsibility for creating a device, such as testing equipment, for the capstone students' use in validating that their design meets requirements. The fourth tier includes grading, advising and responsibility to extend, as necessary, the output of the capstone students' work to create a fully functioning deliverable for the sponsor. The fifth tier is similar to the fourth, but the project topic is a key component of the graduate students' degree research. Through case studies, faculty and graduate adviser grade comparisons, and content analysis from student reports, Graduate Assistants have been observed to be valuable contributors to an enhanced capstone course at all levels of involvement.

Keywords: senior design; capstone; graduate advisers; graduate mentors; mentor; protégé

1. Introduction

Traditionally, faculty members served as project advisers at the School of Mechanical, Industrial and Manufacturing Engineering (MIME) at Oregon State University. However, with an increasing number of projects, a growing class size, and more demanding industry sponsored projects, the demands on time from faculty members has increased to a point that is not manageable anymore. Utilizing graduate students as advisers can help alleviate the faculty's load and potentially become a viable solution to meet the demands of Capstone courses. Therefore, the purpose of this paper is to present preliminary results based on the use of graduate students for Capstone project advisers at the School of MIME at Oregon State University. The authors conducted a study to explore the potential benefits of graduate students serving as Capstone project advisers under the supervision of a course instructor. It is worth noting that the authors of this paper have been involved with the MIME capstone senior design class, as graduate advisers and as faculty instruc-

tors/advisers. The study relied on the use of five layers of mentorship to categorize graduate student advising involvement levels. The observations were supported by a comparison between faculty and graduate student grade data, as a means to verify the consistency between both groups of advisers. Finally, based on successful characteristics of mentor-protégé relationships [1, 2], a content analysis was performed utilizing student deliverables such as final project reports and experience memos in order to compare undergraduate student satisfaction before and after graduate student involvement in Capstone courses.

The authors (i) provide a brief summary of supporting literature (ii) an overview of the OSU MIME Capstone design course, (iii) describe the specific roles and duties of GA project advisers through a series of case studies based on mentor-protégé relationships, (iv) present a comparison between observations and data analysis (v), provide an overview of the benefits for graduate advisers, (vi) explore potential issues that may arise with the practice, and (vii) present conclusions and future work.

2. Literature review

2.1 Capstone projects and their purpose

Capstone projects are used in almost every university in the United States that offers an engineering degree [3, 4]. These courses fulfill key requirements outlined by the Accreditation Board for Engineering and Technology (ABET) [3, 5, 6]. They are used to teach the design process while giving students the ability to apply their knowledge in (near) real-world scenarios. Capstone projects serve to bridge the gap between classroom learning and application [7]. Though every course is different, all courses require that students design a solution to a given problem, and then, in many cases, implement this design. These courses not only give students the chance to apply their knowledge in real-world scenarios, but they provide a method for assessing a student's engineering abilities as a whole.

One particularly effective style of capstone design course uses a system where teams of students are given projects sponsored by industry or other external partners [3, 4, 6, 8] (i.e. not from faculty in the department offering the capstone course). Businesses are looking for engineers that have real-world experience, so there is a strong push for universities to provide graduates that have experience with realistic projects [8]. This approach helps give students a wide range of design opportunities while cultivating many of the skills that have been taught throughout their undergraduate degree program.

An effective strategy for Capstone courses is to have a portion of student assessment be based on how effectively the student's designs meet the project requirements set out by the project sponsor [6, 7, 9]. This provides a contract between the project sponsor and the group of students. External sponsors are more comfortable investing in projects and course instructors are less likely to have a shortage of projects because the sponsors will return as a result of positive project outcomes and truly useful deliverables. This arrangement is beneficial for the students too; just as with normal classes, a student's grade depends on their performance in the class, but even beyond this, there is an added incentive to perform because the project sponsors are depending on the quality of the deliverable they provide. Consequently, providing students with an opportunity to be responsible to the sponsor for the quality of project's deliverable can potentially motivate them and give them realistic work experience.

2.2 The need for mentorship

One of the largest obstacles that must be overcome with all capstone design courses is the inherent lack

of experience of the students. Some instructors will claim that the students are simply incapable of performing the necessary level of engineering required to reach project goals. However, it has been observed that students may achieve success provided they receive adequate advisement, guidance, and evaluation throughout the design process. There is a need for supervision in terms of technical work and project management; in essence, there is a need for guidance and mentorship. The logical source for this mentorship would be the course instructor or another faculty project adviser/mentor. However, Graduate assistants (GA) can have the necessary skills to be an adviser; therefore, appropriately selected and supervised graduate students offer an excellent choice to serve as project mentors/advisers with externally-sponsored projects [10–17].

2.3 Graduate advising/mentoring programs

Using graduate students to aid with undergraduate classes is not a new idea. Graduate teaching assistants have been used to grade, assist, and teach classes in universities throughout the country. However, there are concerns that undergraduates would not rate graduate students as well as faculty in terms of teaching capability. Daniele [10] showed that in student evaluation forms taken by students at Oregon State University, graduate teaching assistants and faculty were rated the same across a university wide study; thus dismissing claims that graduate students do not provide equal resolution of education when compared to faculty.

Perrin, Thompson, Agarabi (et al.) [11] explored three case studies where graduate students were assigned to work alongside undergraduates to fulfill sponsor company expectations. The first study explored graduate students being assigned work with undergraduates, where the graduate students continued working on the project to meet sponsors' expectations. The second study investigated a graduate student managing undergraduates in a class project. This ultimately helped with the graduate student's thesis completion. The final study focused on a graduate student becoming a teaching assistant for an undergraduate course. The course incorporated a sponsored project which was used to satisfy independent study credits for the graduate student. This also involved a team project for the undergraduate course. Ultimately, this case resulted in the graduate student successfully supervising the undergraduate students to meet customer expectations. These investigations showed advantages for undergraduates, graduate students, and faculty for all cases. The undergraduate students were able to work on real-world problems and were able to develop relationships with graduate students. This

allowed the undergraduate students to understand the process of obtaining advanced degrees. The graduate students benefited directly when the project was applicable to their thesis. Graduate students would also gain the invaluable experience of being a mentor and supervisor. This allowed for faculty advisers to focus on larger programs rather than micromanage undergraduate student teams. By allowing graduate students to serve as the daily point of contact for the local company and undergraduates, the faculty adviser would be able to dedicate time commitments to more pressing responsibilities.

Another study by Sheppard [12] utilized graduate students as capstone project advisers while investigating a systems engineering framework for multidisciplinary capstone design courses. This research also saw benefits of applying graduate students as mentor/advisers. They noted that with faculty involvement, advising allowed graduate students the opportunity to practice leadership and management in a real world setting.

Zhan, Goulart, Morgan (et al.) [13] investigated a capstone course model where faculty members sponsored projects rather than external industrial companies. This particular project forced the undergraduate students to interact with both faculty and graduate students to accomplish project goals and ultimately coordinate a transition from the capstone design course to actual research. The study illustrated how the project design provided an opportunity for all involved parties to work together in a real-world scenario for large scale engineering projects. It was observed that if this process is implemented properly, it could potentially provide unique advantages to undergraduates, graduate students, and faculty.

Odom, Beyerlein, Tew (et al.) [14] described a very successful model in which graduate students were directly implemented as advisers for capstone courses. Specific roles for the advisers involved mentoring, helping to define project scope, answering technical questions, assisting with CNC operations, supporting fabrication processes, and providing team building activities for the undergraduates to ensure a successful project. This model was applied successfully with many graduate students stating that the capstone mentoring program enhanced their graduate education. They noted that they received real life experience in engineering soft skills such as leadership, teamwork, and communication. Similar investigations observed that the increased work load on graduate students may interfere with thesis and coursework; however, the developments of professional skills that come with mentoring are priceless [15–17].

2.4 Mentor/protégé relationships

In order to successfully implement a mentor/adviser program for capstone courses, one needs to consider the requirements for successful mentor-protégé relationships. A study conducted by Cesar and Fraser [1] described a method for graduate students to evaluate faculty as advisers and mentors and concluded that the main factors for successful mentoring are the following:

- Genuine interest in educational development.
- Ability to provide constructive advice and assistance on research, data collection, data analysis, and report writing.
- Friendliness and availability.

This list of necessary aspects can be directly translated to undergraduate students and graduate mentors/advisers in capstone courses. In order to have a successful capstone experience, effective mentoring practices should be integrated into the activities of the capstone advisers.

Another study conducted by Haines [2] thoroughly investigated mentor-protégé relationships while incorporating the theoretical basis which support mentoring as an education tool. Haines explored attributes of successful mentor-protégé relationships, benefits and pitfalls of the relationship, stages for the relationship, and specific details on how to be an effective mentor. Table 1 summarizes the attributes necessary for an effective mentor.

As with the attributes described by Cesar and Fraser [1], these qualities are directly applicable to the mentor-protégé relationships for advisers and undergraduates in capstone courses. The attributes listed in Table 1 can be used as an effective measure of performance for advising. If these attributes are

Table 1. Summary of Effective Mentor Attributes—Modified from Haines [17]

Provide Support

- Listen
- Create structure
- Express positive expectations
- Serve as an advocate
- Share yourself
- Make special gestures to foster the relationship

Provide Challenge

- Assign challenging tasks
- Engage in discussion
- Explore dichotomies
- Construct hypotheses
- Set high standards

Provide Vision

- Model exemplary behavior
- Develop new language and new ways of thinking
- Nurture the protégé's self-awareness

present in mentors/advisers activities, then it is implied that successful mentor-protégé relationships have been constructed.

3. OSU MIME capstone design course

The capstone design course follows the engineering design method and is required for all undergraduate students in the school of Mechanical, Industrial, and Manufacturing Engineering. The course typically has an enrollment of about 160 students. Approximately 30% of students opt for projects associated with OSU's highly successful SAE formula and baja vehicles and are shifted to a separate section. The SAE section of the course is not discussed further in this paper as it follows its own structure and possesses its own challenges. The remaining students are divided into groups of size three, resulting in approximately 40 project teams. Projects for the course are obtained from both internal and external sources. In both cases, sponsors are expected to provide funding for materials and supplies associated with implementing the design (e.g. building a prototype). For externally-sponsored projects an additional \$5,000 donation ("sustaining donation") is requested. This donation is used for miscellaneous expenses associated with the course. The course spans two 10-week terms (typically fall and winter quarters).

The first term focuses on creating a document that describes each team's design solution in detail. During the first term, the student teams are required to submit three reports, a Background Report, a Preliminary Proposal and a Final Proposal. The Background Report contains relevant information found in current literature and the Customer Requirements (requirements in the language of the project sponsor). The Preliminary Proposal details a minimum of three design concepts and adds Engineering Requirements (technical, measureable, specifications) that are connected to the customer requirements using a House of Quality [7]. The Final Proposal adds a detailed description of the chosen design along with an outline of testing procedures (one for each Engineering Requirement). Student course grades for the first term are based on the degree to which the design process was followed and properly documented.

The second term focuses on design implementation and testing. Students are provided with a budget by the project sponsor and resources to implement and test their design solution based on their engineering requirements. A final report is generated that includes testing results and describes all changes made during implementation. Student course grades for the second term are split 50–50% based on the degree to which the design process was

followed and documented, and on the degree to which the design deliverable meets requirements.

4. Use of graduate assistants as mentors: levels of involvement

4.1 Case study summary

The OSU MIME Capstone Design Course has in the past exclusively used MIME faculty as project advisers. They were typically tasked with grading written reports and acting as a source for technical advice. Starting in 2009, the MIME Capstone Design course began using GAs as project mentors/advisers for some of the externally-sponsored projects. This decision was the result of a growing capstone design program that began requiring more adviser interaction. The first graduate advisers were assigned to projects that were directly related to their own research. Several graduate research assistants that had been performing research with industry or other external partners assigned portions of their work as capstone design projects. Due to the perceived success, more GAs started to be assigned to oversee projects.

In order to illustrate the evolution of the usage of GAs in the MIME Capstone, five representative case studies (projects) were selected and are presented in sections 4.2 to 4.6. Each case study involves a graduate student with a different level of involvement: from simply grading to applying the capstone design project deliverable to thesis research. The five case studies present a combination of GA responsibilities seen in Fig. 1.

4.2 Case study 1: grading

4.2.1 Background

The Oregon State University Solar Car Team has been an innovative program involving engineering primarily from students. The solar car team needed to upgrade their vehicle's front wheel fairings and improve the vehicle's body aerodynamics. To achieve these goals, the team sponsored a capstone project. As a university-wide, student-staffed team

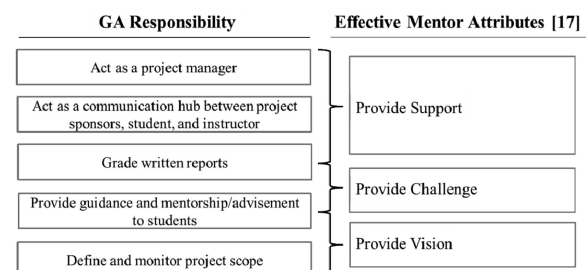


Fig. 1. Comparison between GA responsibilities and effective mentor attributes

the solar car team fits the definition of an external sponsor.

4.2.2 *GA Involvement*

Given the close proximity and interaction with the solar car team, the use for a graduate student in this project was simply to grade the student team's reports. The GA had no other involvement other than grading reports and providing written feedback to the team. In this case, the GA was also the course teaching assistant. His role as grader for this project was considered part of his duties as a teaching assistant. The major advantage the GA provided in this project was to reduce the work-load on the course instructor. Equipped with a detailed grading rubric, the GA was able to properly grade the reports. The GA noted that a disadvantage to this method was that there was limited involvement with the team to discuss grades or ways to improve reports. This in turn, caused some frustration to the student teams. However, the students' scores in subsequent reports improved during the course so, at some level, the necessary communication was occurring.

4.2.3 *Potential implications of involvement*

Employing the GA only as a grader can be effective under certain conditions. First, the external sponsor must provide the necessary technical supervision at a suitable level and frequency. Second, the graduate student must be provided with a grading rubric of sufficient detail to properly grade the reports. Finally, either through meetings or written comments, the capstone students must be provided with the necessary feedback to improve their writing.

4.3 *Case study 2: grading and advising*

4.3.1 *Background*

A common medical device used for immobilization of injured joints is the splint. SAM Medical Products (SAM) is a manufacturer of flexible splints (SAM Splints) for military, backpacking, or other field work. SAM wanted to upgrade their manufacturing process to reduce product-packaging time. The packaging machine used was very operator intensive and did not allow for insertion of accessories, such as bandages, into the splint package. The goal of the project was to create a fully-automated machine that quickly packaged SAM splints and inserted a roll of bandage into the package. For this project, two student teams were assigned each having to come with a unique and independent solution to the project.

4.3.2 *GA involvement*

The tasks for the GA in this project were grading

reports, providing technical guidance, and being a single point-of-contact for all project stakeholders. Performing these tasks involved conducting weekly meetings with the capstone students, weekly meetings with the course instructor, and occasional meetings with the sponsor. The GA had no direct responsibility for the quality of the project deliverable. The time frame of involvement for the GA was a week before the course began to the end of the second term. Involvement before the course consisted primarily of obtaining a list of requirements from the sponsor so he could answer the majority of anticipated student questions. He was paid hourly (from funds provided by the sponsor via the sustaining donation) for his work during the two terms in which he was involved. This GA was responsible for two separate teams working towards the same project goals.

The GA noted that the students were able to receive more direct help when necessary from him rather than trying to work with the sponsor whose availabilities were bounded by business hours. Since the GA's accessibility was more convenient, the students would get their concerns addressed faster as well as receive more group help sessions-an essential ingredient for a successful product. The adviser did have one concern: if he was not knowledgeable about the issue that the students were trying to solve, he would often need to make judgment calls that may have been wrong in the scope of the project. For instance, one of the student groups inquired whether or not the sponsor's facilities had easy access to pressurized air for pneumatic tools. Since the GA wasn't knowledgeable about the availability of air, he had to contact the company sponsor to verify. Thus the adviser felt that his lack of familiarity with the project scope was remedied by simply asking the sponsor for assistance when necessary.

The GA highlighted that even though the effectiveness of the final deliverable was not his direct responsibility, he was still able to successfully guide the students to feasible designs. One team was able to have automated bandage insertion and reduced the packaging time significantly. The second team also reduced the packaging time significantly while employing a very simple and safe design, which involved enclosing all moving parts. The adviser was able to guide the students in designing two unique solutions for the sponsor company; this allowed the company the flexibility to choose between the two products or use a combination of both deliverables. This in turn reduced the responsibility on the adviser to determine an ideal solution.

4.3.3 *Potential implications of involvement*

Using the GA as grader and project adviser without

responsibility for the final design can be a useful approach for external projects when budget limitations preclude a higher level of involvement. That was the case for this project. While the quality of the deliverable would have been improved with greater GA involvement, the sponsor-provided budget was insufficient to fund additional GA time. However, even using the GA in the limited role described here greatly improved the student and sponsor project-experience and improved the quality of the project deliverable beyond what would have been.

4.4 Case study 3: grading, advising, and providing part of the design

4.4.1 Background

Injection sand molding is a common manufacturing process that typically involves a hot and dirty environment. The mold-clamping force between cope and drag required for such processes can vary from 400 to 600 lbs. or more depending on the product produced. A company that utilizes injection sand molding originally had a clamping procedure, which was very user intensive. This system involved an operator who loaded several hundred-pound weights onto the top of the mold to provide the clamping force. The goal for this capstone design project was to design, build, and test a clamping mechanism for sand molds that was more automated yet versatile enough to handle various injection locations. This would provide the sponsor a more effective and efficient sand clamping process. The project was staffed with two capstone teams both working from identical project requirements. This approach results in two different design solutions for the sponsor.

4.4.2 GA Involvement

The GA was responsible for grading, providing technical guidance, and creating a testing apparatus to test the effectiveness of the student team's designs. The GA was also responsible for establishing an effective communication between students, sponsor, and course instructor. It should be noted that the adviser was not responsible for the quality of the final project deliverable (the clamping mechanism), but was responsible for creating a testing mechanism to test the effectiveness of the student-designed clamping mechanism. This involved conducting some background research and communicating with the sponsor to see what was necessary. This work occurred two weeks before the course began. The GA was paid an hourly wage from funds provided by the sponsor via the sustaining donation.

The GA felt that his involvement with the project allowed more one-on-one interaction for the stu-

dents versus the students only dealing with a sponsor or professor. He said that he had time to sit with his student groups to go over their writing content and guide them toward feasible designs outside of normal meeting times. The GA felt that since his availability was more convenient and more accessible than a sponsor or a professor, the seniors were generally able to get more immediate feedback. The graduate adviser also expressed that the experience provided a good perspective on engineering management. The adviser did note that one of the major issues was that he was not intimately knowledgeable about the project itself; however, he was still able to provide useful technical and engineering feedback when necessary. Any questions that he wasn't able to address, the students were able to get answered by the sponsor or course instructor. For example, in the beginning of the project the students were unclear about details of the injection molding process the sponsor was using. Since the Graduate Adviser wasn't able to clearly detail the procedure, he set up a meeting with the student groups to travel to the manufacturing plant and meet with the sponsor. This allowed for all specific details and concerns to be addressed and provided a unique and thorough perspective that the students would have missed if they only dealt with the sponsor through the adviser.

4.4.3 Potential implication of involvement

This level of involvement for the GA should be implemented when the sponsor-provided budget is sufficient and the graduate student has enough time to dedicate to tasks needed. Since this approach does not incorporate the GA's thesis, it is imperative that he has the allotted time to not only design a part of the senior project deliverable, but also focus on his classes and thesis work. Such a scenario would be most effectively employed near the beginning of the GA's graduate career, since his thesis work wouldn't be too demanding of his time.

4.5 Case study 4: final deliverable, advising, and grading

4.5.1 Background

The feeding of pest birds on grapes is a serious problem in Willamette valley vineyards. Some approaches that have been used to protect vineyards include firing gunshots in the air to reduce pest bird infiltration, spraying pesticides, and covering vineyards with nets. The purpose of this capstone project was to develop an aerial vehicle system for the deterrence of pest birds in the Willamette Valley Vineyards. The capstone project used existing R/C plane components to develop an autonomous aerial system that would deter birds from entering the

vineyard. The project was staffed with two teams given identical requirements and tasked with creating two independent and complete solutions.

4.5.2 *GA involvement*

In this project scenario the GA was accountable for the quality of the project final deliverable. The GA was also responsible for grading and advising as in Case Studies 2 and 3. The GA's responsibilities included assisting the two groups with maintaining a schedule, providing graduate level knowledge of the project, holding weekly status meetings, and generating a useful product regardless of the student groups' performance. Thus, despite the students' quality of work, the graduate student was still held accountable for delivering a successful final product. The integrity of the course was maintained by allowing the capstone students to progress through the course and produce a deliverable as usual. However, if this deliverable was insufficient, the GA was responsible to create a useful deliverable in the term(s) following the end of the capstone course. The sponsor provided funding for this additional work. He was accountable for working closely with the sponsor to develop a strong knowledge base and to produce Customer Requirements for the student teams. He also researched as well as ordered all the necessary tools and equipment. The GA was also responsible for testing the device and for presenting final results to the sponsor. His involvement with the project started the summer before the course and extended to the summer and fall terms after the class had completed.

The GA highlighted the major benefits of having a deep familiarity with the project scope. One being that this helped him be a more effective adviser. He was able to motivate a group of students to the point where the students volunteered for project work beyond the scope of the class. Due to his detailed knowledge and his ease of accessibility, one of his student groups were able to achieve a very successful deliverable. He was then able to compile a very thorough and effective final presentation to the sponsor. The GA also noted that the capstone course provided real world experience in project management.

4.5.3 *Potential implications of involvement*

A major drawback in this project was that the GA degree of involvement took away time from completing the GA's thesis work. A large portion of his contribution with the capstone project involved working long after the class ended in order to validate the effectiveness of the final deliverable. This involved a large amount of meticulous testing for the sponsor. Although the GA's involvement as a project adviser provided real world training for

job management, he felt that the experience ultimately took away time for completing his thesis work. Having a graduate student responsible for the quality of the final deliverable without capstone being directed related to thesis work, should be utilized with caution. Although the quality of the capstone design project may be enhanced to a high level, the GA may not be able to spend as much time necessary towards his thesis.

4.6 *Case study 5: thesis application, final deliverable, advising and grading*

4.6.1 *Background*

A manufacturing company that caters to forestry, lawn, garden, and agricultural markets was looking to have a deeper understanding of the cutting mechanics for a battery powered garden pruner. The GA was given the task to create and provide mathematical models for the device. He was also responsible for validating his models with experiments. Completion of these tasks would be the basis for his master's thesis. In order to validate the model results experimentally, it was necessary to construct a device to accurately measure cutting forces under a variety of conditions. The creation of the device was the topic of a capstone project.

4.6.2 *GA involvement*

The GA's involvement included grading, project advising, and applying the students' work to his thesis. Given that the device was needed for the student's degree research, the GA was responsible for taking the output of the senior project and creating a fully-functioning device. Furthermore, since the creation of the device was driven by the student's research needs and not a specific request by the sponsor (they simply wanted a validated analytical model), the GA was also largely in the role of sponsor as well as adviser. At this level of involvement, the GA was familiar enough with the project's requirements and necessary deliverables that he was capable of answering virtually all of the students' concerns. Since this was also related directly with his thesis, the GA also was highly motivated to guarantee the success of the project. The GA directly benefited from the students' work since they saved him the effort of designing and building the device himself. The GA highlighted that his involvement with the project allowed for an increase in the quality of the end result when compared to other less invested advisers. This was directly due to his stake in the successful outcome of the final deliverable.

4.6.3 *Potential implication of GA involvement*

The graduate student noted that he became a strong

influence for the students' design. He felt that this caused the students to lose the chance to learn things they would have otherwise been forced to learn on their own. This took away a valuable experience for the students, however with the GA's involvement the students were able to create a more sophisticated and effective design. He expressed that the down-sides of GA influence could be remedied by further training future GAs to be more effective teachers and leaders. Finally, the GA stated that the outcome of the project was that the constructed device was able to perform several different cutting operations as required, which ultimately allowed for experimental data collection for his analytical model validation. Since combining his thesis work with the capstone project significantly helped the adviser work towards completing his masters, the GA was very pleased with the results. This case study shows that if applied correctly, involving capstone with a GA's thesis can be beneficial for both the GA and the students. Not only did the GA get to work towards completing his master's degree, he was able to gain valuable project management experience. Applying thesis work to capstone should be employed whenever possible.

5. Data analysis

5.1 Graduate assistant and faculty grade assessment

One concern that may arise with the involvement of GAs as mentors/advisers in capstone projects is that the GAs may not provide the same quality of assessment as a faculty member. Grade data for Preliminary Proposals and Final Proposals from three different Capstone Design courses (2009, 2010 and 2011) and grades for Background Reports and Final Reports for two years (2009, 2010) was collected to test the hypothesis that the grades from GAs and faculty mentors/advisers are statistically the same per type of report. In total, 363 reports were considered for this case study. There were 25 faculty that graded 237 reports, and 14 GAs that graded the remaining reports.

Test Hypothesis per report type assuming $\alpha = 0.05$ (two-tailed):

$$H_0: \mu_{yGA} = \mu_{yF}; \text{ where } y = \{2009, 2010, 2012\} \\ \text{and GA} = \text{graduate adviser and F} = \text{faculty} \quad (1)$$

A non-parametric test for difference in means was used to test the hypotheses. Table 2 presents a summary of the results.

Table 2 shows all calculated T1 are within the acceptance range and all p-values are larger than 0.05; therefore the null hypotheses cannot be rejected. This means that there is no difference in grading between faculty and GA mentors/advisers. It is therefore believed that because there is no statistical difference between faculty and GA graders, both are capable of delivering the same quality of evaluation.

5.2 Benefits of using graduate assistants as advisers

In order to provide descriptive comparisons between graduate assistants versus faculty as mentors, an exploratory study was conducted using content analysis. This required a data-mining process on student course assessments from capstone courses using only faculty advisers (years spanning from 2005–2008) and from capstone courses using both faculty and graduate advisers (years spanning from 2008–2011). The characteristics of an effective mentor, described in Table 1, were used for the content analysis. During the content analysis process, the attributes from Table 1 were observed in students' comments. This allowed for a coding process which assigned grades one through five for each mentioned adviser. One represents a poor student/adviser experience and five represents a very successful and satisfactory student/adviser experience. This scoring is further illustrated in Fig. 2.

There were three independent coders in the scoring process with a 50% full alignment in coding and a 0.4 point variance when there was disagreement. The coders reviewed their results and re-calibrated their interpretations. After coming to a conclusion score for each case, average of these scores were taken for years when only faculty were advisers and for years when faculty and GAs were both advisers. It was observed that there was an increase in student satisfaction when graduate students were utilized

Table 2. Test results and grade data

| Background Report | T ₁ (calc) | T ₁ Statistic | p-value | Preliminary Proposal | T ₁ (calc) | T ₁ Statistic | p-value |
|-------------------|-----------------------|--------------------------|---------|----------------------|-----------------------|--------------------------|---------|
| 2009–2010 | −0.210 | ±1.960 | 0.174 | 2009–2010 | 0.137 | ±1.960 | 0.307 |
| | | | | 2009–2011 | −0.110 | ±1.960 | 0.208 |
| | | | | 2010–2011 | −0.244 | ±1.960 | 0.163 |
| Final Proposal | T ₁ (calc) | T ₁ Statistic | p-value | Final Report | T ₁ (calc) | T ₁ Statistic | p-value |
| 2009–2010 | −0.211 | ±1.960 | 0.162 | 2009–2010 | −0.00929 | ±1.960 | 0.246 |
| 2009–2011 | −0.147 | ±1.960 | 0.195 | | | | |
| 2010–2011 | 0.06155 | ±1.960 | 0.274 | | | | |

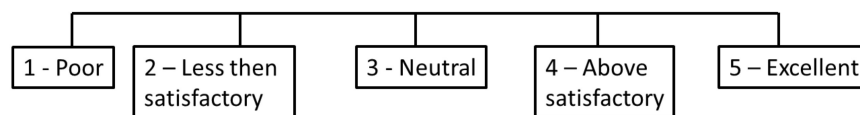


Fig. 2. Score Chart used to code advisers.

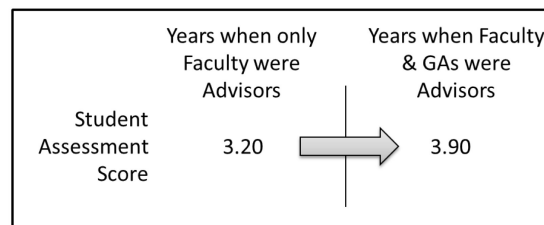


Fig. 3. Student satisfaction comparison of years with and without Graduate Advisers.

from 3.20 to 3.90. Figure 3 summarizes the results of the study.

The results seem to indicate that the GAs involvement has had a positive impact in the MIME Capstone Senior Design class. Based on observations it is speculated that the improvement can be due to three factors:

- (i) The quality of the mentoring activity by the GAs is equally good as the faculty generated
- (ii) The involvement of GAs has freed time for faculty members whom can devote more time to projects
- (iii) A combination of reasons *i* and *ii*.

6. Discussion

6.1 Benefits for graduate assistants

Though it is not the primary concern of this paper, it is important to note that the authors observed that the GAs benefitted by participating in the capstone design course as mentors/advisers. They would gain technical experience, management experience, and grading experience [14–17]. The problems that the capstone design students faced were often very challenging, requiring a great deal of creative thought and technical knowledge. Guiding the students through such difficult content would also strengthen the technical skills of the GA.

Managing groups of people is a skill that is usually acquired through experience and is difficult to teach. It was shown that the top ten professional skills of emerging engineers valued by the work force included teamwork and communication [17]. This model allows the graduate students to gain management experience by being responsible for supervising teams of student engineers. Because many engineers with masters degrees go on to take

a management role, this experience will benefit the GAs in their future careers.

Using the GAs as graders also made them better at evaluating technical documents. GAs were made to read very long technical reports and attend grader workshops where technical writing skills were reviewed. Not only would the experience help them to be more critical of others writing, but it would improve their own writing. In essence, this is an example of a graduate adviser fulfilling his/her own developmental needs, an immediate benefit of a mentor-protégé relationship [2].

6.2 Potential issues with using graduate assistants

Though the use of a GA seems to have largely positive effects, there may be some negative consequences. There will also always be variations between individuals, supervisors, and departments that are difficult to account for. It was noted that the main difficulties encountered with the use of GAs were the limited amount of technical expertise and professional experience. The GAs also tended to lack the level of maturity and poise that a faculty project adviser might have in the more difficult situations. For instance in Case Study 2 and 3, the graduate advisers noted that there were instances in which they were not knowledgeable enough to offer solutions to the undergraduates. However, the advisers dealt with the situation by contacting the sponsor or the course instructor. In essence there is evidence that these scenarios may be remedied by supporting each GA by a faculty member.

Another potential negative consequence may result from over-committing the GA's time. At OSU, a pay was given to the graduate students as a compensation for their efforts. The GA's faculty adviser may also take issue with their student being over-committed. This must be taken into consideration when selecting potential GAs and faculty.

Faculty will be more willing to volunteer their graduate students when the project has a connection to their own research (this is typically the case at OSU).

7. Conclusion

This paper investigated potential benefits for all parties involved in a capstone senior design course: faculty, sponsors, undergraduates, and graduate students. From this exploratory study, several implications can be drawn. First, it was observed that using graduate students can help to reduce instructor workload, improve the performance of senior project teams, and allow project sponsors to focus on the most challenging issues. Second, GAs tended to be more accessible to students and seemed to ease the burden on instructors and project sponsors. Third, it was observed that having the GA serve as a communication hub allowed for streamlined communications between the instructor, project sponsor, and students. Fourth, using a graduate student as a project manager would allow the project sponsor and course instructor to handle only the most demanding problems. Fifth, it was observed that graduate students were able to provide student assessments that are accurate and reliable. Sixth, the content analysis helped identify that overall capstone students' satisfaction improved when assigned graduate student advisers.

The case studies imply the potential effectiveness of using GAs at varying levels of involvement. Higher levels of GA involvement could translate into higher levels of capstone project output, but even at relatively low levels of involvement, GAs can provide important contributions. Case studies 2–5 contain the role of GA as project single point-of-contact. This is an important role and could be an effective selling point to sponsors when requesting graduate student funding.

Therefore, it is possible to conclude that there is strong evidence based on the experiences and observations in the OSU MIME Capstone Design course, that GAs can potentially be an effective choice for project advisers of industry or other externally-sponsored projects. However further investigation needs to be conducted to draw complete conclusions on observations. This requires looking at the mentor-protégé relationship for each case study. Each level of involvement would need to be thoroughly analyzed in order to draw conclusions that are statistically significant. Further research will be conducted in order to realize the full potential of utilizing graduate assistants as capstone advisers.

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