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A Case Study Approach for Understanding the Impact of Team Selection on the Effectiveness of Multidisciplinary Capstone Teams

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An important ingredient for capstone project success is teamwork. Most, if not all, capstone teams will deal with issues such as poor communication, social loafers, a lack of shared objectives, and an inability to resolve conflicts at various points during the course of a capstone project. In addition to regular instructor mentoring and coaching, team selection appears to play an important role in mitigating such behaviors. In the interest of understanding how team selection might impact team effectiveness in a capstone setting, this paper examines a small sample of capstone project teams over multiple semesters using a case study approach based upon a relatively large population of students. Drawing upon insights from working with students at two different universities (one private and one public) observations on the factors that may impact team effectiveness are discussed. Team composition factors considered in context of the case studies include the impacts of academic imbalance, dominant personality, personality composition, misaligned interests and disciplinary divergence (i.e., fault lines).

Keywords: capstone design; team selection; multidisciplinary; project-based learning

1. Introduction

ABET mandates that engineering curricula prepare students for engineering practice through a major culminating design experience utilizing the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints [1]. As a result, most engineering programs require students to take a capstone course. While there are many variations of how a capstone course might be implemented, the typical capstone course engages students on a significant design problem involving an experiential project-based learning approach [2].

For many students, capstone represents a new form of learning. Instead of focusing on the knowledge of abstract principles, analysis, and engineering problem solving, capstone courses force students to address synthesis and the need to learn new knowledge and skills beyond what might have been taught in prior coursework. In addition to learning about the design process, a capstone experience requires students to deal with organizational issues associated with planning, decision-making, and working with other students as part of a team.

For instructors, implementation of the capstone course introduces a host of pedagogical issues. These issues include how to best teach teamwork, professional communication, and design methodology. Other issues associated with the overhead of teaching capstone include the identification of suitable projects, student team formation, resolution of team conflict, student assessment, and much more.

This paper builds upon previous work to address the issue of selecting and forming capstone teams that enhance the opportunity for student success on "real world" engineering problems [3]. By success, we mean a student team's ability to "effectively" deliver results as described in a capstone project statement of work. For the purposes of this paper, we will assume individual student capstone grades (informed by weekly progress reports, external reviews of project results, various written and oral communication assignments, peer evaluations, etc.) represent a measure of success. An underlying assumption for this approach is that an accurate, fair and consistent means of capstone student assessment is in place [4].

2. Approaches for Creating Capstone Project Teams

A wide range of approaches for the selection of students for engineering capstone project teams, from simple to complex, have been explored in the literature. At one extreme, instructors may simply use a random process, generally ill-advised for engineering capstone projects where the objective is to create effective teams addressing technically challenging problems that may span an entire semester or more [5]. Several authors propose methods based upon student self-selection of teams that is informed by student project preferences and instructor coaching [6, 7]. At another extreme, instructors may choose to make student team assignments based upon academic performance [8], personality profiles [9] and/or the use of sophisticated optimization algorithms [10, 11]. Between these two extremes are approaches that may use a combination of inputs from students regarding project interests and preferences along with information pertaining to the past experiences and capabilities of students [12, 13].

Based upon review of the literature, it is clear that the approaches and processes used to identify, select and form student teams is a subject of some interest among engineering capstone instructors. The practical motivations for this include “accommodation” of student interests and preferences in hopes of influencing student learning outcomes and team effectiveness, while providing an efficient and fair method of assigning students to project teams.

3. Objectives, Assumptions and Methodology

In the interest of understanding how team selection might impact project results in a capstone setting, we collected and analyzed data on over eight-two capstone project teams over four semesters. The data consisted of a combination of quantitative and qualitative parameters including academic performance, practical engineering experience, career interests, project preferences, personality, and technical skills used to assign individual students to project teams over four semesters from Fall 2013 to Spring 2015. Using these parameters as inputs for team selection purposes, we compared end of semester results in the form of student grades and peer evaluations to explore the factors that might have an impact on team effectiveness.

Throughout the exploration we made the assumption that project success is a good indicator of student learning for a capstone experience with the acknowledgment that design iteration with successive opportunities for failure and success are important elements for any design project, whether the design process takes place in an industry or academic setting [14]. Underlying this assumption is the condition that a robust and consistent methodology for assessment of student capstone projects exists for the various process stages of design development.

Comparing grade point average (GPA) and engineering maturity factor (EMF to defined later in this paper) to end of semester capstone grades, we examined variances between inputs and outputs. We included end of semester peer evaluations to provide additional insights on the data.

The data was then sorted from highest to lowest variance between the parameters. Using the data from all four semesters we focused attention on those project teams with relatively high variances between the parameters. Our assumption was that teams with relatively low variance among the parameters would be more likely to exhibit the characteristics typically associated with more effective teams. Conversely, we interpreted the high grade point average versus low capstone grades as project teams exhibiting lower than expected performance. Identifying a smaller subset of this latter population, we selected project teams for case study exploration in the interest of understanding the potential team composition factors that may have influenced team effectiveness.

4. Matching Students to Projects Based Upon Requirements

Fundamentally, the team formation methodology assumed for the case studies presented in this paper is that students are assigned by instructors to projects teams based upon a mapping of the interests, knowledge and skills needed to fulfill project requirements. The process of matching students to projects starts when students submit their first course assignment, which consists of the types of information that would customarily be found on a job application. The information provided by students is used to compile and understand their capabilities and interests, which includes major(s), grade point average or GPA, past or current internship and/or coop experiences, undergraduate research projects, technical skills, leadership experiences, career interests, project preferences, etc. As a result of using this process, over a period of many years, we have acquired a significant amount of data and insights into the factors that may contribute to capstone team success.

In parallel with the process of collecting and compiling information on student interests and capabilities, project descriptions are developed that are used to introduce the projects to students. The project descriptions include project background, objectives, requirements and constraints, technology study areas, technical references, lab resources, and sponsor liaison contact information. The results of scoping projects with sponsors and collecting the first course assignment from students are combined to develop a master plan that maps the student majors with the disciplinary requirements for each project. Project teams may include participation from multiple engineering disciplines depending upon project requirements. Each project is unique and involves specific domain knowledge pertinent to the problem at hand. To help students develop the necessary domain knowledge, project descriptions are broken down to a level of detail where each student has a unique technology study area to research, explore and report upon as an individual deliverable and course assignment.

5. Factors that Effect Team Effectiveness

Experts in the area of industrial and organizational psychology contend that engineering educators should do a better job of availing themselves of the rich body of knowledge in the area of team effectiveness. In their paper on this subject, Borrego et al. describe interdependence, trust and shared mental models as three constructs that promote team effectiveness [5]. In their review of team effectiveness literature, they note that team processes aligned with team goals "may have a more significant impact on outcomes than focusing on fixed inputs, such as personality types, when assigning team members." Consistent with these findings we did not use psychological assessment instruments to form capstone teams for this study. However, all students were introduced to concepts about teamwork (e.g., personality profiles, stages of team development, conflict management) and are taught how to work together with others who may have varying learning styles and personality preferences.

We know that there is an ebb and flow of student interest and motivation throughout the course of a capstone project based upon a variety of factors [15]. We have noticed that having a diversity of backgrounds and capabilities on a team is a good thing; but we have also noticed that there are times when it appears that diversity may negatively impact team performance, for example, in the case when students at the two extremes of academic performance are placed on the same team. This finding is consistent with those described by Borrego et al. where they observe that academically unbalanced teams may be at greater risk of team dysfunctions, such as "social loafing" and other behaviors that can lead to conflict [5].

Our experience with assessment processes, coupled with the methodology used to match students to projects provides insight into the likely success level for students entering capstone. We assign students to teams based upon factors that we believe promote the overall likelihood of project success. These factors include a mix of intellectual capability, past engineering experience, specific technical skills, student interests and project preferences. The following sections briefly address each of these factors.

5.1 Student Interest Areas and Project Preferences

In addition to basic qualifications, the first course assignment requests that students provide inputs on the types of projects of interest to them. As might be expected, student responses to the question about interest areas vary considerably based upon various factors (e.g., academic performance, disciplinary areas, experience and background). After countless hours in lecture-based courses, however, we find that many students often express a profound interest in a "real-world" experience. Aligned with their interest in a "real-world" experience, many students will express interest in a "hands-on" experience; while others are interested in projects that may involve a more analytical component that exercises their past work in specific course areas (e.g., thermal-fluids, design of machine elements, circuits, controls, materials testing, software development, system design, etc.). General areas of expressed student interest include renewable energy and sustainability, biomedical and health care, manufacturing and consumer products, aerospace and advanced technologies, software development, controls, robotics, automation, materials and more.

While we make every effort to assign students to projects based upon their interest areas, we make no guarantees and expect students to be resourceful. Meanwhile, some students say they are flexible about the project assignment and have an interest in learning new areas. We take special interest in these students, since it indicates to us that they are resourceful and curious about learning new things. We believe this is an important lifelong skill, required for success in the workplace.

It is important to note the distinction between the successful outcome of a project and the ultimate fusion of individual students into an effective team. We have little concrete evidence indicating that initial project preferences make a significant difference in the ultimate success for any particular capstone team, however the case studies of project teams presented in this work indicate that alignment of student interest areas with project area may have a significant impact on team effectiveness. We notice that project preferences may initially impact an individual student's performance. For example, in cases where we might assign a student to a project involving multidisciplinary participation, some students may find it difficult to appreciate their particular role on a project. We find that project preferences may be a factor during the initial weeks of the semester when students are becoming acquainted with a project, however, a study of end-of-semester reflective memos indicates that as a project progresses, other factors, beyond initial project preferences provide much of the motivation needed for team effectiveness and success [15]. This transient motivation effect appears to be asymmetrical with regards to the magnitude and duration of the motivational influence. Specifically, a satisfactory alignment of interest and project area may create a modest positive motivation of short duration, while an unsatisfactory alignment may have a stronger negative motivational influence of a more enduring nature. This transient period creates what may be viewed as either a window of opportunity or a window of vulnerability, and the magnitude and duration of these influences are worthy of detailed study. Given the variability of the data correlating capstone grades with academic performance and past experiences, it is clear that other influences have a more enduring impact on individual student performance in capstone, and ultimately team effectiveness and the potential for project success [3]. Meanwhile, we know that interest and motivation are well recognized by educators as dominant factors for successful engagement of learning [16]. In addition, a variety of external distractors may also play a role (e.g., extra-curricular activities, outside employment, long term career goals, etc.). Understanding the duration of the motivation transient caused by alignment/misalignment may provide insight as to when (and which) other motivating influences may become the dominant motivational factors. A deeper understanding of this evolution could also lead to more effective mentoring techniques.

5.2 Academic Performance as a Factor

In an attempt to maintain a level playing field, students are generally assigned to projects such that the average GPA is at or above 3.0 for each project group. Since the average GPA of students entering capstone is 3.3, it facilitates this goal. In some cases, we will group students with higher GPAs together and assign them to projects requiring more abstract thinking skills and conversely group students with lower GPAs on projects that may require more concrete thinking skills [17]. Past data indicates that individual student GPA is not highly correlated (range .27 to .36) with capstone grades [3]. Nevertheless, the data also indicates that in general (i.e., on average), students with higher GPAs will perform better (i.e., earn a higher grade) in capstone than students with lower GPAs. Despite these inferences, given the variability of the data, it is clear that GPA in isolation of other information is not a sufficient predictor of capstone success. There is significant variability in the data, which may account for situations where students with significant "engineering maturity" step up in a capstone experience and take on leadership roles. Conversely, the variance also accounts for the case where high GPA students with little "engineering maturity" and primarily coursework may not always live up to expectations. As noted earlier in this paper and will be shown later using project case studies, we have also observed instances where academically unbalanced teams appear to be at risk of various forms of team dysfunction.

5.3 Engineering Maturity as a Factor

It's logical to expect that students with engineering internships, cooperative education assignments, undergraduate research projects or other engineering experiences (e.g., student design competitions such as SAE Formula Car and AIAA Design Fly Build) would have an edge over capstone students with only coursework. Various authors have explored the relationship between such experiences and identified the positive impacts of such real-world experiences on academic performance [18, 19]. Similarly, we have observed that students with significant engineering related experiences may exhibit more confidence and are often well respected by their peers. They will sometimes stand-up and take on project leadership roles. The number of such experiences for an undergraduate engineering student will typically range from none (i.e., coursework only) to a single or multiple engineering related experiences. In the interest of quantifying the impact of prior engineering experiences on capstone performance and the possible use they may have on team formation we have defined the engineering maturity factor or EMF (Table 1).

Table 1. Engineering Maturity Factor (EMF) Level Descriptions

EMF	Description
4	Multiple engineering experiences (internship, co-op, undergraduate research project, or participation in significant engineering design competitions)
3	One engineering experience (internship, co-op, undergraduate research project, or participation in significant engineering design competitions)
2	No engineering experience (coursework only)

As a practical matter, we do not make student assignments to capstone projects based upon EMF. Our process tends to be more detailed and specific. We look for students with engineering experiences related to the project area and who may have acquired pertinent skills and capabilities. For example, a student having a co-op or internship with a power company would most likely be assigned to an energy related project.

5.4 Fine Tuning Team Assignments Based Upon Skills

After most students are matched to projects and the database of student majors, academic performance (i.e., GPAs), interest areas and engineering experiences has been compiled; we supplement the database with an extensive compilation of specific student skills. At this point, we undergo a vetting process among the various instructors who are assigned to serve as mentors for capstone projects. Depending upon specific project requirements, individual instructors will make team composition adjustments if necessary.

5.5 Uneven Engagement of Team Members

It is intuitive to anticipate that a highly effective team will have all members fully engaged in the capstone project. What may be less intuitive is that it is still possible to form an effective team with less-than-fully engaged participants. To fully appreciate this, it is necessary to separate the concepts of overall project outcomes from effective functioning of a team. A team composed of fully engaged students will most likely have a first-tier, successful project outcome, while a team composed of less dedicated students may still have a positive team experience and achieve a second-tier result on the project itself. Our observations indicate that an ineffective team (or a dysfunctional team dynamic) is far more likely with disparate levels of commitment from team members.

Detecting incomplete engagement can be difficult, and heavily relying on the observational skills of mentors/peers to detect it can lead to inconsistent ability to address the situation in a timely fashion. It is imperative, then, to give guidance on what type of distractors may be present that preclude full engagement. A suggested, but certainly non-comprehensive list might include lack of maturity or a solo-working preference. Other possibilities include a disenchantment with the engineering profession as a whole, a focus on a career path other than engineering (medicine, law, business), or an inclination towards research over applied engineering. We have also observed students with excessive extracurricular commitments (employment, athletics, clubs), students who already have job offers and are coasting through their final semester(s), and students whose learning styles are theoretical in nature and do not translate well to experiential learning.

It is somewhat counterintuitive to think that creating a group of students who all have outside employment as a distractor might actually be beneficial. While it is true that quality of the overall project could potentially be compromised, it is also possible that the students might appreciate the commitments owed by their peers and therefore bond as a team, increasing the team's effectiveness. In this sense, it is the discrepancy between engagement that causes internal friction (reducing team effectiveness) rather than the level of engagement itself that is causing dysfunction.

6. Case Studies: Impact of Team Selection on Effectiveness

An important ingredient for capstone project success is teamwork. Most, if not all, capstone teams will deal with issues such as poor communication, social loafers, a lack of shared objectives, and an inability to resolve conflicts at various points during the course of a capstone project. In addition to regular instructor mentoring and coaching, team selection appears to play an important role in mitigating such behaviors [5, 20]. In the interest of understanding how team selection might impact team effectiveness in a capstone setting, we examined variances between GPA, peer evaluations, EMF and capstone grades for eighty-two project teams over four semesters from Fall 2013 to Spring 2015.

The data was then sorted from highest to lowest variance between the parameters. Using the data from all four semesters we focused attention on those projects teams with relatively high variances between the parameters. Our assumption was that teams with relatively low variance among these parameters would be more likely to exhibit the characteristics typically associated with more effective teams. Conversely, we interpreted the high academic performance/high peer evaluations versus low capstone grades as project teams exhibiting lower than expected performance. Identifying a smaller subset of this latter population, we selected project teams for case study exploration in the interest of understanding the potential team composition factors that may have influenced team effectiveness.

Our case studies initially focused on the following team composition factors:

- Academic Imbalance: Team members exhibit a wide range of academic performance levels.
- Dominant Personality: One team member takes on greater effort to the exclusion of others.
- Personality Mix: Composition of personalities inhibits team effectiveness (e.g., all introverts or all extroverts may lead to communication issues).
- Misaligned Interests: Team members apathetic about project objectives and topic area.
- Disciplinary Divergence: Team members sub-divide project along disciplinary areas and fail to integrate efforts (also referred to as fault lines).

7. Case Study Observations of Capstone Project Teams

For each of the case studies that follow, we include general observations about the project areas and the stated student interests (from their first project assignment) for the project. A chart showing capstone performance for each team member compared to peer evaluations, engineering maturity factor (i.e., EMF) and academic performance (i.e., GPA) is also presented on a common four-point scale. Using direct observation of team performance throughout the semester, coupled with the data, observations for each case study is presented below.

WBDS15 (Figure 1): This project involved a technical area requiring strong analytical skills. The team consisted of three electrical and five mechanical engineering students who all expressed interest in the project area (i.e., energy and power industry). The average team GPA (3.57) was high, but with a wide a range (2.7 to 3.95) suggesting possible academic imbalance. Communication as noted in student peer evaluations was a consistent issue with this team throughout much of the semester. Many (if not all) team members may have had introverted personality styles. Overall the team performed well (i.e., a B grade) on a very challenging project. There was no indication of disciplinary divergence on this team.

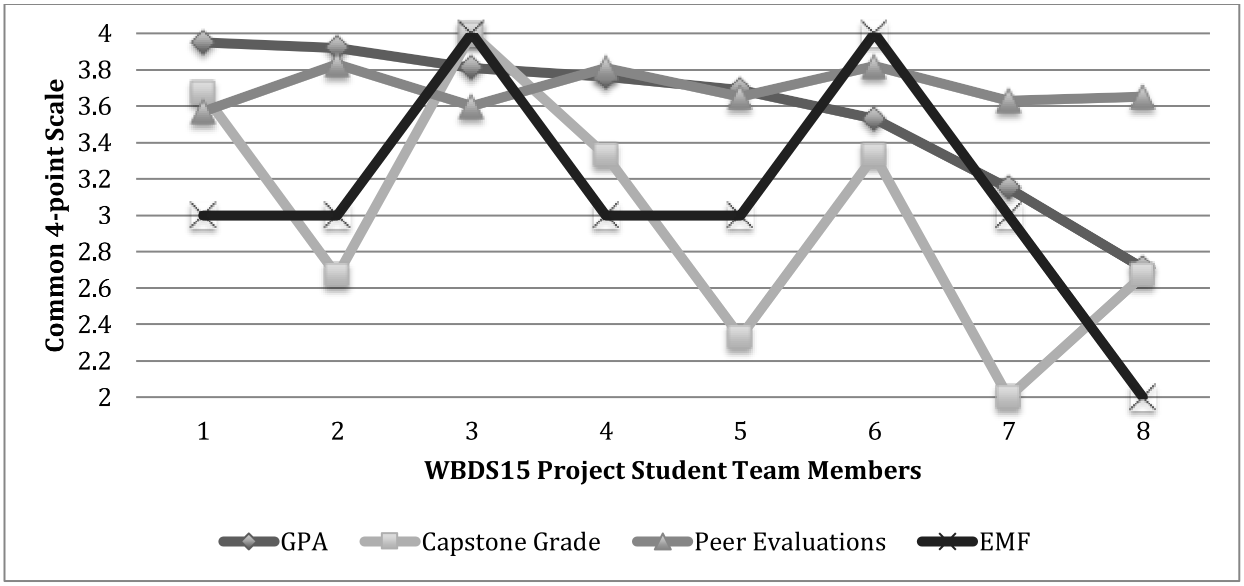

Figure 1. Data for WBDS15 Project Team

CRVS15 (Figure 2): This project involved a concrete "hands-on" effort involving the design and construction of an experimental test apparatus. The team was academically balanced with an average 3.25 GPA (range of 3.09 to 3.58). Only three of the team members had engineering internship experience, with the remainder of the team having only coursework (possible "engineering experience" imbalance). The team included four mechanical, two electrical and one materials engineering students. One thing that stands out about this capstone project team is that there was one team member with a dominant (personality style) who served as a team leader and who also earned the top capstone grade.

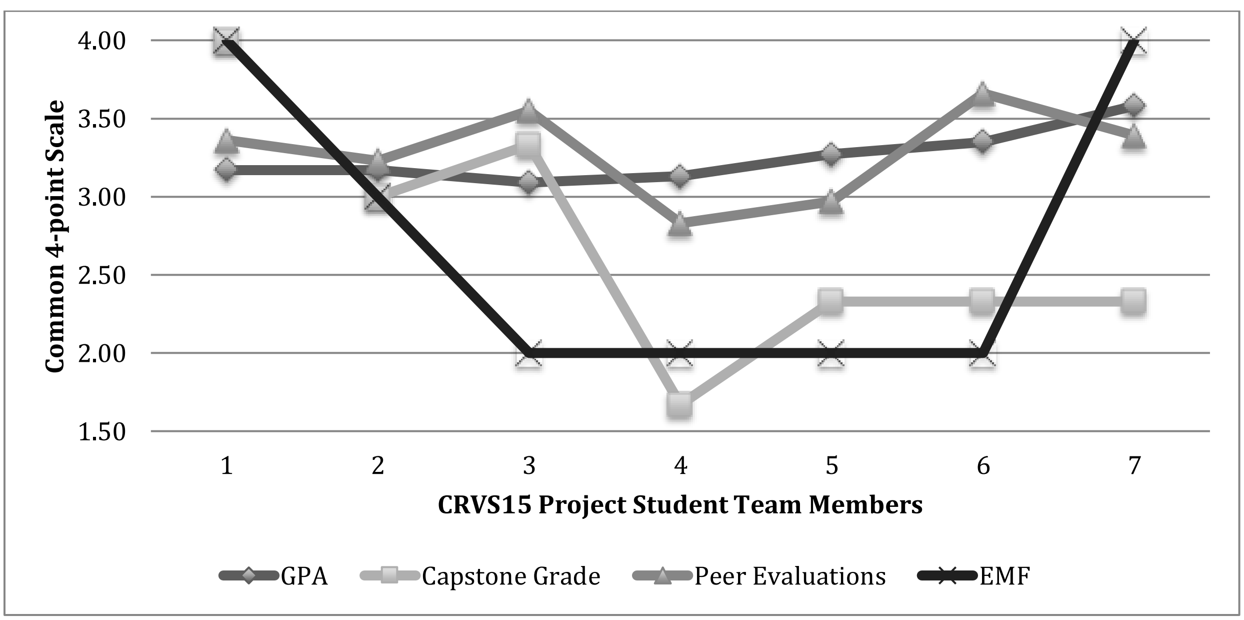

Figure 2. Data for CRVS15 Project Team Members

DLAF14 (Figure 3): This team consisted of students with a broad range of academic performance (Ave GPA: 3.3, Range: 2.14 to 3.95) and could be characterized as academically unbalanced. Since the project involved embedded control, the team composition consisted of mostly electrical and computer systems majors, with a single mechanical engineering student who expressed interest and skill in embedded control based on coursework. In retrospect, the mechanical engineering student may not have been good match for the project and added to the imbalance. Another student who hardly participated due to involvement in extra-curricular activities did not show interest in the project and was an additional source of team dysfunction.

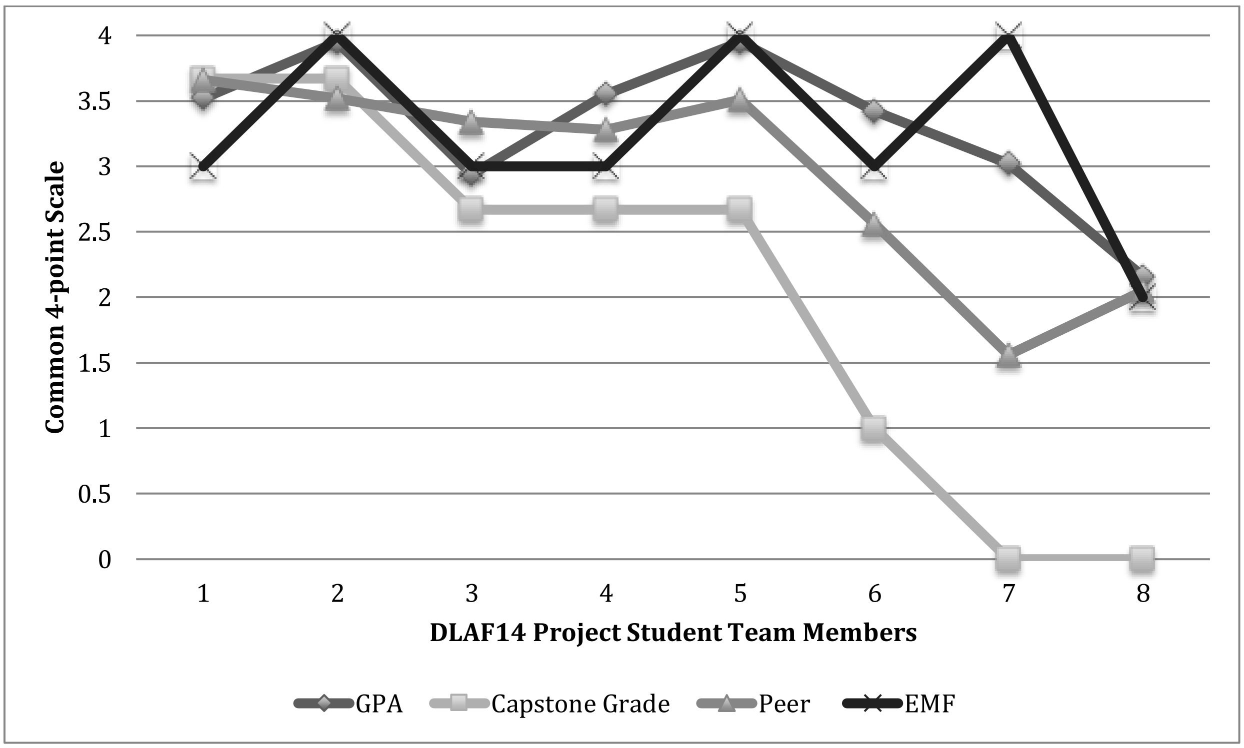

Figure 3. Data for DLAF14 Project Team Members

WTUF13 (Figure 4): The objective of this project was to make upgrades to an existing electro-mechanical test machine used by the power industry. Team composition included students from electrical, computer systems and mechanical engineering with interests in controls, machine design and the power industry. Academic performance was slightly unbalanced (Ave GPA: 3.43, Range: 2.82 to 3.92) although the team composition otherwise appeared to have been well matched to the project requirements. Several of the students on the team lacked resourcefulness, motivation and interest in the project. Half of the students lacked internship or co-op experience (i.e., coursework only). The top (dominant) student on the team expressed interest and willingness to work on any project, had multiple engineering experiences beyond coursework, and a strong academic record.

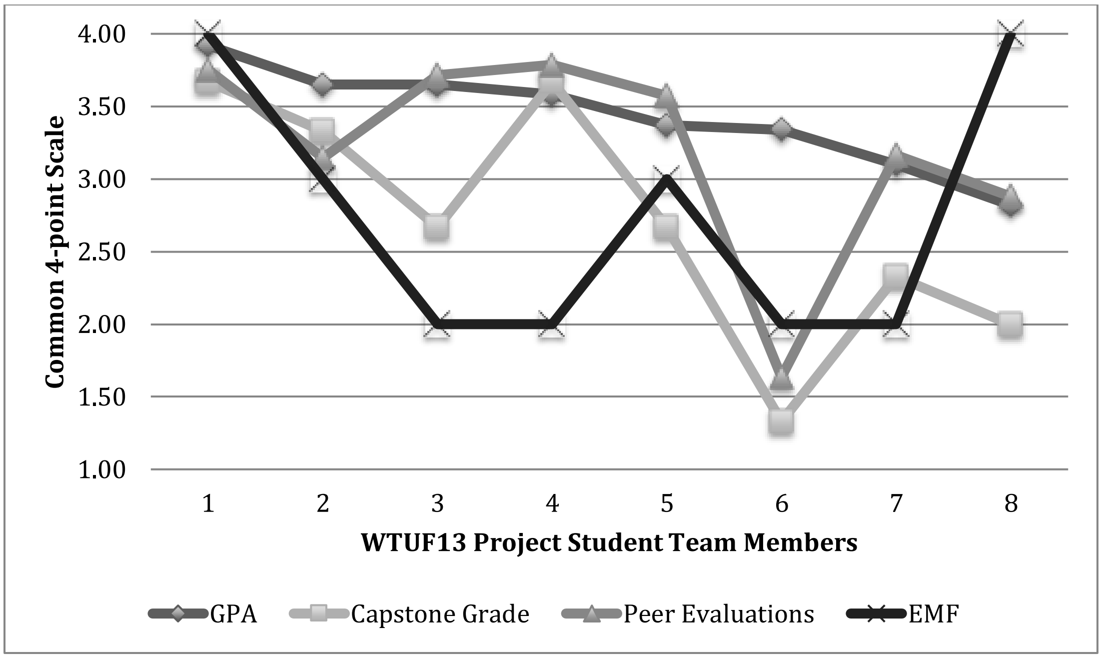

Figure 4. Data for WTUF13 Project Team Members

AMPS14 (Figure 5): This project involved concept development of a new feature for integrated circuit manufacturing machines. All students on the team were high academic achievers (Ave GPA: 3.69, Range: 3.43 to 4.0). The team consisted of four electrical and four mechanical engineering students. Every team member had one or more internship or co-op experiences. Despite the fact that all team members were top performers, the one student with the highest GPA dominated the team, taking a hand in virtually every aspect of the project. Overall project results were good, but might have been much better had more elements of the projects been distributed among the team members.

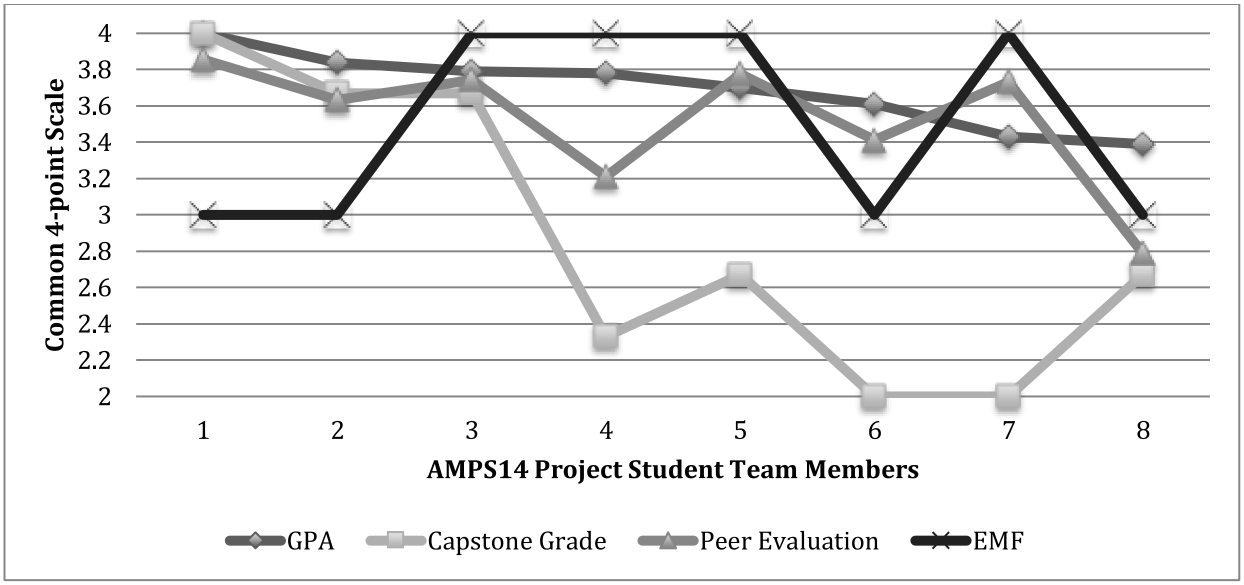

Figure 5. Data for AMPS14 Project Team Members

RWAF14 (Figure 6): The project team consisted of five computer systems, three mechanical and one industrial engineering student. The team was academically balanced with an average GPA of 3.64 (Range: 3.29 to 3.94). Only one student had a strong interest in the project area. This team appears to have diverged along disciplinary lines, with the computer systems engineering students working on software simulation and the mechanical engineering students working on physical application development. The single industrial engineering student attempted to provide project management support.

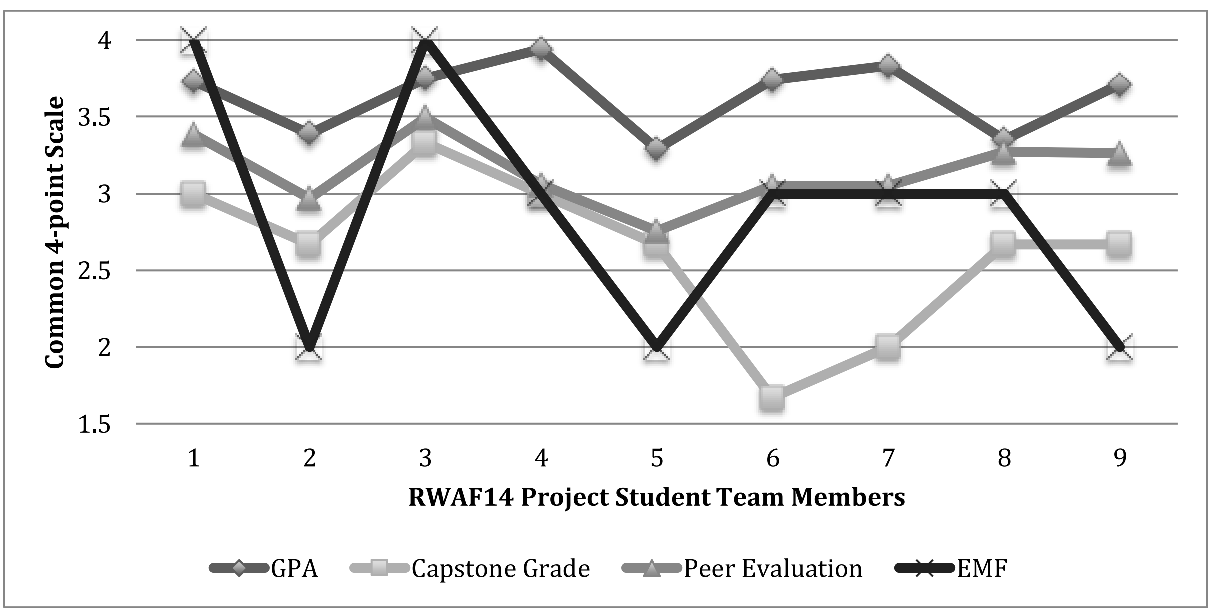

Figure 6. Data for RWAF14 Project Team Members

8. Summary Case Study Observations

Various factors related to team composition including academic imbalance, personality issues and alignment of student interests were examined from a population of eighty-two projects over four semesters. From this population, a subset of sixteen project teams where identified that had an average GPA that exceeded average team capstone grades. Case studies were conducted for six of the sixteen teams (Table 2). Three of the six teams may have suffered from issues associated with academic imbalance. Four teams may have also experienced issues associated with personality, where in three of the four cases there was a team member with a dominant personality style and one case where most (if not all) team members may have had introverted personalities and may have experienced a combination of academic imbalance and a personality mix issue. Three teams appear to have experienced issues with misaligned interests. One of these teams may have also diverged along disciplinary lines. For all six cases, the impact of team composition issues on team effectiveness might have been mitigated with improved communication among team members, a more uniform distribution of work efforts and greater motivation toward shared project objectives.

The case studies provide some insight into various types of factors which could potentially correlate to team underperformance. While the sample is small, it does provide the opportunity to stimulate thoughts and observations concurrent with team activities, potentially leading to predictive observations and/or interventions. Ultimately, our goal is to develop a deeper understanding of team effectiveness issues so as to provide more effective mentoring. It is noteworthy in this case that the admittedly-small sample size of the case study evidenced a misalignment of interest, one of the factors that is both more nuanced and harder to detect.

Table 2. Summary observations of team composition factors with possible influence on team effectiveness

Project Team	Academic Imbalance	Dominant Personality	Personality Mix	Misaligned Interests	Disciplinary Divergence
WBDS15	X		X		
CRVS15		X			
DLAF14	X			X	
WTUF13	X	X		X	
AMPS14		X			
RWAF14				X	X

In most cases, the peer evaluations for high GPA students exceeded their capstone grades, indicating these students lacked awareness of their actual capstone performance [21, 22]. Most projects involved top academic performers (GPA $\approx$ 4.0) who often made up for team deficits by taking on a greater portion of the overall effort. Although providing technical leadership, these dominant team members failed to cultivate interdependence, resulting in less effective teamwork. While the exact role that team composition may have played in team effectiveness is debatable, based upon the strong positive relationship found between average team GPA and average team capstone grades, it seems reasonable to expect that all of these teams should have demonstrated better performance and that team composition may have been a factor.

9. Summary Discussion, Conclusion and Future Work

In this paper, we have presented case studies in the interest of understanding the potential impact of team selection on the effectiveness of multidisciplinary capstone teams. Factors used for team selection included academic performance, engineering maturity and student interest. Relationships of the factors to team effectiveness has been explored and analyzed, although further work is needed to better understand the possible interactions between the factors, as well as possible quantification of student interest and motivation. Nevertheless, we have shed some light on some of the factors that influence team effectiveness and believe they should be considered when forming student teams. Clearly, academic performance and prior engineering experience are two factors that are related to team effectiveness. Matching students to projects based upon their interests is another, however as previously noted, further research to better understand the impact is needed. Having students with a diverse set of interests and backgrounds that are well aligned with project scope and objectives is vital, but must be complemented with a combination of the understanding of teamwork, teaming skills and appropriate on-going mentorship from experienced faculty advisors. We have observed that the best student teams are adaptable and possess a level of curiosity, motivation, interests, and willingness to learn topics beyond their disciplinary area that transcend the curriculum. In the real-world this will be a requirement [23].

The case studies uncovered various forms of unbalance or “divergence” beyond academic unbalance. These include “disciplinary divergence”, “dominant personality”, unbalance in engineering experience, resourcefulness, etc. We propose that continued observational studies will engender a deeper understanding of the nature of the imbalances that apparently result in team underperformance. A three-step, comprehensive process of detection, categorization, and (most importantly) mitigation will result in an improvement in the team effectiveness, the project outcomes, and the educational experience as a whole.

As a general guideline, we want to emphasize that we do not recommend random assignments or student self-selection of teams for challenging real world engineering capstone projects. Students generally do not have the experience to properly scope level of effort and foresee the potential issues that will challenge success. Scoping and planning are among the lessons learned by capstone students [4]. As with any learning experience gauging the appropriate level of challenge is an important consideration when planning capstone projects that can have a direct impact on student motivation for learning.

Our case studies indicate that we have opportunities for improvement. For example, based upon the generally high academic performance and corresponding engineering maturity of the project teams in the case studies, it’s logical to expect that many of these teams could have and possibly should have received higher capstone grades, however they did not. Clearly, these two parameters are not sufficient predictors of team success. As a practical short term remedy, we would prescribe improved team effectiveness training to help students become more aware of personality preferences and how to more effectively work together. In so doing, it is our hope that we can move a greater number of teams from the “norming” to “performing” stage of team development [24].

We take the position that the individual student, their classmates (both team-members and non-team-members), as well as their peers not enrolled in the capstone course are part of a social network. Taking advantage of prior knowledge in the area of industrial and organizational psychology, our future work will utilize Social Network Analysis (SNA) to study the types, quantity, and quality of social connections both at the outset of the capstone project as well as how those connections are established, evolve in nature, strengthen, weaken, or potentially are broken [25]. We propose to correlate (both positively and negatively) information regarding the strength and quality of social connections as an indicator of team synergy and effectiveness. As a diagnostic tool, we believe that SNA would be one method of identifying healthy and unhealthy trends as they develop and would allow for the appropriate diagnostic and mentoring interventions to take place in order to remediate teamwork deficiencies, capitalize on inter-team and intra-team strengths, and optimize the learning outcomes from the capstone experience.

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