Capstone Teams: An Industry Based Model

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Abstract. Project teams, a mainstay in industry practice, are being employed in many capstone design courses. This paper examines industry models for teams and their application to a specific capstone design course. Following Katzenbach and Smith's basics of high performing teams, teams are formed based on individuals skills. The team is made accountable and committed both as a group and as individuals through the structure and format of the course. The course structure is then planned so that teams progress through Tuckman's development stages of forming, storming, norming and performing, during their two semester capstone design project.

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Introduction

Project teams are a mainstay of current industry practice. Following years of measurable achievements due to teamwork[1], demand for engineers who are capable team players continues to rise.

Academia is listening, to wit surveys report that 80% to 100% of responding programs utilize teams in their capstone design projects [2,3,4]. Accreditation from ABET includes the outcome (d) an ability to function on multidisciplinary teams. Yet student project teams do not often develop enough to become a true team (as defined in literature[5,6]) versus a group of individuals.

Teams, given enough time and pressure, tend to follow Tuckman's stages[7] of "Forming, Storming, Norming, Performing and Adjourning." Another staple in the business world of teams is Katzenbach and Smith's triangle of basics[8] for high-performing teams: "Skills, Accountability and Commitment". This paper examines team development in the Capstone Senior Design experience in the Mechanical Engineering Department at Bradley University (BUME). BUME seeks to create an environment where students experience all of Tuckman's stages and develop a performing team: their team is assigned based on skills and they must work to completion, on small teams with tight budgets.

Capstone Course Timeline

The BUME Capstone Senior Design experience[9] spans two semesters of each student's senior year. The projects begin at the start of the fall semester and continue until the end of the spring semester. To enroll in the classes, a student must be within three semesters of graduation. The students are assigned to teams of 3-4 members with a faculty advisor. The team's purpose is to deliver value to a client through an engineering solution to some need.

The timeline for the activity begins with student interest surveys in April. Teams and projects are assigned by the instructor in August. A team leader is appointed in September. A written proposal that is acceptable to the student team, the client, and the faculty participants is completed by the end of October. The proposal includes background material, a description of the clients needs, a problem statement, a value proposition, a completed plan for a technical approach to the problem solution, a description of the required budget, and a list of deliverables. Once the proposal is accepted, the team completes a technical review in February. Further milestones are project and client dependent. The project is expected to be completed by early May.

Team Forming & Skills

Current practice in most companies involves creation of problem solving teams in all aspects of business – from business planning to technical design to installation and troubleshooting. In most cases, teams are formed by management, who assign individual members to the teams and often appoint the team leader.

The Course Coordinator does assignments to teams in the BUME course. As in other institutions, considered student characteristics include student interest, cumulative GPA, demonstrated ability in project relevant courses, work experience, and software competencies[10,11]. Historically, Myers-Briggs Type Indicators have also been used, however due to the prominence of the "INTJ" type among BUME students, the indicators provided little value in team assignment decisions. Though several methods to make the selections with this information have been proposed – including fuzzy optimization[12] and goal programming[10], the process generally involves division by interest, assignment by skill level and the assignor's knowledge of the student personalities. There seems to be no replacement for knowing the individual students that are available to be assigned.

The Forming stage occurs in September and October. As the team begins their project, course coordinator and project advisor observations are used to guide the project leader selection. As in industry, the project

leader assigned and is the primary point of contact between the team, the client and the manager (the advisor). Student teams are encouraged to do individual skill assessments – having frank discussions about the individual team members' strengths and weaknesses. Teams do research into their client, their project area, and relevant synthesis and analysis methods. By the end of this stage, the team has developed a plan of activities with milestones and deadlines that are presented in a written proposal.

Team Storming

The Storming stage is where the differences between ideas, work patterns, methods and behaviors of individuals on the team create conflict. In industry, it often falls to the team leader to develop conflict abatement strategies, one of which tends to include their vested authority as leader. However, even in industry some teams never beyond this stage. In the capstone project setting, the leader and members of the team are all true peers, so authority is of very limited use. Students are presented with material[13] on teams, roles and responsibilities in the lecture part of the capstone course. The goal is to get each and every team through the Storming Stage as quickly and efficiently as possible.

The Storming stage is the one in which the student engineer develops into an engineer. As work progresses in technical detail, quantity and client deadlines, the pressure mounts. Students learn that their usual coping methods – such as "I'll do it all myself" or "I can forget about it after the due date" – that worked on projects in 'normal' courses don't work due to the magnitude of the projects. Students discover their great ideas to get the project done faster/better are only great when they make themselves heard. Students also realize that there is more to creating value for a client than the pure number crunching many had grown accustomed to. In short, the student engineers storm through not just their team development but their professional development as well.

Depending on the personalities of the team, the team leader, and the advisor, this Storming stage can be either a mild drizzle or a hurricane. In either case, the problems usually come to a head in late January as the deadline for the technical review approaches.

Norming

Team norming occurs as the members begin to work together effectively. In the capstone project setting, this is evident as the teams divide the tasks and develop the beginnings of simultaneous rather than sequential activities.

Trust of a student's classmates with the student's individual grades can make this process psychologically challenging. So, the common norming phase is when teams divide the work, yet cover each other. For example, a team may divide the tasks so that two students work on one task while two others work on another. More creative teams turn the norming process into more of a round-robin activity. Students A and B work on one task; students B and C work on another task; and students A and C work on yet another task.

The norming phase for the BUME capstone students seems to last until the end of March, just after the Spring recess.

Performing

The Performing stage is the goal of teams. In this stage, a "unified-group approach is applied to the task[7]." The team works as a team and accomplishes the work efficiently and effectively.

In the BUME Capstone projects, this stage is when the students finally realize some of the accountability and commitment features of the capstone. The course coordinator and faculty advisors role is generally to get out of the team's way. Weekly meetings, which were essential to ensure progress in September or January, become a way to keep the advisor in the loop rather than a way for the team to get advice.

These young engineers learn the quantity, quality and types of tasks that each team member can handle and divide up the work accordingly. They come to understand that in order for any of them to be successful, they need to be successful together. The sheer quantity of work remaining at this point tends to force the top achievers to trust that even the lowest achievers can do useful work. The low achievers discover that with their degree comes the responsibility to engineer, rather than to nap through lectures.

This exciting phase ends when the project is completed.

Adjourning

The Adjourning stage is the natural wrap up to a successful project. In the case of capstone projects, adjourning tends to be more emotional in that it is not just the project or the team that is concluding, but rather the end to many students' undergraduate years. Alumni who have been through this process and achieved a performing team report that they maintain contact with their senior design team members long after they have left the institution.

Accountability

Individual accountability in the workplace often culminates in an "annual performance review". Such reviews are often the basis for promotion, raises and even firing of workers. The BUME capstone course employs two types of accountability assessments: a totem pole and performance review.

In the totem pole assessment, the team members are asked to rank each member of the team in terms of their contribution to the project. The team members complete the ranking each month, with the expectation that the rankings will vary from month to month based on other courses, work or personal responsibilities. Flags are raised to the advisor and course coordinator when an individual is always on the bottom or if there is great disparity between the self-ranking and the ranking from the teammates. By the end of the year, the cumulative rankings provide insight into the team's dynamics and form part of the basis for the individual component of the course grade.

The team also completes the performance reviews for each individual team member. BUME has obtained performance review worksheets from two major corporations and has the student use these forms verbatim. The students learn reviewing both as the reviewer and the reviewee. The concept of average is also covered – in that "meets expectations" is an should be the most common result. The first performance review is completed in December and the second is completed in March. These performance reviews also form part of the basis for the individual's grade.

The totem poles and performance evaluations are also used for an unpleasant purpose. Students can be "fired" from their teams. Students who are performing at such a level that they are providing negative value to their team or client can be "fired". For example, a student who promises for weeks that they will design or build something and then the resulting product is so subpar to the effect that someone else has to redo it. As in the real world, being fired is not good and has serious consequences. On average two students per year, in classes of 65, must face being "fired" from their team.

A "fired" student is given a related, small, independent project that, if completed, will benefit the team and, if not, won't do much harm to the team. The student then must work for approximately two weeks on the independent project and submit the completed results to the advisor, course coordinator and team. If the "fired" student is successful, they earn their way back onto the team. This results in a positive experience for both the "fired" student, who gains self-confidence, and the rest of the team, who regain respect for the "fired" student's abilities and typically learn to understand different working styles. Nearly all "fired" students have had this outcome.

Students who do not successfully earn their way back on the team get one last similar opportunity and then fail the course. Both the student, course coordinator, advisor and the department are aware that this outcome requires that the student stay a full extra academic year, thus while such decisions are not made lightly, students are held accountable for their action or inaction in the capstone course as they would be in industry.

Commitment

In industry, teams work to complete projects with deadlines. The focus in projects is to *complete* them by the deadline. In schoolwork however, the focus often becomes to turn in whatever you have done by the deadline – and don't look back.

In Bradley's Mechanical Engineering Capstone Design course, the projects are pushed to the industry model of work to completion. Students are not done with their project until their advisor and/or their client says the project meets its intended specifications, as created by the students in their project proposal. Thus the proposal is a commitment by the students to deliver some specified value to the client.

Of course there are hard deadlines ("no one leaves the office until it's done") and soft deadlines ("if we don't finish it today, it will still be waiting tomorrow"). Student-set milestones, are soft deadlines. If they are not completed on time, there is generally no real penalty, other than it delays the rest of the deadlines. Once a team has missed more than one milestone however, they are responsible for creating a Recovery Plan to get back on track and must get their client's approval for the plan.

There is only one hard deadline – their graduation. All projects must be completed by the end of the spring semester or there are serious consequences. A grade is not issued for the capstone course, until the project is completed. Thus, the graduation of the entire student team could be delayed. The few teams that have experienced this alternative end up working very diligently and complete their project.

This drastic measure usually provides enough motivation and creates common sense of purpose to unite the team's efforts – and to avoid such a conclusion.

Team vs Individual Assessment and Grading

In industry team and individual recognition are often interlinked and reflected in job satisfaction and annual performance reviews. In an academic setting, students need to receive grades. Much has been published about teams and individual grading. The BUME Capstone Design course faculty have tried several methods.

Team grades based on the project outcomes. This method was the easiest to implement – if the client loved the deliverables, the students got A's. Unfortunately, the students did not see this as fair or reflective of their individual efforts or the tasks that they individually had to two. Not all projects are equal in demands; not all clients have equivalent expectations.

Individual grades based on the project outcomes. This method allowed the advisors and course coordinator to create a range of grades for the individuals on the team based on personal observations.

The project outcomes determine the median grade for the team, then students who visibly put in the most effort were graded higher and those who put in the least effort were graded lower. Students still complained at the lack of periodic assessments of how they were doing and what grade they should expect based on their efforts.

Individual grades based on the project outcomes and totem poles. In this grading strategy, the final results of the project and the monthly evaluations outline in the Accountability section, were combined to determine individual grades. This strategy was generally accepted, however the subjectiveness of the project outcome portion of the grade left the faculty in a less than ideal position if a student were to challenge their grade.

Individual grades based on 3 mid-project reviews, a final review and totem poles. This is the current strategy that has been implemented for 1.5 years. The strategy involves rubric-based evaluations of 4 project reviews conducted by the faculty, peers, graduate student, clients and alumni in addition to the individual evaluations. To date the only concern raised for this strategy is the emphasis of the presentation about the final deliverables rather than the deliverables themselves. Time (and course assessments) will tell whether this strategy meets the needs and expectations of all of the constituents.

Conclusions

This paper presented a model for capstone design courses that attempts to have student teams experience teamwork in a way that closely follows accepted business practice. Using Katzenbach and Smith's Smith's triangle of basics[8] for high-performing teams, teams are formed based on individuals skills. The team is made accountable and committed both as a group and as individuals through the structure and format of the course. Tuckman's group development stages[7] are generally commonly accepted as stages that every team goes through. Through course planning, policies and expectations, student teams pass through each stage during their two-semester capstone project. This complete experience leaves the students poised for success as they begin their careers as engineers and team members.

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