Graduate Student Team Formation for Promoting Broad-Based Engineering Skills

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Abstract

Graduate education is highly focused on the development of technical and analytical skills, but typically provides minimal experience in team formation and interpersonal growth. To assure a more balanced graduate school experience, Idaho Engineering Works (IEW) at the University of Idaho is formed of a diverse group of graduate students whose purpose is to develop an environment that fosters professional as well as technical excellence. This paper analyzes the actions taken each year by IEW leading to the formation of well-trained, collaborative, and highly-reflective cohort of graduate students that support design education. This team is developed through directed study courses, team projects, personal reflections and monumental technical and interpersonal challenges. Since 1994, IEW has been successful in delivering hardware that exceeds expectations of industry customers, shortening time frames required for large-scale design projects, enriching senior design mentoring, and expanding the number of members. Each academic year produces a unique engineering leadership experience that has lifetime impact for its members and a legacy of improved infrastructure for design education. In this paper, the teamwork model derived from Larson and LaFosto is used to reflect on the people, strategy, and operations that form the IEW. Based on this analysis, strengths of the IEW experience are unified commitment and creation of a collaborative environment while several improvements could be made to improve its results-driven structure.

Background

Idaho Engineering Works (IEW) began as a way to improve the graduate experience. Traditionally, graduate students are paired with a member of the faculty with similar interests of study to work on research and complete a thesis. The student generally works exclusively within a group that specializes in such research, minimizing exposure to other engineering disciplines and insights. In fact, this pairing often discourages interaction with other students and certainly other professors. Unfortunately, this traditional arrangement does not adequately train graduates for today's job market. The Society of Manufacturing Engineers (SME) conducted a survey that questioned corporations that employ manufacturing engineers and technologists[1,7]. This survey revealed that educational institutions fail to prepare graduates with necessary skills in project management, written and oral communication, and business management skills.

IEW, on the other hand, is a unique graduate experience at the University of Idaho in its Mechanical Engineering Department. Composed of a diverse group of graduate students and faculty members with different specialties, IEW attempts to make the graduate student experience more than an act of technical skill development. Such development is accomplished through the responsibilities that each IEW member accepts in addition to his/her scholastic duties. These roles include the joint participation in large-scale team projects, while mentoring multiple Senior Capstone Design teams from project inception to final fabrication.

Furthermore, The close interaction between graduate students involved in this program allows shared learning of professional skills and a more detailed understanding of design for manufacturability than is possible in the traditional graduate student model. The resulting product is engineers who are not only technically competent, but also possessing skills in leadership, team dynamics, communication, customer relations, creative thinking and professionalism.

Model for Benchmarking Team Performance

Larson and LaFasto describe a model for characterizing successful teamwork that applies to communities of engineers[2]. In order to strengthen the team as a whole, individual members must also grow and develop in competency and skills. Many of these personal development needs are summarized by Leise in his model for self-growth[3]. We have synthesized these two models in Table 1.

Table 1: Characteristics of a Successful Team

Clear and Elevating Goal	The team must have a clear understanding of the goal to be achieved along with the belief that it embodies a worthwhile result. This goal should be personally challenging for each member as well as include specific performance objectives stated precisely and unequivocally for both team and individual.
Results-Driven Structure	Within the team setting, all actions by each individual should result in progression towards the common group goals, thus elevating the skills of the individual members and team as a whole.
Competent Team Members	Each member must have the necessary technical skills and abilities to achieve the desired objectives, exhibit a strong desire to contribute towards the common goal, as well as have the personal characteristics required to achieve excellence in a team setting.
Unified Commitment	All individuals within the team must have dedication to the endeavor laid out in the goal and be willing to work with others in the team towards this result.
Collaborative Climate	All team members should exhibit actions that are beneficial to the trust developed within the team such as honesty, integrity, openness, willingness to share, receptivity to information, consistency, and respect for their teammates.

Creating Elevating Goals

The notion of creating a clear and concise goal is not new. However, a goal can be established that clearly identifies the objectives of a project, but if the team members do not find that goal worthwhile then individual commitment and focus can be compromised. In other words, not only must a goal be clarified, but also the members of that team must all contain the belief that the goal embodies a valuable and important result.

A central role of IEW members is to provide guidance to the seniors design teams enrolled in Capstone Design. Those involved in the UI Capstone Design process must clearly identify the goals of the project, make design decisions based on analysis, and provide a functioning hardware prototype compliant with the design specifications. A successful prototype cannot be obtained without effective communication, teamwork, and professionalism. IEW mentors provide servant-leadership in such areas as client communication, project management, conflict resolution, and machine shop training.

Most new IEW recruits participated in the aforementioned senior design process, and, as such, were exposed to this mentoring program. This firsthand experience allows potential team members to see advantages of the servant-leadership in the education experience. For these recruits, graduate school becomes more than just an exercise in obtaining technical knowledge; it also provides an opportunity to impart this knowledge to others while developing skills in leadership and management. Therefore, the goals established by the team maintain this focus.

However, though common interests prevail between all IEW teammates, individual goals must be acknowledged to insure personal buy in. Each year, as new graduate students leave the program and new students are acquired, IEW must reform to meet the requirements of the new group. With the influx of new teammates comes the influx of new ideas and desires. Due do these new ideas, the IEW members will establish goals that fit the new and unique team. Often, goals from previous years are adopted, but a new mission is established in the end that all of the members find important. Since the team decides the new goals, the members are more committed to fulfill those goals.

This philosophy of elevated goals carries over into the various projects that IEW undertakes. Each year IEW seeks to tackle a challenging project that will stretch the abilities of the members involved and foster individual and team growth. Commonly referred to as Big Hairy Audacious Goals (BHAG), these large-scale projects require the collaboration of the entire team in order to complete.

In 2002, IEW accepted the BHAG of completing a drawings package using ProEngineer software for a high impact tester that consisted of 398 unique parts. Originally designed by the Navy in the 50's, this machine was used to shock test circuit boards for naval warships. Due to the incompleteness of the original blueprints provided, many of the components were redesigned for proper tolerance and stress constraints. Upon completion, the new design was delivered to a major electronics company for eventual fabrication. The result is shown in Figure 1.

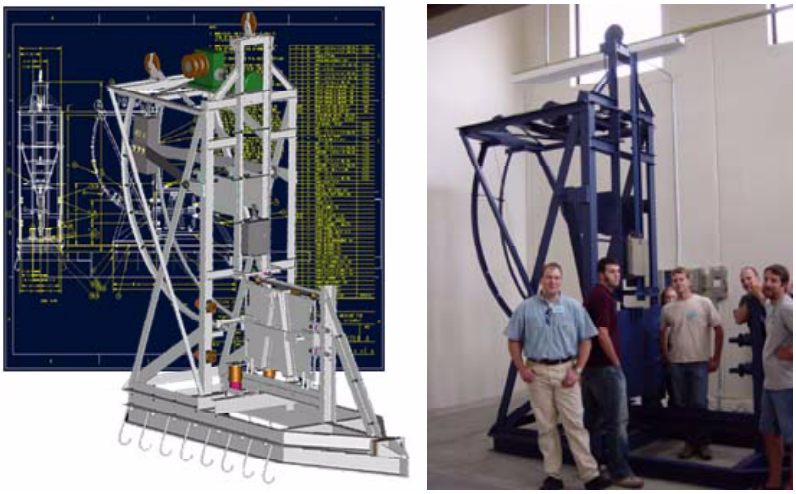

Figure 1: High Impact Tester BHAG

Results-Driven Structure

The structure of the team itself can be the factor in differentiating a greatly successful team from an unsuccessful one. For a structure to be useful, it must be established in a manner that promotes individual and group efforts that always culminate at the desired goal. The team must ask itself, "What should be the result—or objective—of our collective effort?"[2]

As stated earlier, one of IEW's chief concerns is to provide an excellent Capstone Design experience for the undergraduate seniors. Past experience has shown that seniors often need substantial shop training in order to complete their projects. This lack of experience often leads to extra fabrication time, thus reducing the availability of shop facilities for other design teams.

To reduce such inefficiencies, a summer course in Lean Manufacturing is offered as a means of introducing future seniors involved in Capstone Design with basic machine shop skills. IEW team members provide the students with manufacturing projects designed to introduce Lean Manufacturing principles while exposing the students to key machine shop tools. One-on-one machine shop training is then provided (see Figure 2). Upon completion of this course, students have a fundamental understanding of how to eliminate waste in the design process and possess knowledge of how to design for manufacturability. This preliminary introduction allows for more self-reliant senior design teams and streamlines the manufacturing process.

Figure 2: Machine Shop Training

A pliers project has also been used to introduce new seniors to machine shop tools (see Figure 3). Introduced during the first semester of Capstone Design, this project provided seniors with early exposure to the manual mill, manual lathe, and drill press. In the process, the students obtain an idea of what the machine shop is capable of producing while gaining insights into design.

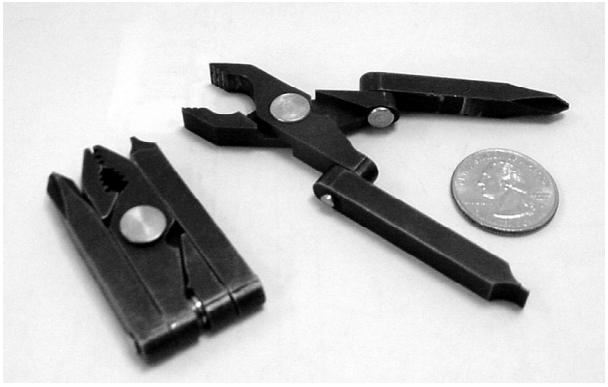

Figure 3: Pliers Created in Shop Orientation

The demanding task of mentoring senior design teams takes leadership, management, and organization skills. In order to better educate the mentors in these skills, a semester long graduate seminar is conducted focusing on such issues. Examples of successful and unsuccessful management models are explored and analyzed with the intent of gaining understanding into Capstone Design mentoring possibilities. This course also allows IEW members to share and reflect upon actions taken with individual teams to find collective solutions for common problems. Furthermore, since self-assessment is crucial for insuring personal growth[3], such reflection allows members to incorporate, or reject, the principles discussed into their own internal processes.

Competent Team Members

Selecting appropriate team members is always a challenge when forming a team and IEW is no exception. There are three fundamental characteristics that are desired for each member of the group: a strong desire to contribute, essential skills and abilities, and the capability of collaborating effectively[2].

Within IEW, the team members are selected from undergraduate candidates who have expressed interest in the team and illustrate a desire to join the group. Fortunately, IEW by its very nature attracts only students of a certain mindset. By and large, prospective graduate students want to become involved due to their interest in teaching/mentoring and in personal excellence as an engineer. Because IEW is formed of only graduate students in Mechanical Engineering, their entry-level technical skills are rarely in doubt. The vast majority of candidates meet this criterion. However, often the non-technical skills are what may dictate their success or failure within the group. Because these candidates are referred to the faculty advisors for the final decision as to their enrolment in IEW, many of these non-technical skills cannot be adequately assessed prior to their introduction in the group.

To improve these non-technical skills, many of the activities done by the IEW group are targeted at the development and use of these non-technical skills such as trust, leadership, organization, personal accountability, and management skills. One of these developing activities completed in the initial team-building stage of the group is a rope course that is used to cultivate communication, trust, and teamwork within the group. Other activities include coursework, in which organization, planning, and mentoring skills are developed; a shop introduction and practical whereby valuable shop skills are developed and employed; and BHAG projects that draw on the developed trust and communication skills from the ropes course and allows the group to complete an amazing assortment of challenging projects.

Unified Commitment

The majority of those involved in IEW have several experiences in common that help foster unity within the group. Nearly all have been through the Capstone Design experience to which the members of IEW dedicate much of their time in mentoring. This commonality allows the group to start with a basis from which to develop many of the non-technical skills that are so valued in the industrial world[1] without having to first develop an understanding of the problem at hand. As well as starting from a common foundation, at the beginning of each academic year the members of IEW contribute to the development of the goal statement that will apply to that year's activities. By including all members in this discussion, everyone can voice their opinions and provide valuable input from their personal experiences in Capstone Design to the goal statement. By developing the team goal statement based on the team's previous Capstone Design experiences, the members of the team exhibit a high level of personal commitment to the completion of these goals.

Collaborative Climate

Perhaps the most crucial of all teaming aspects is the idea of a collaborative climate. Simply stated, a collaborative climate refers to the amount of trust and interdependence present in the team. Only through interdependence can a team achieve its highest potential[4], but only through trust can interdependence operate.

Communication between different functions in the design process is necessary for providing efficient product development[5,6]. Effective communication can foster trust between teammates. To help facilitate such communication, all members of IEW share the same office. Collocation of IEW members allows efficient transition of knowledge between teammates, while cultivating a supportive atmosphere (see Figure 4). Furthermore, the IEW office space is located in close proximity of the Capstone Design suite and machine shop. Such collocation encourages lateral thinking in the development of solution concepts.

Figure 4: Computer Rendering of Shop, Assembly Area, and Conference/Study Area

IEW teammates have learned to work with each other while relying on individual strengths to accomplish the team's goals. As mentioned previously, a Lean Manufacturing course is offered over the summer to incoming seniors to better train them in machine shop skills. It is the role of IEW to create projects that the seniors can fabricate which will not only train them in the necessary machining skills, but will also introduce them to lean manufacturing principles. IEW teammates collaborate by creating solid models of each project and then providing a drawing package for the transitioning seniors. Furthermore, due to the individual strengths of each teammate, tasks are allocated to most efficiently reach the objectives.

Until recently, a formal training program for training new IEW teammates was not in place. The responsibility of learning necessary design tools fell upon the individual. In 2003, IEW instituted a structured machine shop training program for incoming graduate students. For this training, senior IEW mentors, adept in specific machine use, provide one-on-one training for inexperience operators. Thus the incoming mentors can become fully prepared on every machine before the senior design process ensues.

Conclusions

The success or failure of IEW at the conclusion of any academic year is twofold. IEW has been successful if the group as a whole has met or exceeded the goals outlined at the beginning of the year and the group has had a positive effect on the engineering department. However, unless each individual within the group has a positive impression on their individual participation within the group, IEW was not a success for that person, and it could be argued that it was not a success at all.

The Larson-LaFasto model, in conjunction with insights about personal development by Leise, serves as a good tool for benchmarking IEW performance. It can also be utilized to identify strengths and weaknesses that can be used for improvements in structure and planning for IEW activities for the next academic year.

Based on the analysis presented in this paper, the two greatest strengths are (1) IEW's ability to adapt their goals to the interests and needs of new members each academic year and (2) the collaboration between members of IEW and each year's Capstone Design class. By allowing this adaptability, IEW members are more committed to team goals established each year because these align more fully with what each member finds meaningful. Collaboration between graduate student mentors and Capstone Design students is critical for undertaking industry projects that involve state of the art technology and manufacturing processes. Over the last eight years, we have seen a dramatic increase in the scale and complexity of hardware prototypes delivered by the Capstone Design program.

One major area for improvement within the group suggested by the Larson-LaFasto model is regulating and balancing the workload within the group. All IEW members are dedicated to servant-leadership in support of the Capstone Design program. Because undergraduate students comprise the design teams, common manufacturing resources between teams can become an issue causing mentors to find themselves overloaded. This is a result of poor time management skills of seniors leading to problems in meeting project milestones. One possible solution to this recurring problem is to modify the capstone team/mentor assignments such that multiple mentors can be brought in to work with teams on an as-needed basis for prototype manufacturing.

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