AC 2007-1023: TEAM-COMPOSITION METHODOLOGIES FOR MANUFACTURING ENGINEERING TECHNOLOGY PROGRAM PROJECTS

James Rumpf, Ferris State University

Team-Composition Methodologies for Manufacturing Engineering Technology Program Projects

Abstract

The ability to work effectively as a member of a team has always been an integral component of a manufacturing engineering professional's skill set, but never more so than now. Incorporation of practices such as lean manufacturing and third-party certification into companies' standard operating procedures have heightened the awareness among employers of the desirability of so-called "soft skills" in their prospective employees. Consequently, teamwork is more a fundamental part of modern manufacturing-related curricula than ever before as well. However, the best way to impart soft-skill lessons, especially in hard-skill fields, is open to debate, especially in the academic environment where outcomes assessment is stressed. Factors such as the size of classes, complexity of projects, strengths versus weaknesses of class members, diversity initiatives in place, and many other dynamics may play a role in the formation of project teams. Simultaneously addressing the needs of each individual student, the needs of the class as a whole, and needs of industrial partners is a delicate balancing act that calls first and foremost for careful consideration of all pertinent factors, followed by insightful decisions and proper monitoring.

This paper addresses methods of forming project teams in on-campus courses delivered by traditional methodology in the Ferris State University B.S. program in Manufacturing Engineering Technology. It discusses our different approaches to team composition including their pluses and minuses, application of those methods in various courses at Ferris, assessment techniques of those team exercises, and suggestions for improving the process.

Introduction

In the competitive world of manufacturing, employers need new engineers to be able to earn their keep right from day one. Companies have always expected graduates to have mastered technical aspects of the trade, with such other traits as good presentation skills and leadership qualities often determining the difference between who gets a ride on the company's fast track and who goes down some corporate cul-de-sac. However, those skills once considered "soft" are increasingly necessary not just to climb the corporate ladder, but even to access the first rung. Chief among those newly necessary soft skills is the ability to work as a member of a team. The big question is how to impart soft-skill lessons, especially in the academic environment where outcomes assessment is increasingly more important.

In one form or another, though, team projects are an integral part of the manufacturing education experience. A large body of work on team dynamics exists, as a quick literature search can easily verify. However, assorted internal and external factors of a practical nature such as the size of the class versus complexity of the project, strengths versus weaknesses of class members, and many other dynamics can play a role in the formation of project teams for specific tasks. Balancing all concerns for each set of constituents is an increasingly difficult task for instructors to carry out.

Ferris' Manufacturing Program

The Bachelor of Science - Manufacturing Engineering Technology (MFGE) program at Ferris State University has been supplying graduates to manufacturing facilities in the Midwest since 1978. The MFGE program is a "+2" program, meaning that we do not start at the freshman level with students; those wishing to enter our program must already have an associate degree (or equivalent) in a manufacturing-related program. To this experience we add (depending upon specific courses taken) 41 credits of MFGE-major courses plus a 4-credit internship, 9 credits of related technical coursework, 8 credits in math and science, and 12 general education credits. Our primary feeder programs on the Ferris campus are the AAS programs in Mechanical Engineering Technology, CAD Drafting & Tool Design, and Manufacturing Tooling Technology, and, to a lesser degree, AAS programs in Plastics Technology and Welding Technology. In addition, every year between 40% and 60% of our incoming juniors come with AAS degrees from community colleges in similar fields to those we offer.

Regardless of where and in what field they did their AAS work, these incoming juniors tend to be stronger in either design- or process-related skills. We use the first semester of their junior year to help equalize their experiences (e.g., students from tooling programs must take a statics and strengths course, while students from design programs take a CNC course, etc.). Theoretically, by their second semester of their junior year, each student is at least as capable as any other in every field, but realistically we know this is not true.

We stage at least one major term project in each of the four academic year semesters in the MFGE program. Difficulties arise on large comprehensive projects, where division of labor is a necessity for timely completion. Students, being human, tend to display a predilection toward the familiar and divide up work along AAS-degree lines. While this may replicate what occurs in business practice, it tends to minimize expansion of skills and experience. In essence, instead of learning new things, each person may end up merely practicing skills already mastered, defeating some of the purpose of assigning the project in the first place. Also, one cannot assume that just because students have worked in teams before that they know how to work together.[1] Add to that the desires every instructor has for a student team (e.g., to get all members to participate, to develop in each member some degree of leadership skills and group cooperation, etc.) and it is apparent that careful consideration of team composition is essential.

Team Composition Methods at Ferris

A group of individuals with technical expertise alone is not enough to constitute a team. In an ideal academic model, we would have the exact perfect balance of number of members, backgrounds, personal levels of motivation, technical abilities, etc., to produce the optimum learning experience for each and every participant. The absence of that, though, requires compromise. Some common team composition schemes used at Ferris and their associated pros and cons are listed below:

- Random – the instructor uses some random process to determine who is assigned to what group. Although it carries with it an inherent sense of fairness, random assignments may not optimize learning opportunities for each team member.

- Alphabetical – initially the same as random assignment, repeated usage of this method will end up assigning the same groups of students together, negating the fairness benefit.
- Seating habits – the instructor arbitrarily assigns contiguous groups according to where the students normally sit in the room. As creatures of habit, students repeatedly sitting near each other are likely to be at least acquaintances or share some personality traits that may improve their comfort level of working together.
- Geographical – the instructor assigns students who live and/or work near each other to groups. This method is primarily beneficial and particularly useful for evening program students or those who commute for the convenience of working together outside of class.
- Self-forming – the instructor determines the size of each group, and lets the students pick their own teams. Research by Scott and Pollock shown that self-selected teams can be very effective[2], at least in the field of information systems. Many students like this method as it gives them a sense of control and allows friends to work together, but it only works if the group members already have some experience with each other. Unfortunately, new or less-gregarious students can feel left out if not approached for inclusion.
- Balance experience – the instructor attempts to make sure each group has at least one person with skills required to complete the project (e.g., CAD, machining, etc.). This simulates cross-functional teams formed in many companies, but virtually guarantees division of labor along lines of experience.
- Unbalance experience – the instructor attempts to make sure each group is homogeneous (e.g., assign just CAD experts to one group, just machinists to another, etc.). This guarantees that at least someone on each team has to perform activities outside of their area of expertise.
- Maximize diversity – in courses with multiple small assignments with no required carryover (such as weekly lab exercises), the instructor makes sure that each student works with members of other race, ethnicity, and/or gender groups as much as possible. Though this method may fit in with university-wide diversity initiatives, this may degrade into a form of "tokenism", in which minority group members may be treated as just another piece of equipment that everyone gets to try. It has also been argued that the bigger deal you make of the color or shape of someone, the more people will think it's important.
- Rank in class – the instructor ranks students by class scores and assigns them to groups from top to bottom. This method has several advantages. Since better students tend to get better jobs at better companies, and vice versa, this can be a preview of one possible future for some. It also has the tendency to reward good students by letting them work with other high achievers (although sometimes alpha personalities can conflict, introducing a whole new set of problems[3]), and can motivate underachievers when they realize that there will be no coattails to ride.
- Solo – the "Army of One" approach, the instructor rewrites the project assignment to sacrifice depth but keep the breadth so that each student must perform activities in each area for him- or herself. Relying on the tenet that to be a good team member, you must be able to pull your own weight, this unfortunately limits the scope of project due to time constraints. It also requires more effort in grading on the part of the instructor, and does not develop any interpersonal skills.

Combinations of some of these methods are possible as well.

Present Practices

Different courses, with different projects and students at different places in their academic careers, require different approaches with respect to team formation for group projects. MFGE faculty have utilized the following approaches for the sampling of classes below in recent years:

Junior year, fall semester

- Cost estimation term project – essentially a time & motion study project during their first semester in the MFGE program, every student is on the same footing as none enter the program with prior experience. Whereas we used to assign groups randomly, we now use the rank in class method to motivate underperforming students and give them one final chance to demonstrate subject mastery.
- Computer applications project – a project that requires students to develop an Excel spreadsheet to solve an assigned set of engineering problems, write a training & operations manual for the spreadsheet in Word, and present their efforts to their peers using PowerPoint. Because students in the computer applications class come from multiple programs, projects are written to fit into the students' various majors and randomly-assigned homogeneous teams are formed so that the students can use their developed software in later classes in their home programs.

Junior year, winter semester

- Tool engineering project – a project across three courses (tool engineering, SPC, and metrology), all students are from the MFGE program and all have, by this time, at least rudimentary design- and machining skills. True random selection is typically used here to provide a change from previous and upcoming projects.

Senior year, fall semester

- Process planning project – a two-part project that requires students to first design a production process, then swap process plans with another team run each others' parts in a production environment. For phase one, unbalanced experience teams are assigned by grade rank, but then for phase two plans are swapped with teams that have complementary skills. For example, a team may be composed of three MFGE students with CAD backgrounds for the design phase, but they would run the production of a team composed of machining graduates, and vice versa. This ensures that each person's envelope of comfort is pushed at least for part of the project, but they work to some degree with other students from different backgrounds. They also learn the value of good process plans and the cost of bad ones.

Senior year, winter semester

- Automation & plant layout joint project – as the senior capstone experience, students work on this project by themselves. Main points we try to instill in this project are the importance of being a self-starter and being adaptable to any aspect of a typical manufacturing engineer's workload. It also adds another facet of the student's work to their portfolios to show to potential employers.

Assessment Methods

Instructor review of submitted project materials can evaluate the technical merit of the effort as well as written- and graphical communication skills, and evaluation criteria should be discussed at the time of the project assignment so that team members know what metrics they will be graded against. Oral communication skills and a modicum of participation evaluation can be made by direct observation during presentations. But unless the instructor is present for each team's every meeting, the instructor can really only evaluate teamwork by indirect observation. However, we can not assume that just "good" teams finish high quality work within time constraints, and vice versa. That is why peer evaluation plays an integral role in this area.

Agogino, Song, and Hey have addressed indicators of student success[4], noting the correlation between peer evaluation analysis and project success. On Ferris MFGE program projects, we use two primary types of student peer evaluation: percentage of participation and quality of participation. Each is officially considered advisory only to the final grade in order to insure normalization of ratings across all groups and prevent abuse of the system, and asks team members to only evaluate team-management issues, not technical merit of efforts. Common to both are the precepts that the instructor is ex-officio member of each group, and that cooperation, respect, and participation are mandatory.

Percentage of participation

In this type of evaluation, each student is asked to provide a quantitative assessment of team members' efforts. An example of peer evaluation form instructions from a process cost estimating project follows:

> Your term project grade is significantly influenced by evaluation by your peers. You are asked to consider each of your team members' conduct throughout the project period and determine what share of the total project points they should receive. As you evaluate them, consider factors such as participation (how much each person took part in the group responsibilities), accommodation (how much each person let you participate), quality of work, timeliness, leadership, etc. Ideally, each person pulls their weight and you can honestly rate each other at 100, but this system allows you to recognize both the slackers and the people who pick up that slack.
>
> Award each person in your group a percentage between a minimum of 75 and a maximum of 125 as a percentage of the final point total for your

project. Their scores plus your 100 points must add up to 300 if you are in a 3-person group, and 400 if you are in a 4-person group.

The average score of 100 is imposed to insure that students do not succumb to the temptation to rate all team members at the maximum, and to make them recognize the point that, in a zero-sum situation, if someone does not pull their own weight, another (or others) must do extra. Each student's average peer evaluation is multiplied by the instructor's grade for the project to arrive at the final grade for each student. Example: if the project is given a grade of 90, and the student's peers have rated that student at 90%, that student's final project grade would be an 81. Conversely, if that student's peers acknowledged a 110% effort, that student would receive a grade of 99. This technique of differentiating rewards based on effort helps avoid the "social loafing" problem as reported by Van Slyke, Trimmer, and Kittner.[5] In practice, we have rarely had group members rate each other outside of a 90%-110% band; when we have seen students given especially low or high ratings, it generally came as no surprise.

Quality of participation

In this type of evaluation, each student is asked to provide a qualitative assessment of team members' efforts. An example from a computer programming project follows:

Evaluate each member of your group, including yourself, for each of the following categories. You may use duplicate scores within a category. These evaluations will be held in strictest confidence, and your evaluations will not be shown to any other student.

Rating Scale:
1 – (F) Minimal or no participation, and/or ineffective or no contribution.
2 – (D) Marginal participation or sporadic attendance at group meetings/classroom work sessions.
3 – (C) Participation was reasonable at times, but missed some meetings and/or deadlines.
4 – (B) Good participation, very supportive. This is the minimum expected level of participation.
5 – (A) Participation above and beyond what could be expected.

Team member names **Project Phases**	(self)			
Initial project planning				
Formula investigation & development				
Excel spreadsheet development				
Excel spreadsheet tryout & debugging				

Word manual development				
Word manual proofreading				
PowerPoint presentation development				
Overall rating				

The primary drawback to this is the tendency of students to inflate their own grades. We have also noted a tendency for the effectiveness of this method to degrade in situations where division of labor is strong. Typically, this self-evaluative effort of team activities is combined with a qualitative review by peer groups as well as the expected one by the instructor.

Suggestions for Improvement

We are always open to new ideas that will help us better develop well-rounded graduates ready to excel at their careers. One avenue under investigation is directing general education electives that either develop students' abilities for group work or require team collaborations as prerequisites for technical courses. A pilot program along those lines is currently under discussion.

Assessment of such subjective traits as "cooperation" and "team attitude" will always be difficult. Rather than waiting until the end of the term to evaluate non-technical aspects of a project effort, periodic checks throughout the term may provide more timely feedback and help solve problems when they are manageable rather than letting them grow beyond a correctable size. This would also have the added benefit of aiding the students having the problems rather than just preventing them for future classes.

Conclusions

Rigorous scientific analysis using strictly designed experiments would be difficult if not impossible for team projects run in our program, given the sheer number of variables involved. However, from our experiences with numerous team projects over many years, we can draw some conclusions that may prove useful to others:

- Getting to know your students is key. The manufacturing engineering technology program at Ferris is small and our faculty group is close-knit, so we get to know our students very well. We work across the curriculum to make sure they each have a wide variety of experiences.
- "Task orientation" must be a priority on each project. It needs to be stressed that the dynamics between team members are secondary to accomplishing the task. In the working world, developing a good working relationship with one's team members means nothing if the work is not completed. In our experience, sublimation of personal concerns to the good of the group actually works to focus the group on the common goal, which fosters cooperation (regardless of motivation).

- Regardless of which composition methods are used, and as with rules for technical and communication requirements, teamwork-related performance expectations must be stated up front so that students know what metrics they will be measured against.

Summary

Many factors need to play a role in the formation of student project teams. Simultaneously addressing the needs of each individual student, the needs of the class as a whole, and needs of industrial partners is a delicate balancing act that calls first and foremost for careful consideration of all pertinent factors, followed by insightful decisions and proper monitoring. A coordinated approach is appropriate, as instructors need to utilize the appropriate method to meet the goals for each student in each class in conjunction with the overall goals of the program. Conscientious assignment and management of student project teams will help ensure the best possible experience for students, instructors, and employers.

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