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## Talkin' Teams – Strategies for Elevating Student and Team Skill Development over Project Completion

Dr. Greg Kremer, Ohio University

Robe Professor and Chair of Mechanical Engineering, and the director of the "Designing to Make A Difference" ME senior capstone design experience.

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## Abstract

The purpose of this paper is to share the author's experience over the past 12 years of integrating relevant theories and practices concerning authentic development of team skills and team member skills in a year-long team-based capstone design experience. An integrative learning approach to team skills is described that includes: grading and performance reviews that reward participation in building team skills, team formation and ongoing support based on cognitive diversity and collaborative skills, peer coaching based on areas of specialization, and consideration of team and individual tasks when structuring deliverables (including reports and presentations).

## Introduction

There are many excellent articles and texts on the topics of team-based learning<sup>1</sup>, collaborative learning<sup>2</sup>, learning organizations<sup>3</sup>, effective teams<sup>4</sup>, intra-team communication<sup>5</sup>, and professional skills.<sup>6</sup> The purpose of this paper is to share the author's experience over the past 12 years of integrating relevant theories and practices from these and other prior studies in a year-long team-based capstone design experience. Reproducible characteristics are presented that have yielded positive results in supporting the development of team skills and team member skills and not allowing these important outcomes to get lost in the rush to project completion.

For team skill development, overcoming the 'dominant team member' scenario and the use of 'divide and conquer' approaches that provide short term productivity but limit actual skill development is a challenge. Experience has shown that care must be taken in selecting the types of team effectiveness activities implemented and timing their use in order to balance team and team member development. This paper describes an integrative learning approach to team skills that includes: grading and performance reviews that reward participation in building team skills, team formation and ongoing support based on cognitive diversity and collaborative skills, peer coaching based on areas of specialization, and consideration of team and individual tasks when structuring deliverables (including reports and presentations).

In this paper, team skills refers both to the level of project work the team is collectively capable of accomplishing, and to those things that fall under the umbrella of 'teamwork.' An increase of team skills occurs when the team is able to accomplish something it was previously unable to (such as prepare a set of assembly drawings and parts list for a product), when the team is able to function together more efficiently (such as by using action item lists and project schedules effectively), or when more team members are able to accomplish something that fewer teammates were previously capable of (such as one manufacturing leader training two additional team members to machine a part on a CNC mill). Team member skills include all team skills that the members are able to transfer to a new situation (such as a member using action item lists in a different project context), as well as skills that individual members develop that are not

transferred to the team (such as an individual developing improved written communication skills independently of any other team members).

Background on the capstone design course where lessons have been learned and applied

Since culture and context have a significant effect on the success of any educational approach, some important details are included here about the academic setting where the author learned these lessons about promoting the development of team skills. The Ohio University Mechanical Engineering capstone design experience has been an intensive year-long experience since 2000. The undergraduate ME curriculum supports the capstone experience, and the capstone projects are given high visibility in the college and the community. The capstone experience is an integral part of the culture of the department. Ohio University is in Athens, an Appalachian county with little industry but plenty of individuals and groups with real needs but with limited resources to meet those needs.

Over the years, team size has been an area of experimentation, and the best team size for balancing learning teamwork and enabling effective project work was found to be five members. Teams are formed based on diversity of skills, cognitive styles<sup>7</sup> and natural team roles<sup>8</sup>. Student teams partner with individuals or groups in the community that have a need that can be addressed by a student engineering project. The overall theme for our capstone projects is expressed as “D<sub>MAD</sub>: Designing to Make a Difference.” Many teams partner with individuals with disabilities, and our teams have won four national awards in the past four years in competitive national student design competitions. Other projects engage local farmers and locally owned small businesses, and an effort is made to have at least one international project each year so that all students are exposed to the different design considerations for those projects. Most of the team expenses for the projects are covered through college support and departmental fundraising. Some industry sponsors have chosen to provide funds for projects that benefit the community, rather than funding projects that benefit their specific company. Some sponsors speak of this as an effective alternative to funding scholarships at a university, since they get more exposure and impact more students. The design teams complete an entire design process from problem definition through delivery, testing and product support for their design solution. The learning approach is experiential and integrative and the assessed course outcomes include a balance of individual engineering skills and team skills. Direct assessment of student work and behaviors and example-based performance reviews (that include a range of professional and team skills) are used to assess team skills and team member skills, and to assign grades.

Other aspects of the capstone design experience that influence team and individual skill development include the use of collaborative project management tools, mentoring relationships with freshmen students in the Introduction to Mechanical Engineering Course, a checklist-based approach for creating an ongoing dialogue between the design teams and Industrial Advisory Board project mentors, requirements to reflect on and evaluate decisions as a team, and a significant emphasis on professional skills reinforced in an ongoing dialogue with teams and students.

## Challenges to Developing Team Skills and Some Ideas for Overcoming Them

Teams and teamwork have become an essential aspect of modern engineering education, spurred by the needs of industry and the requirement to prepare students to meet ABET engineering criterion 3d: “an ability to function on multidisciplinary teams.” Anyone who has been on an engineering team either in professional practice or in an academic setting has likely experienced at least as many teamwork challenges as team successes. This is due in large part to the fact that diversity amongst team members is necessary to gain the benefit of a team, but it also creates the conditions for the communication and inter-personal challenges that confront teams. A group of engineers that apparently lacks diversity in the standard sense (race, gender, nationality) will nonetheless possess a diversity of skills, intelligences, cognitive styles, learning styles, communication styles, relational styles, decision making approaches, experiences, perspectives, maturity, biases, opinions, motivations, concerns about grades, and so on. It is essential that an instructor or team facilitator address diversity at the beginning of the team experience in a positive yet realistic way and then continue to provide guidance and coaching on effectively using team member diversity throughout the stages of team development, continuing to challenge student teams to work together in ways that allow them to perform as a team rather than a collection of individuals sharing a workload. One important aspect of this team development is to take the time to have team members develop self awareness of their preferred styles of thinking, learning, communicating, etc. and to develop an appreciation for the fact that having different styles represented on a team is essential for the team to be more creative and effective problem solvers than they can be individually. Based on student feedback provided through individual reflections on their learning process, the most effective way to get team members to appreciate the benefit of positive conflict on a team’s ability to generate and execute creative solutions to problems is to show examples of diverse high-performing teams such as the design teams used in the innovate product development company IDEO. A segment from ABC News “Deep Dive” that highlights a multi-functional IDEO team working together on a conceptual design of an innovative shopping cart is used in class to show that this innovative company: a) uses teams of people with diverse backgrounds, including many non-engineers; b) awards failures (to encourage risk taking); c) values ideas over status or title; and d) discourages negative idea-stopping comments (since crazy ideas often spur innovate yet feasible approaches).

Next to diversity, time pressures have proven to be the next biggest challenge to development of true teamwork and team skills. The fact that teams exist to accomplish a task or a project provides a constant temptation to be project-centered rather than team-centered. It is obviously necessary that most team time and resources are directed toward the project, but teams can be said to adopt a ‘project-obsessed approach’ when they place short-term progress over long-term effectiveness and default to some variation of a ‘divide and conquer’ approach. Taking a design report as an example, if all team members are willing to trust each other to work on behalf of the team (or if they care more about getting it done than doing it right), the project-obsessed team breaks the report into sections with each member having responsibility for one section, and the sections are somehow combined and submitted, usually with some members never having read the entire report. In a project-obsessed mode neither the team nor its members develop good group report writing skills. In a project-obsessed team where there is a diversity of concerns about grades (those working for an ‘A’ and those happy with a ‘C’), it is more likely that the grade-focused members will control most of the work and ‘enable’ the other members to do little

or none of the report writing. In this case some members get additional report writing experience, some get little or no experience, and no members develop good group report writing skills. Although project-focused grading is easiest and therefore is a common approach for team-based design projects, it can unintentionally reward project-obsessed teams. Grading practices that include peer ratings do serve to increase accountability and when done effectively make the individuals grades more fair, but if the peer ratings are project focused they do very little to actually promote team skills.

Continuing the report writing example, the desired team approach to report writing for simultaneous development of team skills and team member skills is for all team members to participate in outlining the content of the report sections and reviewing the completed content for completeness and correctness. Those with better technical writing skills would mentor those who lack those skills while they work together on a section of the report. Then the member who was mentored would apply the newly learned skills to independent work on another section of a report, with review and feedback from other team members. The technical communication leaders would serve as the overall editors for style and grammar consistency. This group report writing experience may seem idealistic and is in fact hard to achieve in totality, especially if certain students lack the motivation or the basic skills to participate. But it is possible to get an overall positive group writing experience for most team members if team members are motivated to participate using a performance review process that includes ongoing dialogue about group report writing as a useful professional skill, and if the instructor regularly meets with the entire team to discuss the report and the writing process and to provide feedback and mentoring on both.

The performance review process mentioned above has proven to be successful in supporting team skills. A performance review grading system looks at a student's overall performance in assigning a grade, rather than looking primarily at team deliverables and then modifying grades based on peer ratings. If the performance review self-report includes an item that requires each student to provide examples of how they worked with other team members in a coaching or mentoring role to develop the team's skills, and if the students are aware that this is one of the characteristics or professional skills that they must demonstrate in order to get a good grade in the class, then most students will participate in the team writing process or other similar processes where they operate in either a mentoring or a mentored role.

#### Key factors in the simultaneous development of team skills and team member skills

A thoughtful and well planned approach to team development and support is needed to counter the challenges presented by time pressures, to help change previously learned habits associated with working in teams, to convince students that development of team skills is a required outcome of the course on a level similar to project completion, and to help teams harness the benefits of diversity rather than allowing non-constructive conflict to hamper team effectiveness. Key factors that have proven to support the simultaneous development of team skills and team member skills in the context of the mechanical engineering capstone design project at Ohio University are listed and explained below. The primary assessment data that supports these statements are the examples provided by students in written and face-to-face performance

reviews that address both team skills and project quality, and the quality of the team experience and the team output as assessed by an external advisory board via interactions with teams throughout the design process and review of the working prototypes.

**Factor 1: Create a team culture:**

The culture sets student expectations, and those expectations can make or break any attempt at educational innovation. During the first few years of our new approach to the capstone design experience, team effectiveness was impacted by the prior culture. Prior to 2000 the application-based senior project was a one-quarter individual effort, paired with a one quarter mechanical design course and a one quarter thermal design course which each had ‘paper’ design projects. The students entering the capstone after 2000 had only experienced groups in lab courses and small class projects, where little or no time was spent on developing effective teamwork and students were left to figure out how to work together on their own. The expectations of the students in the new year-long capstone experience was that their experience would be strongly ‘individual’ like those they knew of from previous years. It took time to shift the culture to one where students expected to have a team experience and either looked forward to it or at least were prepared for the experience. We created a team culture in our capstone experience through years of clear and consistent expectations regarding teams and teamwork, through developing a freshman-level team design project in which the freshmen teams receive significant mentoring from the senior design students (and therefore see and experience teams early in their academic program), and through implementing reward (grading) structures that showed we placed a high value on team skills. When an attempt at promoting team skills is meeting resistance, take a step back and ensure the background work for creating a team culture has been accomplished.

**Factor 2: Form diverse teams based on skills, cognitive modes and natural team roles, and set up conditions that empower teams to harness the power of diversity:**

To create the conditions for development of team skills it is vitally important to form cognitively diverse teams. However, the presence of diversity is not a sufficient condition for learning teamwork or improving team performance. The question about the relationship between diversity and team performance is a many faceted one, and to be meaningful any statement about the impact must be qualified to a specific type of diversity. Some recent work reported in *Teamology – the art and science of design team formation*<sup>9</sup> shows that even at the level of cognitive diversity it is not possible to make sweeping statements about diversity’s impact on team performance, and the actual performance impact is often negative. This is understandable in that diversity by its nature is disruptive, and only when managed properly can the expanded perspectives and skill sets be harnessed to improve team creativity and decision making. Interestingly, the *Teamology* study also found that cognitive diversity does not correlate with either individual or team level satisfaction, or in other words diversity did not impact the team member satisfaction with other team members or the overall experience.<sup>9</sup> Studies that reinforce the idea that diverse teams need assistance in making use of their diversity include *Bringing in the Experts: How Team Composition and Collaborative Planning Jointly Shape Analytic Effectiveness*<sup>10</sup> which studied expertise (similar to cognitive diversity) and use of collaborative planning both individually and in combination and found the presence of experts in a team had a negative effect on team performance without collaborative planning but a positive effect when that expertise is present in combination with collaborative strategies to properly use the expertise.<sup>10</sup> Rentsch et. al., in a useful article in *Small Group Research*, found that “Problem-

solving teams composed of members possessing unique knowledge tend to be ineffective because of impediments that limit information sharing... The training strategy appears to be effective in aiding teams to ameliorate communication impediments.”<sup>11</sup>

*Evidence for a Collective Intelligence Factor in the Performance of Human Groups*<sup>12</sup> supports developing team skills in the context of diverse project groups. Wooley et. al. studied whether “collective intelligence” exists for groups of two to five people and found that although no factor correlates with average or maximum individual intelligence, there is a correlation with factors related to group collaborative ability (what they called the average social sensitivity of the group members). Social sensitivity was stronger in groups that practiced conversational turn-taking and groups that included a higher proportion of females.<sup>12</sup> Finally, the article *Disruptive Diversity and Recurring Cohesion: Assembling Creative Teams in the Video Game Industry*<sup>13</sup> found in studying a huge dataset over a thirty year time span that teams with a diverse set of stylistic experiences outperformed teams with less diverse backgrounds, but only when those teams had a high level of social cohesion. Cohesion enables teams to “harmonize the noisy cacophony of an (otherwise) excessive plurality of voices, thereby exploiting the potential beneficial effects of cognitive diversity.”<sup>13</sup>

To form diverse teams, the cognitive mode approach promoted by Doug Wilde<sup>7</sup> at Stanford has proven to yield excellent results for the Ohio University capstone design teams. Additionally, the CATME Smarter Teamwork tools available at [www.catme.org](http://www.catme.org) continue to get better and are very useful for automating both team formation and team performance assessment. Concept generation and decision making are two team activities where diversity can make a noticeable and positive difference if managed properly. Instructors or mentors should work with teams during these project times to reinforce the message that more diverse ideas lead to better solutions (the IDEO design process is a great example of this) and that many decision making failures are due to lack of consideration of diverse perspectives (illustrative examples can be found in *The Art of Critical Decision Making* by Michael Roberto).

Encouraging specialization within the team by empowering teams to assign roles for each team member (preferably based on skills and natural team roles<sup>8</sup>) is more effective in helping teams benefit from diversity than a homogenized approach that suggests that all members should be involved equally in all aspects of the project. However, these roles need to be understood in the context of supporting the team and building team skills, rather than being the only team member that does work in that area of specialty. Authentic specialization leads to improved team relations and improved team performance, and is representative of actual team scenarios in industry. Care must be taken to help the teams see the difference between general skills (that all students should demonstrate) and specialized skills (that each team should demonstrate, but not necessarily each individual), and grading procedures should also account for these differences. The instructor must also be mindful of the difference between team tasks and individual tasks when structuring deliverables and presenting them to the teams. For example, reports and presentations are best accomplished via a mix of individual and team tasks. Team writing by everyone sitting around a computer screen while one person types is a mode that some teams initially try, until they realize how ineffective that mode of group writing is. Coaching the teams as they develop the team skill of task distribution will help each team learn from experience how to use their resources effectively.

**Factor 3: Choose appropriate projects that balance feasibility and technical challenge:**

There is no ‘best project’ for a team-based experience, but in order to support team development the project must require involvement of the entire team to complete it, but not be so large or complex that it promotes rushed work without concern for proper processes and skill development. It is better to err on the side of being too simple rather than too complex if team skills are to be developed. Examples of projects that worked well for skill development are assembly jigs, assistive technology, small mechanical projects for sheltered workshops, and other projects that generally cost less than \$500 for materials and fit on a table or in an area less than 3 foot by 3 foot. The size limit suggested here from experience is based on a loose correlation of size with number of parts, number of manufacturing operations, etc. The more parts and manufacturing operations required, the harder it is to get the teams to do the proper level of detailed work on each part. Projects that have been too complex to allow adequate time for skill development are small vehicle projects (like a one-person electric vehicle) that require a complete design and build, or any large systems (like manufacturing equipment) which require significant mechanical and electronic design and build.

In a project-based course with a real customer that the teams directly interact with and to whom they deliver the finished product we find intrinsic student motivation to be high for some aspects of the course (the project work), but not very high for other aspects (relation to professional skills). Based on our experience, there is no comparison in terms of team motivation to fully complete a project between projects that will help people that the team personally knows versus projects that will be demonstrated in a competition but will not actually help someone. For promoting team motivation and engagement we have found that it is best to allow teams to select their own projects from a range of possibilities that meet a defined set of conditions rather than having the instructor assign the project. Having a range of potential projects for teams to consider, in addition to encouraging students in their junior year to be on the lookout for potential projects, helps speed up the process of project selection while maintaining team ownership of their project. We have experimented with including project preference in team formation, and as long as team diversity has priority in the formation of teams and steps are taken to limit the ability of students to use project preference as a means of trying to get on the same team with friends, it can be a good way to increase the chances that students get to work on a project in their area of interest. This has proven to be an important factor in promoting international projects, since project implementation often happens after graduation for an international project.

**Factor 4: Carefully use peer coaching to enhance accountability without sacrificing team unity:**

Although some method for making all team members accountable for their performance is necessary, any peer rating system that creates winners and losers (since some members get an increased grade at the expense of others who get a decreased grade) puts a strain on team unity and can be very harmful to the development of team skills. I didn’t realize the full impact of this effect until a few years ago when one of our best students commented that the numerical peer rating system actually encouraged some destructive team member behaviors and therefore were counterproductive. For example, the direct rating system encourages those in ‘power’ to marginalize those with fewer skills rather than to help them develop their skills, because if they just do more work themselves other team members are likely to reward them and punish the

lower contributing members. This team failure was very common when we were using the numerical peer rating method. In my individual meetings with students I would hear both sides of the story – one subgroup of the team complaining about those who didn't do as much work, and another subgroup complaining that they were not given meaningful work to do. In these cases it isn't important to find out which subgroup is right and which is wrong, because a system error is causing the problem. In order to address the system error we changed the expectations for the team members 'in power' from project-completion at all costs to team development that leads to project completion. As discussed previously, assigning grades based on the performance evaluation process with a focus on desired behaviors that support team skills is a key part of achieving accountability without harming team collaboration. Rather than an impersonal rating, the performance review approach establishes a dialogue around these important and sensitive issues, with the outcome of increased learning, empathy, and fairness. Teams define important skills and provide peer coaching to each other, taking into account the different roles and areas of specialization. Each team member is given a chance to respond to the coaching comments, which the instructor reviews along with each team member's example-based narrative on their own performance in the professional skills and technical skills areas. Online tools like Google Forms or CATME Smarter Teams provide useful support for a peer coaching approach. Setting up expectations and grading systems that challenge team members to work with other members they find difficult, and to include them and help them build their skills provides a much more valuable experience in real teamwork than promoting behaviors that are disruptive to team building such as allowing a team member to be marginalized or fired.

**Factor 5: Use an integrative and experiential learning approach, and provide feedback and tools at the proper time:**

Most students in a project experience seem to both enjoy and value project work more than professional skills and team skills. The usual method of presenting teamwork and project management tools at the beginning of the project and encouraging or requiring their use does nothing to change this. Most teams will view tools presented this way as a hurdle rather than a help, and many teams will not put any effort into learning how and when to use the tools since they are so focused on the project that they view the team effectiveness tools as a distraction to get out of the way as soon as possible. One way to change this is to allow the teams to start the project experience and monitor them as they attempt to work together. If the team has some significant deliverables it does not take long for them to feel the need to be more effective, as they get frustrated by lack of progress. It is at this time that they are eager to hear about the tools and best practices for team effectiveness that address their current frustration. This requires a large shift in instructor input and involvement from up-front presentations of material to real-time monitoring and prompt feedback. This is not an easy transition to make, and overall it requires a little more time from the instructor or team mentors, but the increase in effectiveness is worth it. The time that was previously spent preparing lectures or presentations is spent in compiling good resources and making them available to teams when they are ready to use them. As an example for illustration, it was not uncommon for teams that were required to create a set of team operating procedures early in the project to include items like agendas and action items because they were presented in class as tools and were included in the example procedures available to the teams. However, in the context of discussing team performance after completing conceptual design it was also common for a team to decide that to improve their performance they needed to get serious in using agendas and action item lists. Some teams even forgot that

they had agreed to do these things to begin with. This is just one example that demonstrates that teams will often mindlessly follow team effectiveness procedures if required to, but will usually not really embrace them and develop those skills until they feel the need. An integrative and experiential learning approach with interventions placed after the need is felt works better than a lecture and assign approach in supporting the development of team skills.

**Factor 6: Make sure words and actions (especially grading practices) support team-based project work rather than undesirable project-obsessed approaches.**

The claim that the importance of team skills must be communicated by actions and grading practices, not just by words, has been discussed throughout the paper. Although listed last, this factor may be the most important in supporting the development of team skills.

The question of student motivation is an interesting one. The goal is to intrinsically motivate students, but we know from our own experience and from research studies that most situations involve a mixture of intrinsic and extrinsic motivational factors. As a clear example, consider how many students would submit a design report documenting their work if it was not being graded and the only motivation to do so was to get experience writing and to get formative feedback from the instructor to improve their writing skills. The book chapter *Motivation to Learn in College Science*<sup>14</sup> details various factors that influence college student motivation and lists some practical suggestions for increasing it, including showing relevance of activities, empowering students to set their own goals, speaking directly to the positive interplay of intrinsic and extrinsic factors, giving students some degree of control over what they learn and how they learn it, modeling good learning behavior, using collaborative learning strategies, and setting high but reasonable expectations and communicating them clearly and early. These strategies in combination with the extrinsic motivation of a grade impact have been shown to positively influence student performance relative to team skill development.

A previous ASEE paper on *Using Performance Reviews in Capstone Design Courses for Development and Assessment of Professional Skills*<sup>15</sup> includes more details on implementing performance reviews that evaluate and reward (in terms of assigning grades) participation in building team skills. An advantage of the performance review method is that most students who have been on co-op assignment have experienced this form of evaluation, and it is easy to present it to all students as an authentic way to evaluate engineers. And since one of the goals of the capstone experience is to help students make the transition from student to engineer, the grading system for a capstone project should reflect this transition and reward characteristics of a good engineer rather than the characteristics of a good student.

## Conclusion

It is possible to simultaneously develop team skills and team member skills in a student project course, but it will not happen without careful attention to developing a culture that is supportive of teams, using appropriate methods for setting up and working with teams, selecting appropriate projects, using appropriate methods to ensure team member accountability, providing feedback and interventions at the proper time, and assigning grades in a way that shows that team skills are valued. The appropriate use of grading practices and the use of formative feedback after teams

have experienced frustrations due to ineffective team practices have been found to be the most influential factors in balancing the development of team skills with project completion activities.

The assessment of the factors listed in this paper has been based primarily on authentic assessment data (observations of team member and team performance) and a performance review approach, and that assessment data shows that a large percentage (over 90%) of students can discuss important factors of teamwork and identify 'team skill development' projects to implement to enhance their team's performance. Additionally, the performance of over 80% of the teams meets or exceeds expectations with respect to project performance without signs of project-obsessed behaviors.

It is encouraging to see advancements in the tools and research surrounding student teams, learning teamwork, and team effectiveness, especially with the CATME Smarter Teamwork initiative. The author plans to continue to develop an approach to simultaneously developing and assessing team member and team skills, making greater use of the improved tools now available.

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