Team Skills of Engineers – Do We Teach What Industry Wants?

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Abstract *--The Building Engineering Team Skills program is a multi -phase project designed to:*

-identify the team skills valued by industry,
-capture the best practices used by industry to improve tho se skills, and
-develop and incorporate those best practices into engineering undergraduate curriculum.

There are six major phases of the project, and here we report some results from the first phase , which entails interviewing experts from industry with s ignificant experience managing teams of engineers. Based on the team skills identified in these expert practitioner interviews, and a review of team training techniques of engineers identified in the academic literature, we address the question, 'Are we t eaching engineers the team skills valued by industry?'

We begin by examining the degree to which previously identified team skills coincide with those valued by practitioners who manage engineers working in teams. We identify discrepancies between what is valued by practitioners and what is being taught in Universities, and discuss the implications for modifying what is taught to student engineers in academic settings. We also use the expert interviews as a preliminary source of 'best practices' for how team skills are taught in the professional setting. We examine these practices in terms of feasibility for and transfer to academic settings. Implications for further research are also discussed, with emphasis on potential contributions of the Building E ngineering Team Skills program to address critical needs. Chief among these needs are the need to investigate these 'best practices' from the engineer's perspective (rather than solely from the engineering manager's perspective), and the need to design, i mplement and assess recommended curricular changes.

Index Terms *--Teams, Team skills*

INTRODUCTION

This work seeks to give preliminary answers to the following questions:
What team skills are currently being taught to engineering undergraduates?
What team skills are valued by practitioners?
Analysis will consist of comparing the answers to these two questions to identify degree of convergence and 'gaps' between what is valued and what is taught.

To address the first question completely would require extensive research via data collection from engineering educators, engineering students or both. Another approach to a comprehensive answer could be developed through thorough research of material from all applicable engineering journals and conferences, searching for reports by faculty of team skills taught. Though necessary and informative, such formidable task is not attempted here.

Rather, the approach used here is to identify readily available materials presented in a form convenient to educators. The reasoning is that these are the education practices that are likely to be known to a majority (or at least a significant minority) of educators and to enjoy more widespread use than a collection of innovative practices reported in disparate articles and proceedings. Almost by definition, the reports in journals and proceedings are noteworthy because they are new and different rather than common and widespread (at least at the time of publication).

With this reasoning in mind, the question of "What team skills are currently being taught to engineering undergraduates?" will be answered by examining the following three works:

- The Team Developer [1]

- Teamwork and Project Management [2]
- Teams in Engineering Education [3]

We chose these works because they were developed for/by engineers; they are designed for use as teaching tools & materials; and they include the specific details concerning the content of the materials. In short, these works provide the interested reader with recommendations, materials, exercises, discussion points, simulations and references to be used in teaching team skills to engineering undergraduates.

TEAM SKILLS AND TRAITS

The following tables show the team skills or concepts that are addressed in each of these works [1], [2] and [3]. Note that in order to be included, a skill or concept had to appear as more than an item in a list or a reference, it had to be emphasized in some way, such as elaborated in the text by the author, the topic of some exercise, a 'discussion point', etc..

To provide insight to the question of what team skills are valued by practitioners, we rely on our interviews of engineering managers [4]. One of the interview questions was, "What are the non-technical skills required of engineers working in a team environment or project?"

Though we asked the question in those exact words, we found that the answers included not only skills (An ability to perform an action, usually acquired by training or experience), but also traits or attitudes (a distinguishing feature of one's personal nature). The list of identified skills and traits are shown in the following tables, with Table 1 devoted to skills and Table 2 devoted to traits. Note that we consider this to be only a preliminary answer to the question of what skills are valued by practitioners. We are currently conducting a statewide survey that will allow a more complete answer.

In Tables 1 and 2, the first columns show the skills and traits identified by our interviewees. Columns 2, 3 and 4 show the presence or absence of the skill or trait in each of the set of team training materials. In Table 3, the first column shows skills and traits that were not mentioned by the interviewees, but were covered in one or more of the team training materials.

There are a few striking elements in the Table 1 that bear comment. First is the volume and variety of skills mentioned by interviewees. 27 such skills were identified by the interviewees. Of these, only two were covered in each of the three team training materials reviewed. These skills are 'communicate verbally' and 'provide leadership.' Ability to 'negotiate or persuade' is covered in two of the three materials, as are 'influence with positive energy', and 'set an agenda'. Eight other skills were each covered by one, but not the other two, material sets.

This means that half of the skills identified by our practitioner experts are not covered in any of the three source materials reviewed. While all three training material sets stressed the importance of verbal communication, the practitioners made distinctions between a number of types of communication including 'ability to communicate in writing,' 'to express ideas professionally,' and 'to present in plain English.' Though 'communicating to non-technical audience' is not mentioned specifically in the team training materials, relevant guidelines are given such as, "avoid jargon." A number of the interviewees stressed the importance of being able to communicate and interact with non-technically oriented people, confirming the ABET criteria emphasis on ability to function in a multidisciplinary team.

Of the 22 traits identified as valued by practitioners (see Table 2), 'adaptability/flexibility,' 'interpersonal skills,' and 'cooperation' are covered by all three training materials. 'Confidence in own skill' and 'appreciation of perspectives and acceptance ideas of others,' were each covered by two of the materials, while a further 8 traits were each covered in one of the three training material sources (see Table 2). This leaves over 40% of the traits mentioned by practitioners uncovered by any of the three the training materials. This may not be surprising, given that by definition, traits are somewhat internal to the individual and not as easily learned as skills.

It may be surprising to the reader that we included 'interpersonal skills' as a trait rather than a skill. We felt that this was somewhat of a toss-up, as to whether the ability to get along with others is a learned skill or a feature of one's personal nature. It certainly seems that some people acquire this ability without formal training, and it seems equally true that it is possible for some people to improve this ability to some degree based on training.

TABLE 1. Coverage of Team Skill

Team Skills Valued by Interviewees	Teamwork and Project Management	Team Developer	Teams in Engineering Education
Communicate verbally	X	X	X
Provide leadership	X	X	X
Negotiate, persuade(1)	X	X	
Influence with positive energy		X	X
Set an agenda (2)		X	X
Understand policies (3)	X		
Interact with a multidisciplinary team (wide variety of people without technical background)	X		
Work with people outside the team		X	
Understand		X	
Listen		X	
Collaborate		X	
Manage time (punctuality, complete assignments on time)		X	
Triage (know what is important and what is not)			X
Communicate in writing			
Coordinate			
Express ideas professionally			
Follow instructions			
Get along with others			
Give and receive help			
Handle ambiguous or incomplete information			
Know end result (know when the team is finished)			
Know project status			
Multi-task			
Present in plain English (without technical details)			
Provide consultation			
Provide realistic commitments			
Understand what it takes to implement action items			

1-Materials emphasize 'conflict management'

2-Materials emphasize 'effective meetings'

3-Materials emphasize understanding 'context of problem'

TABLE 2. Coverage of Team Member Traits

Team Member Traits Valued by Interviewees	Teamwork and Project Management	Team Developer	Teams in Engineering Education
Adaptability (flexibility in taking on different roles as required)	X	X	X
Interpersonal skills	X	X	X
Cooperation	X	X	X
Appreciation of perspectives and acceptance of ideas	X	X	
Confidence in own skill (1)	X		X
Ethics	X		
Commitment to the team		X	
Respect (self respect and respect to others)		X	
Honesty		X	
Outgoing/energetic (2)		X	
Participation		X	
Dependable, responsible			X
Self motivation, initiative			X
Accountability			
Being humble			
Discipline			
Empathy			
Integrity			
Patience			
Professionalism			
Tolerance			
Trustworthiness, credibility			

1-Materials emphasize 'self esteem'

2-Materials emphasize 'encourage/support teammates'

Classroom time is limited, and team skills are typically taught in a situation where the students are expected to learn or apply other skills as well. So it should not be surprising that all the valued skills and traits identified by practitioners are not covered in all three of the team training materials researched. However given this lack of available time, it is interesting that we find many topics are covered that are not among the skills or traits valued by practitioners. Twenty such topics were found (see Table 3). These include some of the staples of teaming materials, such as nominal group technique, team developmental stages and brainstorming. Some of these topics are very basic, and may have been overlooked by practitioners because everyone is thought to have the requisite knowledge (e.g., definition of team, importance of teams). Some topics may be of emerging importance (e.g., diversity), and academic emphasis may be leading the way by providing skills that will be of increasing value in the future.

TABLE 3. Topics and Tools Not Validated by Interviewees

Topics and Tools not included by Interviewees	Teamwork and Project Management	Team Developer	Teams in Engineering Education
Importance of Teams for Engineering	X	X	X
Team development stages	X	X	X
Decision-making	X	X	X
Management/Self-management	X	X	
Definition of Team	X	X	
Maintenance	X		X
Diversity	X		
Process check	X		
Standards of excellence		X	
Roles defined		X	
Giving and receiving feedback		X	
Seek input and ideas of others		X	
Issue bin			X
Interdependence			X
Task characteristics			X
Brainstorming			X
Affinity diagrams			X
Quality planning tools			X
Process check			X
Nominal group technique			X

DISCUSSION

Skills and Traits

Admittedly, analyzing the degree of agreement between our interview results and the team training materials requires a fair amount of interpretation. This is because we wanted to capture the skills from the interviewees in the language that they use and from their experience. We did not provide them with a list to choose from. The resulting list of skills were then compared to the team training materials [1], [2], [3], which again may have used language different from each other as well as from that utilized by the interviewees.

We also acknowledge two critical truths: just because material is not included in a text or source, does not mean that it is necessarily not taught by the instructor. And the corollary: just because material is included in a source or text does not necessarily mean that it is taught by the instructor. Acknowledging these caveats, we observe that

- A significant number (53%) of the skills and traits valued by practitioners are included in the materials reviewed, though a fairly small number of those skills and traits (10%) were covered in all three of the sources reviewed
- A significant number (47%) of team skills and traits valued by practitioners are typically not taught to engineers
- A number of skills and traits (roughly 43% of the topics covered) commonly taught to engineers are not identified as necessary by our interviewees

There are a number of potential explanations for these results. We asked our interviewees for a complete list of non-technical skills required by engineers working in a team environment or project. It could be that though the team materials reviewed do not cover all the valued skills and traits, they do cover the most important of the team skills and traits. This is a question we will attempt to answer after a later phase of the project, when we conduct a survey wherein we supply practitioners with a list of skills to choose from and ask them to rank in order of value. Until then, we only comment that a number of skills and traits identified by the interviewees as important are

not covered in the materials, and reserve comment on the relative value of the covered skills versus the skills not covered.

Some skills may be assumed by instructors and therefore not covered in the 'teaming' materials. By now, most university programs have requirements for a technical writing course, so while this skill may be very important for team performance, acquisition of this skill my not occur in the course where team skills are being taught. However it does seem that such a valued skill should be emphasized, practiced and reinforced in a course where teams are used.

Another potential explanation for our results is that team skills and team teaching materials used in engineering schools have been influenced more by academic experiences and custom than by industry needs. Another explanation is that needs could vary significantly by industry or region. Though our interviewees had experience in service, manufacturing, government, construction and process design, our set of experts were all from the west coast, and possibly contained an over representation of 'high tech' organizations (e.g., Intel, HP and Applied Materials accounted for 5 of the 13 interviewees).

In our eyes it is significant that many of the 'skills' identified by our interviewees are more appropriately termed traits or attitudes. The implications are also significant and beg important questions: "Is skill or attitude most important for team performance?," "Can we teach traits or attitudes?" and, "Can we identify the traits and attitudes of individuals and utilize them to enhance team performance through selection of team members?" As educators, we are more interested in improving the traits of our students, not pre-categorizing some as having valued traits and others as not having those valued traits. However if traits cannot be taught, we would still like to be able to teach our students how to identify desirable traits and select team members who have those traits when given the opportunity.

Practices to Create and Improve Team Skills

We asked our interviewees to tell us what practices were used in their organizations to create and improve team skills. A full report on their responses is forthcoming, however a few of the practices will be discussed here as they appear promising for improving and identifying traits, and they are typically not included in current academic offerings. These practices are experiential training, mentoring, and use of consultants.

'Experiential' learning refers to learning achieved from a hands-on experience rather than lecture, video or reading material. Such experiences usually involve problem solving, physical challenges, danger and reliance on a group of people. They are sometimes referred to as team building or trust building activities. Examples include 'ropes'-climbing or rappelling a sheer surface, 'planks'-using a limited number of planks for the group to traverse a body of water, or outdoor activities such as river rafting or backpacking. Such tasks require communication, problem solving skills and trust. Obviously, 'ropes' requires significant trust between the climber and the belayer (the one controlling the ropes).

The experiential tasks differ from normal work tasks in that they take participants out of their areas of expertise, fostering reliance on others, and freedom from boundaries that may exist within the organizational structure. They can also be challenging and stressful to participants, allowing participants to glimpse more of the traits of teammates. They also are geared toward a successful outcome, allowing participants to achieve a sense of accomplishment, and to construct a shared experience that can be drawn upon in future (work) situations.

Mentoring is the long term guidance and counsel between (typically) less experienced and more experienced individuals. It is usually between two that are following a similar career path, but are at different stages of their careers. It is an attempt to put into practice the adage, 'If I knew then what I know now…', by taking the knowledge and experiences of the mentor and transferring them to the mentee. This typically happens between people who are not members of the same team but can be focused on transfer of team skills or knowledge about how teams function.

Consultants are used widely for teaming in industry. Activities include team facilitation, team observation and critique, individual observation and assessment, and team training. Consultants are similar to mentoring in that they are usually a method for transferring knowledge and skills from an experienced expert to people less experienced. Consultants are dissimilar from mentors in that consultants typically have knowledge that is not specific to an organization and the personalities of its personnel, the interaction typically takes place over a short timeframe, and the activities often occur on a group rather than individual basis.

Can these practices be transferred to the academic setting? Consulting is similar to what many engineering professors do--transferring expertise to a group of people. The problem is that most engineering faculty are not experts at teaming. To the extent that faculty can gain that expertise, this practice is the most easily transferred to the academic setting.

One of the most important functions of team consultants is that of facilitation. This typically occurs in the team meetings, helping to encourage communication and to diffuse tense situations, keeping activities task focused and devoid of personal conflicts. It is this function that is unlikely to be feasible for most faculty to accomplish given time constraints.

Mentoring is similarly difficult to accomplish beyond a certain level due to student faculty ratios. In a professional setting a mentor may have one or two, or at most a handful of mentees. In an academic setting the reality is that for each student to have a mentor, each faculty member would have dozens of mentees. While mentoring is common between faculty and graduate students, it is much less common at the undergraduate level in an inclusive way such that all students have a mentor and that goes beyond advising on course schedules and career opportunities.

If mentoring and consulting practices are to be successfully transferred to the academic setting, it will likely require resources beyond what faculty can offer. However, such practices might be implemented using experienced students to mentor and consult less experienced students. While not widespread, such practices are meeting with success, such as utilizing juniors and seniors to act as team facilitators for 1st-year design teams [5].

Experiential training is likely to be harder to transfer to the academic setting, given the requirements for equipment, facilities, time and expertise, none of which are likely to reside within the resources of engineering schools. However, it may be possible to partner with others that have those resources, for example physical education-kinesiology departments or ROTC programs might have such resources. If not, then utilization of consultants is a possible alternative, though cost is likely to prohibit this option for most institutions.

CONCLUSIONS AND FURTHER RESEARCH

Whenever an instructor is contemplating topic, exercise, lecture or assignment, it would be beneficial to be able to consider the desired educational outcomes in relation to a list of valued skills and traits. Similarly, when analyzing the course curriculum as a whole, it would be beneficial to be able to refer to a list of valued skills/traits and map the abilities gained by students across all activities. In this way 'holes' in the skill set could be identified, as well as 'overemphasis' on a subset of skills at the expense of others, or of overemphasis of less valued skills.

While it is still premature to revamp team skill teaching materials based on our research results, it is not too early for educators to reflect on what skills are valued by practitioners and to consult with industrial advisory boards and employers of graduates to determine which team skills and traits they value, and then to scrutinize the skill set that engineering graduates are currently being provided with. We have provided a first pass at such a list of valued skills, and plan to refine the list as future research activities come to fruition.

What methods, content and practices are most efficacious for creating and improving valued skills and traits in engineers? Again we seek guidance from the experience of practitioners to address this question. Our interviewees were all engineering managers with at least 10 years experience, with exposure to many practices aimed at improving team skills. As research continues with the Building Engineering Team Skills Project, we will survey a number of engineers that have been subjected to these practices, and ask them to tell us which of the practices were most helpful at improving which of the skills.

We anticipate that some of the practices, such as use of consultants and mentoring, can be modified and transferred to academic settings while others, such as experiential training, have constraints that make them less suitable for utilization in the academic setting.

ACKNOWLEDGEMENT

Funding for this work has been provided in part by NSF Grant #0234987 and California State University, Hayward.

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