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Using Reflection to Promote Teamwork Understanding in Engineering Design Education*

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While most engineering design takes place in teams and most engineering educators agree that teamwork is important, less is known about how to provide effective instruction in teamwork. Yet this instruction is increasingly important as globalization creates teams that must bridge ever greater technological and cultural divides. To address this area, over the past four years we have investigated various pedagogical approaches to combine teamwork experience with reflective activities to help students learn what constitutes the high-performing teams that industry seeks and how to capitalize on their strengths and minimize their weaknesses to operate optimally on a design team in school or in industry. An analysis of this work, asking students to identify essential characteristics of successful teams, suggests that reflection provides opportunities for students to abstract key principles about teamwork from their activities and that students understand and value most of the same characteristics of successful teams identified by studies of successful teams in industry. For example, results indicate that students make the connection between effective teamwork and essential design activities like open-mindedness, collaboration, and innovation. In addition, our data show that students understand the value of having a shared goal and high performance standards, communicating effectively and drawing on team members' diverse strengths. However, students use slightly different language from that found in industry, and more research needs to be done to see if cognitive growth about teamwork improves performance in design.

Keywords: design teams; engineering design; reflection

INTRODUCTION

ENGINEERING CURRICULA are placing an increasing emphasis on design and practical applications of engineering concepts to solve realistic, open-ended problems. Engineering students complete at least one design course as part of their upper-level requirements, and many engineering schools include a required freshman design experience as well [1–3]. Furthermore, several engineering schools have explored various approaches to integrate more design experiences throughout the engineering curriculum [4, 5]. One thing in common with all of these educational experiences is that design almost always occurs in teams.

Professionals in industry as well as academia work together to solve complex, interdisciplinary problems that require multiple perspectives and talents to produce meaningful solutions. Just as teamwork has become standard practice in most professional design endeavours, it has also become prevalent in engineering design courses [6–13]. Reflecting the demands of a quickly changing engineering workplace, ABET 2000 and the *Engineer of 2020* list teamwork as an essential skill for engineers in the future [14, 15], and taxonomies of engineering skills include teamwork as a required core competency (e.g. CDIO at MIT, the VaNTH ERC taxonomy of core competencies) [16, 17]. Furthermore, the challenge of teamwork grows every day as more and more companies engage in global projects spanning what is now often called our 'flattening' world [18].

However, while most engineering educators agree that teamwork is important, there is less consistency regarding how to provide instruction in teamwork and evaluate its impact [9]. From a traditional constructivist perspective, we might argue that providing students with teamwork experience defines the instruction and is sufficient by itself. In contrast, from a traditional lecture-based perspective, one might argue that delivering lectures on teamwork, and perhaps requiring outside readings, is an effective instructional approach. Finally, from Schon's argument for educating the reflective practitioner [19], we might argue that the best way to help students develop teamwork skills is to combine experience with coaching and opportunities for guided reflection.

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In our work we have been exploring the role of these perspectives in helping students learn about teamwork and in teaching ourselves how teamwork instruction can be effectively integrated into design education experiences. One of our working assumptions is that experience alone does not help students learn what constitutes the high-performing teams that industry seeks [20, 21] or how to capitalize on their strengths and minimize their weaknesses to operate optimally on a design team in school or in industry. By exploring the pedagogies mentioned above, we are trying to determine exactly what it is that students learn about teamwork on a design team and how, in the Segal Design Institute (Segal), we can teach teamwork more deliberately and systematically. Segal courses are an ideal venue for this exploration because they build on a foundational course required of all freshman engineers—Engineering Design and Communication (EDC)—that integrates teamwork, communication, and project work in design [1, 22, 23].

For the past four years, particularly in EDC, we have been gathering information about student knowledge of teamwork and team experiences in order to offer more meaningful teamwork instruction. We have taken the approach that teamwork experiences, along with formal teamwork instruction and feedback, combine to create a learning environment that scaffolds students' development of teamwork skills. Drawing on Schon and Kolb [24], we use reflective activities as a central component of our teamwork instruction. As students work in teams and experience team success and difficulties, we ask students to reflect on their teamwork practices by filling out reflective online assessments, working together to develop team standards, and writing memos about their teamwork values and experiences to their teammates and course instructors. The reflections serve as a starting point for teams to engage in discussions about best practices and to alert faculty to potential problems [25, 26]. Using students' reflections as baseline data, faculty can more effectively serve as coaches or mentors to offer 'learner-centered' instruction [27] and respond to specific teams' needs [25].

Building on an initial analysis of our students' understanding of teamwork [26], this paper presents findings from a current study that sheds considerable light on how students think about teamwork and what they value. The analysis suggests that:

a) reflection provides an opportunity for students to abstract principles about factors that contribute to high performing teams;
b) students value most of the same characteristics of a successful team identified by the literature about successful teams in industry;
c) students use slightly different language than that which the literature employs.

The study also points toward areas for further research to assess the connection between greater cognitive understanding of teamwork skills and performance indicators of success.

BACKGROUND

As explained elsewhere [1, 22, 23] Engineering Design and Communication (EDC) is one of two core sequences that all engineering students (approximately 380) take at Northwestern's McCormick School of Engineering and Applied Sciences. Its companion sequence, Engineering Analysis (EA), integrates math and science with engineering applications, giving students the opportunity to apply the theory they are learning to engineering problems. EDC complements EA, introducing students over two quarters to a version of the user-centred engineering design process typically used to solve complex engineering problems. The EDC hallmark is 'real projects and real communication for real clients'. All sections of EDC are team-taught by instructors from engineering and communication, and all communication instruction—written, oral, graphical and interpersonal—is project-centred. About a third of the engineering faculty have worked as design engineers at leading product design firms or in their own consulting design companies. In fact, some of these design engineers helped to develop the EDC curriculum, which draws on the user-centred design processes followed at such leading design companies as IDEO and Herbst LaZar Bell [22, 23] and advocated in current literature on design [28, 29]. About half of the communication faculty have taught technical communication and/or done consulting in industry with engineers at companies such as Amgen, Baxter and Medtronic.

EDC students work in teams for one major client each quarter. In the fall or winter, when all four teams in a section work on the same project, the projects focus on universal design. Most first-quarter projects come from the Rehabilitation Institute of Chicago. For example, students might build a device to help stroke survivors with leg weakness and only one hand to don a shoe; or they might design an apparatus to help amputees with limited hand-strength grasp and release adaptive ski poles. In the spring quarter, with a new team and new instructors, each team works on an individual project for a client in industry, a school, a non-profit organization, an upper level design course, or an entrepreneurial enterprise. In the spring, students take more responsibility for client communication and project management. Since its inception ten years ago, EDC has been a team-based course grounded in situated learning, thus providing an ideal environment for motivating students to acquire the skills they will need later in actual practice. In the course, as in the future, teamwork skills were and will be a key to their success.

RATIONALE FOR INTEGRATING REFLECTION IN TEAMWORK INSTRUCTION

Teamwork instruction has always been a part of EDC. Early iterations of the course included a lecture on teamwork, a chapter in the EDC textbook, and mentoring of teams by section instructors. In course evaluations and surveys of alumni, students generally said that 'teamwork' was something they valued about the course [25]. Nonetheless, once the course was well established, faculty believed that too many students found their team experience to be a bumpy ride; students complained about team members who dominated the discussion, or conversely, who slacked off and failed to submit their work in time to meet course deadlines [25].

At that time, as we explain in a previous study [26], we introduced several instructional teamwork tools that allow students to reflect more deeply and regularly on their team experience and their own strengths and weaknesses as a team member. Typically, these included a pre-course question that students answered online; two or three 'process checks' where students rated their team on such characteristics as 'sharing the work equally' and 'listening to everyone's ideas'; two or three 'peer reviews', where students rated their team members and themselves on specific teamwork attributes; and memos that students wrote at the end of the first quarter to their spring quarter team or at the end of the spring quarter to their instructors.

Embedding continuous reflection into a course is consistent with Kolb's model of experiential learning [24]. Kolb states that learning is best conceived as a process, not in terms of outcomes; that is, 'ideas are not fixed and immutable elements of thought but are formed and re-formed based on experience' [24]. Kolb has suggested that learning is a four-stage process involving the four learning modes of concrete experience, reflective observation, abstract conceptualization, and active experimentation.

In Segal courses, the team-based projects serve as concrete experiences where students actively experiment with different teamwork, communication, and engineering design ideas. However, as Kolb suggests, it is not just experience that contributes to learning; it is the coupling of experience and experimentation with reflection and abstraction that combines to form a holistic adaptive learning process. Therefore, we aimed to embed explicit opportunities for students to reflect on their experiences and, based on these reflections, abstract principles of effective team performance. We emphasize the reflection and abstraction modes of Kolb's model through the team memos, the team process checks, and pre- and post-course questions such as the one described in the current study. In this way, EDC provides a holistic learning experience by providing equal emphasis on each of the modes presented in Kolb's model.

ISSUES RAISED BY OUR PREVIOUS STUDY

In 2003, two independent raters used a criterion-based scoring rubric to analyse 56 pairs of student memos (112 of 345 students completed both the pre- and post-memo assignment) [25]. Students were asked to provide a response to the following prompt at the start of the course, and again at the end:

> Describe your past team experiences, and what these experiences have revealed about your strengths and weaknesses as a team member. What can you tell your new EDC team members that will help them understand you and how to work with you successfully?

The pre-assignment was designed to reveal students' initial ideas about teamwork and provide information about their previous teamwork experience. The post response provided a basis for comparison to determine the extent that students' ideas about teamwork evolved to reflect the concepts and models from class activities and the textbook, which were based on the literature about what constitutes an effective, 'true', or 'high performing' team (see Table 1) [20, 21, 25, 26].

This early study [25] provided us with rich information about students' thinking and did show that students could thoughtfully discuss a wide range of teamwork essentials that reflected the course goals. For example, 88 per cent of the students considered 'sharing the work' to be an important concept; 79 per cent mentioned the importance of communicating and meeting regularly; 75 per cent talked about a team benefiting from the team members' diverse strengths. In addition, students raised important issues that we had not considered before the study. Many said that this was their first experience with a 'real team' and that it was hard for them initially to trust their team members because they had never before been on a team with other smart, responsible people. They did, however, learn that trust is an essential attribute of a true team.

Nonetheless, despite these positive findings, the study also raised some issues of concern. For example, although the teamwork literature says that commitment to a shared goal or common purpose is the most important component of a high performing team [20], only 48 per cent of our students referred to a 'shared goal', and of those—clearly at odds with the literature—only half

Table 1. Teamwork concepts stressed in EDC

Team formation process	Leadership
Shared goals	Decision-making
Diversity	Communication
Division of work	Monitoring team performance

associated this characteristic with their definition of a 'true team', and only seven per cent related the idea to performance standards.

As a result, we took steps to improve teamwork instruction in EDC in the following year, specifically by having students develop written teamwork standards early in the quarter and refer to those standards as they completed their team process checks and team reviews. The class discussions and team process checks also included 'shared goal' as a consistent course theme. However, we also looked more closely at the limitations of our study, in which the data were hard to analyse because we were applying very specific criteria to open-ended questions. Thus, if a post course memo failed to mention 'true team' or 'shared goal', we could not tell if the absence of that terminology meant the student was unaware of that crucial trait or had simply chosen not to discuss it.

STUDY PURPOSE AND METHODS OF INQUIRY

Study purpose and instruments

The current study was designed as a more structured assessment that would still allow students to reflect on the nature of a 'true' or 'high performing' team but would encourage them to identify specific characteristics of successful teams. The questions would still be open-ended but more focused; therefore, the responses would be more uniform and thus easier to code than in the previous study. Just before the course and at the end of their first quarter, students were given a reflective assessment to complete online: 'Identify and discuss the factors that contribute to successful team performance'.

In answering the post questions, students were able to see their original answer. (Indeed, some copied a part of their first answer into the post course question.) Thus, they could clearly see that this online response was designed as a reflective answer, not a test. As in the previous study, the assessment was part of a sequence of tools to help students reflect regularly on their teamwork experience. In other words, the assessment served as a pedagogical tool as well as a mechanism for data collection, with both functions being equally important.

Study participants

All students were asked to complete the assignment. Even though participation was not graded, we had an excellent response; approximately 96 per cent of students completed the pre- assignment and approximately 79 per cent completed the post. We were able to match all of the post responses to the pre, which resulted in a data set of N=270 paired responses. For analysis, we randomly selected 75 paired responses (approximately 25 per cent of the data). The data reported here are therefore a representative sample of our student population.

Data analysis

For coding purposes we developed a set of categories to capture most of the same essential features that we explored in the earlier study, based on widely accepted ideas in the literature about successful teams and what we stress in the course textbook and class sessions (see items A–F in Table 2). Categories A–F were developed before student responses were read. Items G–J reflect themes about teamwork that students mentioned frequently in their responses and thus were added to the categories used for coding. The coding was conducted such that if a student response mentioned an item given in Table 2, the response received a '1' for this item; if not, the response received a '0'. Credit was given for a concept if it included any of the synonyms or related ideas listed in each category. This enabled us to tally results objectively to indicate total scores or percentages for a particular student, as well as total scores for a particular category. The data were organized such that the coder was blind to the identity of the student. However, in practical terms it was easy to identify if a response was pre or post based on the phrasing used in the response. For example, it was common for a post response to say something like the following: 'After experiencing a quarter of Engineering Design and Communication, my views on teamwork have been expanded . . .' Therefore, in many cases the coder could recognize which were post responses.

FINDINGS

The purpose of this study was to characterize the nature of students' reflection on their teamwork experience and to identify what they abstract as factors that contribute to successful team performance. Given this focus, we were most interested in what students say, rather than in measuring quantitative differences between pre and post

Table 2. Factors that contribute to successful team performance

Factors that contribute to successful team performance	
A. Equal division of work • Work ethic • Cooperation • Doing their part	F. Team standards • Rules
B. A shared goal • Common purpose • On the "same page"	G. Leadership
C. Communication • Listening • Having an open mind • Email, meetings, etc.	H. Time/project management; organization
D. Trust/respect	I. Conflict resolution • Avoiding problems • Compromise
E. Diversity/members' different strengths	J. Getting to know each other / having fun/ feeling comfortable

responses. That is, our intention was not to evaluate whether students provide a 'right or wrong' response, and through coding assign a 'grade' to their answers. Rather, we used the results of the coding to identify patterns in the data that might serve as jumping off points to examine (a) how the nature of student responses has evolved along various dimensions and (b) whether our instructional approach appears to help students understand the concept of 'successful teams' as it applies to teams in industry.

From Table 3 we see that in some categories there was a positive change and in others there was a decrease. For example, in the ten categories that were tracked, positive changes occurred in seven areas, where the post score was higher than the pre score. We had, of course, hoped to see positive growth in some of these areas since all ten constitute intended learning outcomes of the teamwork instruction; in addition, the earlier study showed positive growth in some of the categories, so some growth was expected. In eight of the post areas, over half of the responses came from students who had not mentioned that trait in their pre response. In other words, in these instances, students were presenting new ideas, and abstracting different principles about teamwork based on their experiences in the course. This is not an indication that the post-response is better than the pre, but as Kolb suggests, that ideas evolve and are 'formed and reformed' based on experience.

To explore this idea we examined the category 'communication', which showed the largest decrease, but which still showed over half the students (59 per cent) identifying this trait as important. What could this decrease in communication mean? Looking beyond the numbers associated with the students' references to communication, we saw that they associate it with such diverse ideas as 'project management' (staying in touch by email, cell phone, regular meetings), 'listening' to everyone's ideas (being open-minded and respectful), and 'resolving conflicts'. Sometimes all of these ideas appear together, as a constellation of ideas connected to communication, as shown by one student's explanation of 'professionalism' in a post response that links communication to project management, listening, team standards, and a shared goal:

> Professionalism means that each team member cares about the performance of the group and puts their best effort toward helping the team meet its final goal . . . . Each person must be willing to compromise in order to do what is best for the team as a whole. This leads to fewer team conflicts and rapid resolutions to those few conflicts. A good team has effective, professional methods of communication. A set of clear team standards can be used to help facilitate this communication during meetings and outside of scheduled teamwork times (through email, telephone, etc.). The standards, either written or discussed . . . , should state that each member should try to listen and consider each idea presented. . . . A good team works together professionally with mutual respect, clear communication, and care for the final goal. (Student A)

However, in some post responses, a similar identification of ideas—the same kind of constellation—appears without an explicit mention of 'communication' or the synonyms in Table 2 and thus would not be counted in the quantitative data for that category. Nonetheless, the response implies that communication is occurring because team members are using charts to assign tasks, are 'discussing' ideas, are making sure that everyone's ideas are 'heard', and are 'friendly':

> There are several factors that contribute to team performance. . . . Cooperation involves everyone working together to achieve a common goal. Instead of worrying about little things everyone must see the big picture and work towards that together. . . . Organization is another large part of the team performance. By having a chart or any form of making sure everyone knows what their assigned task is, the team is able to meet later and have made significant progress; . . . The last significant quality . . . is respect for one another. Each person must realize that everyone is different and that everyone has something different to bring to the table. . . . With respect, every person is heard, everyone's idea is discussed and everyone is happy to work with one another. . . . If everyone likes the group because everyone is friendly . . . it is more likely that everyone will work hard to help the team. (Student B)

When we looked at areas with the greatest gains (see Fig. 1), such as 'project management/organization' and 'resolving conflicts', we saw that students often replaced 'communication' with these other, more specific terms. Consider the changes made by Student C, for example. In his pre response, he says that communication is 'essential' for getting things 'done in an organized fashion'. Team members have to collaborate so there is 'not one boss spitting out orders' at the others. However, in his post response, Student C does not even refer to communication; he focuses instead on team members working out problems 'as soon as possible so that the problems don't affect the team's performance'. Thus, his response offers an example of how communication is implied, but to avoid coding based on inference,

Table 3. Pre and post-results for all categories

	% mentioned pre	% mentioned post	% change [post-pre]
Communication	77	59	–18
Equal division of work	65	77	12
Diversity	37	32	–5
Shared goal	33	47	13
Trust	31	29	–1
Leadership	17	20	3
Time/project mgt	16	32	16
Conflict resolution	12	27	15
Get to know others	7	16	9
Team standards	4	12	8

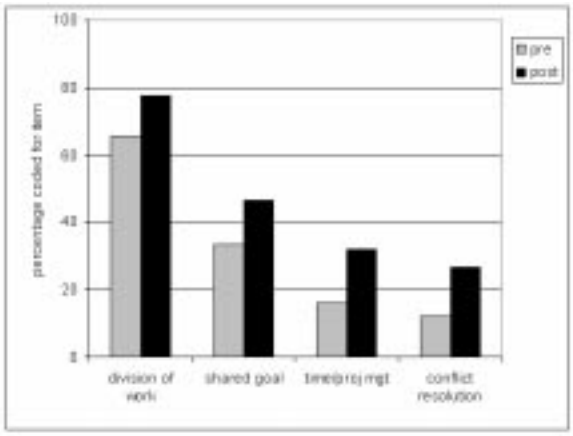

Fig. 1. Four categories with the largest gains [all > 10%].

the response was categorized as 'conflict resolution'.

In some instances, instead of mentioning a number of traits necessary for a successful team, a post response focuses at length on a single trait. For example, Student D spends four paragraphs elaborating on one idea, the importance of designing and building a 'workable model' for their client by the end of the quarter. She states, 'The single most important thing that creates a successful team is commitment to a goal'—and then goes on to discuss how her team worked to accomplish that goal. Again, good communication was implied—a necessary step toward accomplishing the goal—but not specifically mentioned.

DISCUSSION

While our earlier study (2003–2004) revealed that students were learning important lessons about teamwork in EDC, it did not demonstrate whether they were benefiting from the specific language about teamwork used in our lectures and textbook to describe a 'true team' and important teamwork strategies. In that study, we used very specific terminology to code the memos, looking for phrases such as 'true teams' [20, 21] or 'forming, storming, norming and performing' [30], classic terms from teamwork literature used in the course to describe high-performing teams and the team formation process.

In this new study, with several new teaching strategies in place and a different theoretical framework and assessment tool, we aimed to know whether we would be able to say with greater confidence that students are familiar with these concepts and thus leave our foundational design course with an understanding of teamwork and teamwork strategies that are likely to improve their upper level performance. Since we specifically asked students to 'identify and discuss the factors that contribute to successful team performance', it was in general easier to draw conclusions by noticing what concepts students did or did not use and then look more closely at the students' language to see what it reveals about their understanding of teamwork. Using this combination of methods, we conclude the following:

- While students do not often refer specifically to a 'true team'—a term commonly found in the teamwork literature—many show an excellent understanding of a 'true' or 'high performing' team in language that demonstrates an understanding of the concept.

Students' discussions show an understanding of synergy—how a well functioning team of individuals working together can accomplish more than any one of them could accomplish alone—along with a focus on a shared goal or common purpose. These are the key elements of a 'true team'. Note this example from one of the post responses:

> Many factors contribute to the success of a team . . . . The most important . . . is a unified commitment to a clear and urgent goal. It is this commitment to a goal that binds a group together and allows members to work interdependently toward a shared goal to work as a real team. Without this common commitment, communication breaks down and the team members feel little motivation to work together. (Student E)

This student's discussion clearly illustrates an understanding of a 'high performing' team as described by Katzenbach and Smith, whose 'fundamental premise' in *The Wisdom of Teams* is that 'there is nothing more important than each team member's commitment to a common purpose and set of related performance goals for which the group holds itself jointly accountable'.

- Although the numbers in some categories do not change much, or may even decrease, the content indicates considerable growth in understanding teamwork and the nature of teams.

This shows up in the greater specificity and elaboration of many post responses, even if the student's focus is on a specific teamwork trait rather than an increased understanding of a 'true team'. For example, in his pre response, Student F emphasizes 'communication' but defines it briefly and narrowly: 'Communication is key. Clearly communicating jobs and expectations is a must'. In contrast, in his post response, he spends three paragraphs discussing how good communication goes 'hand in hand' with team dynamics and organization to create a successful team, and he refers to specific instances of organization, such as discussing meeting times in advance, meeting on a regular basis, and keeping in touch via e-mail. This pattern—of greater understanding following experience combined with reflection—appears in a number of pairs, where students move from a general discussion in their original memo to a very specific discussion in the post.

In other instances, students discussed the same trait in their pre and post memos, but described

them quite differently. For example, one student associates communication in the pre memo with group updates, performance reviews, and mediation, but in the post response, reflecting upon her specific team experience, she associates communication with the intangibles needed for successful performance, such as enthusiasm and trust. This shift implies a greater understanding of a 'true team' since enthusiasm and trust are needed to maintain a team's commitment to their goal and high energy to perform their work. This elaboration in the post responses shows that students are not merely reiterating teamwork-specific terms that they have memorized but rather are using the terms with an understanding of the concepts that they represent.

- As students discuss key ideas about communication, open-mindedness, and respect, they connect them to essential design activities.

In other words, students are not talking about respect and open-mindedness just because they want to be nice to each other or to avoid having their feelings hurt. Rather, their comments reveal an understanding of how these traits are needed to create innovative designs. That is what will make them a 'high performing team'— a true design team that focuses the group's diverse skill sets toward a common purpose. They realize that good communication or project management or skill in listening fosters creativity and a wealth of ideas.

Some students come into the course with awareness of this crucial connection:

> There are many factors that contribute to team performance, but I think that the most important three are a team's ability to deeply listen to each of its members, the ability to work together despite personal differences and finally, the ability to continue generating new ideas. (Student G)

> Each team member must be tolerant, or willing to listen to and consider the ideas and alternate methods of each other. This will put the team on the path to innovation and original ideas so they may exceed the expectations of future clients. (Student H)

For other students, who make this connection between innovation and design in their post responses, their awareness apparently surfaced as a result of their EDC experience:

> Consistent communication guarantees the flow of new ideas. (Student I)

> [Team members] don't necessarily have to be friends, but they should know each other fairly well and get along most of the time. Good intra-team relationships foster creativity, effort, and the ability to complete high-quality work. (Student J)

Again, we can see students developing the connection between team cohesiveness, creativity, and performance.

- One limitation of this study—that teamwork traits overlap and are therefore difficult to code and interpret—offers an ironic insight into understanding teamwork instruction.

Consider again the case with 'communication', which signals wide-ranging ideas to different students and receded from the forefront of students' discussions in the post memos. Is 'communication' too amorphous a term to be useful as a category for instruction or evaluation? Katzenbach and Smith warn against the 'all-too-common misconception' that 'team effectiveness depends only on communication and openness'. Good communication and openness, they say, are important teamwork practices (such as active listening, sharing, and giving the benefit of the doubt), but useful only when they 'enhance the quality of decisions' that lead toward the accomplishment of the team's goals.

With this warning in mind, we can see that it may be good that a broad term like 'communication' is replaced in the post-responses by the more specific related ideas that it entails. When the general term 'communication' is replaced by other teamwork traits, and their relationship is discussed, scores for 'communication' may decrease, but students may be exhibiting growth in understanding.

- Finally, looking at the data with a combination of quantitative and qualitative approaches spurs reflection on our part about similarities and differences between high performing teams in school vs. high performing teams in the workplace.

To what extent is it possible to help students in required classes develop the sense of commitment that motivates the most successful teams in industry? In some cases, the parallels are clear: students with authentic design projects are highly motivated to perform. Some are eager to develop new solutions that may lead to patents. Others are eager to produce workable designs for corporate clients or individuals in need. In addition, many students are eager to maintain a high grade point average, and they enjoy working with friends on a project that affords them hands-on activity and a break from problem sets. These students resemble the high performing teams in industry that are motivated to help their department or company achieve its goals and that are richly compensated for their work with successful project outcomes.

Similarly, poor performing teams in school are not so different from poor performing teams in industry, where commitment to an overall goal is lacking, team members have few teamwork skills, and the teams lack discipline. However, in the workplace, a poor performing team member can more readily be replaced or let go than can a poor team member in school.

Another key difference lies in one of the main purposes for which we assign students to teams in design classes. We are trying to teach them good teamwork practices and help them understand what constitutes a high performing team. They need to

learn, for example, not just that project management is important for a team to accomplish its goal, but how to manage a project using tools that are commonplace in industry such as meeting agendas, responsibility matrices, and Gantt charts. Thus, in academia there is a balance to strike between completing the project and allowing students to learn from mistakes. This pedagogical function of teamwork may be undesirable or irrelevant in industry but is fundamental to the classroom.

CONCLUSION

This study suggests that through experience and reflection, freshman and sophomore design students can abstract principles about factors that contribute to high performing teams. Project-based design work, accompanied by knowledge about teamwork that is reinforced consistently through reflective activities, meshes well with the knowledge and experience of teamwork that students bring to foundational courses in design; in addition, it allows them to test their ideas and grow in several positive dimensions. For these reasons, opportunities for reflection on teamwork appear to have a useful place in design courses in the engineering curriculum: our study lends support to others who advocate reflection in teamwork education [9, 12].

However, further work needs to be done to explore the relationship between this growth in teamwork and the students' performance in design, both at the freshman level and in upper-level design courses. While some work has been done in industry to explore the link between positive team performance and team achievement [31], little has been done in team-based engineering classes. Thus, we still need to know whether students who acquire a fuller understanding of teamwork and, as a result of reflective activities, report greater satisfaction with their teamwork education, function more effectively on design project teams in school or as team members later in the workplace. Do they become more capable team leaders and managers?

A related area of research, particularly relevant to an increasingly global workplace, is to apply the reflective approaches used in our course to distributed teams working across campuses and countries. Do reflective activities help to mitigate cultural differences that may negatively affect performance on global teams? Are reflective activities as beneficial to engineering design students from other countries as they appear to be to American students? In the Segal program, we now have global design teams pursuing international projects in South Africa and Panama. Thus, our pedagogy and assessment in upper level classes must begin to explore the challenge of educating team members who are increasingly diverse.

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