Teaching Communication and Teamwork in Engineering and Computer Science

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Abstract

This paper describes a project in which Communication Studies pedagogy was incorporated into Software Engineering courses at California State University, Northridge. Responding to the needs of potential employers as well as the ABET 2000 criteria, faculty from the Departments of Communication Studies and Computer Science developed a variety of instructional strategies to enhance students' ability to work in teams and maximize group effectiveness. The project involved specific instruction in group communication skills as part of the regular course of instruction, the administration of the Kolbe A™ Index, and assessment by students and instructors of the value of the team process and projects.

I. Introduction

Although it is commonly recognized by educators and scholars alike that to be successful in today's workplace, high levels of teamwork and communication skills are necessary, instruction in these areas in Engineering and Computer Science is minimal, if undertaken at all. During the past four semesters, we have introduced students to the study of group process and have assessed the value of such instruction. In designated sections of Computer Science 380, "An Introduction to Software Engineering," we provided some specific, but limited instruction in group communication and administered the Kolbe A Index.[1] The Kolbe A Index is an instrument that measures conation, or a person's inherent talent or natural way of doing things and predicts what a person will or will not do, given the freedom to act. Widely used in the corporate world, the Kolbe A Index is valuable method for putting together synergistic teams.

Our experience has demonstrated the value of instruction in group process and the benefits of assigning students to teams based on their conative talents. An analysis of success of team projects over a two year period shows a statistically significant correlation between team synergy and scores on team projects. Furthermore, teams receiving specific instruction in communication skills also performed better and viewed the team projects more positively. Although this study was done in computer science courses, the results clearly suggest the applicability of these pedagogical methods to any course where communication and team building skills are important.

II. Background

It has long been recognized that engineering and computer science students need to learn communication and collaboration skills. In his 1992 article on "Educating a New Engineer," Peter Denning states that "a student must learn not only the technical side of engineering, but also skills of listening, completing and communicating."[2] Although engineers and computer professionals are stereotypically viewed as introverted independent specialists, it is important that students in these fields "learn the skills for working effectively as members of groups."[2]

More recently ABET has emphasized both communication and teamwork skills in the 2000-2001 criteria for accrediting engineering programs. Specifically, the guidelines state that "engineering programs must demonstrate that their graduates have . . . an ability to function on multi-disciplinary teams . . . [and] an ability to communicate effectively."[3]

Unfortunately, as Simon McGinnes states in regard to teaching information technology, "the skills of communication and collaboration . . . have often been undervalued in computing courses."[4] Similarly, Karl Smith observes that in engineering courses, "seldom is there explicit attention paid to helping students develop teamwork and project management skills."[5]

Although many universities have recognized the need to assign group projects and have begun efforts to improve engineering and computer science curricula in this regard, students seldom receive any training on how to function collaboratively before such assignments are given, and little attention is given to how teams are formed. Consequently, teams often fail to function effectively. Furthermore, students do not learn much from participating on dysfunctional teams and often develop negative views about the value of teamwork.[6]

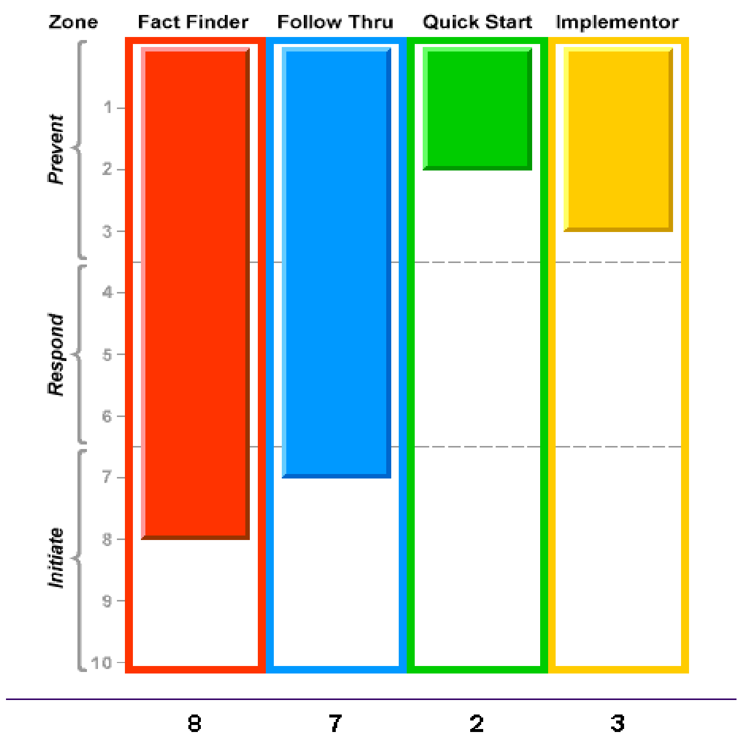
Simply assigning more team projects is not sufficient in addressing the need for students to learn teamwork skills. In order for students to benefit from these team projects, efforts must be made to ensure that the teams are well formed and given the knowledge and tools necessary to operate effectively.

III. Summary of Previous Work

Last year as a joint effort with the Communication Studies Department at CSU, Northridge, some specific, but limited, instruction in group communication was given to two of the four sections of Computer Science 380, "Introduction to Software Engineering."[7] The other sections received no such instruction. The instruction consisted of discussing the group process and how teams function. Students participated in an exercise that demonstrated the value of the group process, discussed group members' roles, analyzed their individual talents and those of their group, and assessed the group process at various points in the semester. Students wrote about the problems they were having in completing their group projects and the instructors tried to help them solve those problems. Although limited time was spent in focusing specifically on group communication skills, students who received the instruction seemed to appreciate being given some guidance and recognized the importance of improving these skills.

Additionally, groups were evaluated for group synergy using the Kolbe A Index.[8] According to Kolbe, group synergy contributes positively toward group productivity. If true this would suggest that forming groups to maximize synergy would result in groups that worked together more effectively and would, therefore, provide students with a more beneficial group experience.

The Kolbe A Index is an instrument that measures conation or a person's inherent talent or natural way of doing things and predicts what a person will or will not do, given the freedom to act. Whereas intelligence tests measure I.Q. and personality tests measure values and preferences, the Kolbe index measures the conative, the way people act while trying to achieve goals. It identifies four modes or striving instincts -- Fact Finder, Follow Thru, Quick Start, and Implementor -- each prompting people to act in a certain way. The Fact Finder probes, asks questions, weighs pros and cons, and uses experience. This person collects data and establishes priorities before making a decision. The Follow Thru individual seeks structure and makes schedules. This person needs a sense of order and plans ahead. The Quick start individual innovates, takes risks, improvises, and plays hunches. When asked to give a presentation, the Quick Start comfortably ad libs. The Implementor uses space and materials, builds, constructs, and uses hands-on equipment with ease. This person creates handcrafted models and insists on quality materials. Everyone has each of these abilities to some degree. However, people are most productive when they are able to utilize their strongest conative talents.



The picture to the right graphically depicts the degree to which each of these abilities is present. The four striving instincts are expressed through three possible operating zones, indicating how the individual will make use these talents. A score of 7 to 10 in a given mode places the individual in the insistence or initiating zone. This indicates *how the person will act*. A score of 4 to 6 indicates the response or accommodating zone or *how the person is willing to act*, and a score of 1 to 3 represents the prevention or resistance zone or *how the person* *won't act*. It doesn't mean people can't act in all of these ways; it just means that some won't come naturally.

According to Kolbe a productive team requires all of these talents, but they must be balanced with respect to the operating zones in order to maximize synergy.[8] Synergy is a productive balance of instincts within a team. It is derived from a mixture of complementary, conative talents. Ideal synergy involves not only the right mix of instincts to initiate solutions, but the same amount of energy to avoid problems as well. It was this measure of group synergy that was used in this study.

In the initial study the achievement of 23 teams in four classes over two semesters was analyzed. Eleven of these teams received special instruction in group communication and twelve did not. There were four important findings resulting from this study.

First, the results showed a correlation between the teams' ratings of their effectiveness and the scores on the projects. The correlation was statistically significant at the 0.025 level [$r(21) = 0.451$, $p < 0.025$]. This is consistent with other studies, such as one done at Brigham Young University (BYU), which showed that team process effectiveness was the major factor accounting for the success of group projects.[6] This suggests the importance of teaching group process skills as part of the regular curriculum.

The second finding was that there was a statistically significant correlation [$r(21) = 0.564$, $p < 0.005$] between Project Scores and the combined test scores of the of the team members. That is, teams made up of students who did well on the course exams also did well on the team projects. This suggests that to be fair to all students, teams should be balanced with respect to their cognitive abilities. In subsequent semesters, this was done by delaying team formation until after the first exam and using the exam results to balance the teams.

The third result was related to team synergy. Team synergy was calculated based on the "conative" assessments of all team members using the Kolbe A Index and project success was compared to team synergy. To do this each team member was assessed using the Kolbe instrument, and from that information a measure of group synergy was determined for each team. The synergy was expressed as a percentage where 100% indicated ideal synergy.* One hypotheses of this experiment was that greater synergy would result in higher team scores. At first there seemed to be no correlation between team synergy and project success. However, the high correlation between Project Scores and the combined test scores of the team members might have been obscuring any effect of synergy on group achievement. If only the population of teams without exceptional high or low test scores was considered, in particular, only those teams within

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* According to Kolbe, ideal group synergy results when the sum of the members' instinctive energy is distributed so that 25 percent is insistent, 50 percent is accommodating, and 25 percent is resistant. For the purposes of this analysis, group synergy was calculated as 100 percent minus the sum of the absolute values of the differences between the actual and ideal values in each of the three operating zones (insistent, accommodating, and resistant).

two standard deviations of the mean, there was a significant correlation between group synergy and project scores [r(19) = 0.380, $p < 0.05$]. With these more cognitively balanced teams there was also a high correlation between each team's rating of its own effectiveness and team synergy [r(19) = 0.478, $p < 0.025$]. This suggests that there may be a significant correlation between group synergy and project performance. Further study using cognitively balanced teams is necessary to validate this assertion.

The fourth finding is that the teams receiving instruction in group communication did better on the team projects. The average score for the teams receiving the instruction was 83.45% compared with 79.68% for those teams receiving no instruction as shown in the table below. Although the difference is not statistically significant for this relatively small sample, the results were encouraging.

CLASS	Project Scores	Effectiveness Rating	Team Synergy	Test Scores
F98 (No Instruction)	79.00%	3.45	70.40%	77.90%
F98 (w/Instruction)	85.17%	3.64	75.00%	81.29%
S99 (No Instruction)	79.93%	3.88	64.57%	81.73%
S99 (w/Instruction)	81.40%	3.77	81.00%	77.06%
Total (No Instruction)	79.68%	3.67	65.82%	80.47%
Total (w/Instruction)	83.45%	3.70	77.73%	79.37%

Additionally, when students who received the instruction on group communication were asked if they felt that it was beneficial in improving their group's effectiveness, 93% responded, "yes." More study is needed to accurately determine the effect of such instruction on group performance.

The results of this experiment support the notion that there is a direct relationship between group effectiveness and project success. The results also suggest that group project achievement can be improved by forming more synergistic teams. Furthermore, the results, along with common sense, indicate that providing group communication instruction is probably helpful in improving group performance, but more effort is required to determine the best way of providing such instruction as part of the regular course curriculum.

IV. Analysis of the Student Population

While the previous study suggests that forming synergistic groups improves team performance, this is difficult to accomplish in practice. The population of students taking software engineering tend to be very similar in their natural action modes as measured by the Kolbe A Index. Synergistic teams, however, require an appropriate mix of approaches to problem solving. Simply put, the students studied over a two year period tended to be the Fact Finder and Follow Thru individuals, and very few had Quick Start or Implementor as their primary action modes. When it comes to forming teams, this means that there is insufficient Quick Start and Implementor talent to maximize the productive potential for all teams. Creating synergistic teams from this pool of students is difficult at best.

Specifically, of the 181 students who were given the Kolbe A Index over this period, 87 (48%) had Fact Finder as their primary mode of operation, and 116 students (64%) had Fact Finder as their first or second predominate mode. Nearly half of the students (90 of the 181 students) had Follow Thru as their primary or secondary mode of operation. A more complete picture of this student population is shown in the table below.

	Fact Finder	**Follow Thru**	**Quick Start**	**Implementor**
Prevent	2%	5%	62%	30%
Accommodate	44%	62%	33%	64%
Initiate	54%	33%	5%	6%

For the general population the expected results are:

20% initiating action in each of the four Kolbe Action Modes
60% responding to people and situations through each mode, and
20% resistance to taking action in each of the modes.

In comparing this data with a study done by the Kolbe Corporation,[9] in which 86 semi-conductor engineers were analyzed, we see a very similar profile. This suggests that the conclusions drawn from this study of software engineering students might be applicable to a larger population of technology and engineering oriented students. The analysis of the semi-conductor engineers is shown in the following table.

	Fact Finder	**Follow Thru**	**Quick Start**	**Implementor**
Prevent	2%	6%	53%	34%
Accommodate	45%	49%	39%	63%
Initiate	53%	45%	8%	3%

If we compare this with the data for other fields, we can see a substantial difference. For example, an analysis of marketing managers is shown below.[9] Notice the difference especially in the Quick Start and Follow Thru columns.

	Fact Finder	**Follow Thru**	**Quick Start**	**Implementor**
Prevent	14%	27%	11%	56%
Accommodate	55%	64%	44%	44%
Initiate	31%	9%	45%	0%

The Kolbe analysis further classifies each individual according to their combined levels in each of the action modes discussed. This classification is called the MO (modus operandi) or "natural advantage." It describes the individual's natural or instinctive way of doing things. Seventeen such descriptions have been identified. For example, an individual whose primary action mode is Quick Start and whose secondary mode is Implementor is identified as a "pioneer," the Follow Thru/Quick Start is called a "program developer", and the Fact Finder/Follow Thru person is a "strategic planner."

Interestingly, 30% of the software engineering students (55 of 181) were classified as "strategic planners." This was the largest group with a single classification suggesting that the field of software engineering may attract this type of individual. What is more interesting, however, is that this group did significantly better in the class than those students with other classifications. Their average score in the class was 81% compared with 77% for the rest of the class. This is statistically significant (at a p of less than 0.05) indicating that "strategic planners" may be better suited to the field of software engineering.

However, because this field fails to attract individuals with certain other "natural advantages," team effectiveness may suffer. The primary concern of this effort has been to develop effective strategies for teaching communication and teamwork skills to software engineering students. The key may be in developing techniques for helping these students to operate in ways that may not be instinctive in order to compensate for the lack of certain natural modes of operation within the group. Furthermore, it may be possible to use knowledge of these students' instinctive action modes to design appropriate strategies for teaching these skills.

V. Teaching Communication and Teamwork Skills

Our data indicate that a high percentage of students enrolled in Engineering and Computer Science classes initiate in Fact Finder and/or Follow Thru mode, and these students seem to do well in the Computer Science major. The insistent Fact Finder will collect data, establish priorities, define goals, gather information, and evaluate options while the insistent Follow Thru will seek order, structure, design systems, make lists, have a ritual system and will chart progress and worst case scenarios. One who initiates in Fact Finder mode will focus on details and engage in research. The initiating Follow Thru will develop procedures and seek a sense of order. An insistent Quick Start, however, will experiment, take risks and seek open ended solutions. The preferred mode of communication for the insistent Fact Finder is the written word, for the Follow Thru, charts and graphs. An example of the differing communication preferences came up early in the semester. As an introductory exercise, the Communication Studies professor asked students to think of a good communicator and write down the name of that person and then to write down the qualities that made that person effective as a communicator. After a few minutes, students were asked to “share their ideas,” and instead of talking with each other, as the professor thought they would, students silently handed their papers to each other.

As noted, those with these talents generally do well in the fields of Engineering and Computer Science, but what happens when they participate in team projects? According to Kolbe the most productive teams are those with synergy, or a balance of talents. When a team is composed of like

MO's, inertia develops which means there is too much energy in one of the three zones (i.e., initiation, prevention, or response). If a team is composed of insistent Fact Finders (or researchers), "analysis paralysis" will set in, as members spend endless hours probing, questioning, researching, and organizing. In the corporate world, a manager might try to change the makeup of the team in order to create a more synergistic group, though in certain situations, that might not be possible. In a university class, where most of the students have the same MO, strategies must be found to enhance the effectiveness of the group. During the past semesters, recognizing the possible inertia that might develop given the similar MO's of the students, we have incorporated a number of exercises that help students improve communication and team building. We understand the importance of helping students understand not only the technical side of engineering and computer science but also the necessary communication skills. Too often courses seem to be product oriented, ignoring the process.

One of the great advantages of assessing students with the Kolbe instrument is that it validates their natural way of doing things and gives them a useful vocabulary for talking with fellow team members. Students come to understand not only how they work best but also how others function in problem solving situations. Although many of the students share the same natural talent and understand the way they work best, problems arise because the team lacks the other necessary talents that make a highly productive effort. For example, if a group has no Quick Start initiator, it will undoubtedly forgo the valuable process of brainstorming at the beginning of the project. A Quick Start initiator is an innovator who will urge new directions and ideas while the Fact Finder and/or Follow Thru dominant modes will focus on more secure and tried and true solutions. Students can easily get bogged down with gathering information and not let ideas flow spontaneously. We have developed a number of exercises and assignments that promote communication and teamwork to compensate for the over abundance of Fact Finder/Follow Thru initiators in a group.

It's important to remember that the Kolbe A Index indicates what a person will or will not do naturally, not what the person can or cannot do. Therefore, as we discovered the preponderance of "strategic planners" and "researchers" in the classes, we recognized the need to help students learn effective methods of communicating and team building. We might assume that engineering students will have similar MO's, and in fact, one study indicates just that.[9]

Students who know the results of their Kolbe A Index have a basis for communicating and seem to get to know each other quite easily. They also recognize what can happen when a group lacks synergy. We as instructors, cannot change the class makeup but we can create pedagogical strategies that help students develop communication skills. It is true that communication skills, like other skills, can be improved through practice, and engineering and computer science classes must incorporate methods to provide students will valuable and practical experiences.

During the past few semesters, we have engaged students in the following assignments in an effort to enhance their communication and teaming skills, taking into consideration the need for structure as well as improvisation.

In Class Activities

Think, Pair, Share: Early in the semester, we involved students in several activities to motivate them to recognize the importance of improving their communication skills. As noted above, students were asked to think about good communicators they knew and consider the characteristics that made them so. Using, "Think, Pair, Share," in which students first write down their thoughts, talk about them with one other person and then share with several others, we compiled a list of communication skills. The class then as a group discussed the need for communication in the field of computer science. We also asked them to write down their own strengths and what they would like to improve. Our goal was to encourage our students to think about communication as a set of skills they could improve and that would help them in their daily and professional lives.

Lost on the Moon: An excellent simulation exercise to emphasize the advantages of teamwork is " Lost on the Moon," an exercise that asks the students to imagine being lost on the moon and to decide which, among a list of items, they would choose as most useful. After they have made their individual decisions, students are assigned to small groups and to decide by consensus what items would be needed. After about twenty minutes, students are then given the answers determined by NASA and they score the results. Invariably, the group scores are better than the individual scores.

Glop Shop: Glop shop is an exercise designed to demonstrate how Kolbe index results predict how a team will function when encouraged to act on instinct. Three to four students with widely varying MO's are asked to perform a task as a team by designing an educational game out of a bag of junk and then to "sell" it to the class. They have three minutes to design and prepare the presentation. Inevitably, participants will clearly exhibit their natural instincts to examine, sort, organize, or create something different, or in the case of an insistent Implementor, will try to take things that are more mechanically oriented and try to figure out how to make them move. The class and the participants themselves gain empirical evidence as to the way students perform and interact and recognize the value of the Kolbe index.

Explanation of Kolbe A Index Results: Students are given a brief overview of the results of the Kolbe analysis that they have completed on line. The final eight page report comments on their talents, their innate ways of performing tasks as well as the causes of stress. When they meet in their project teams, they exchange their results and discuss how to maximize their talents and compensate for those MO's that are not present. Students are reminded that we all can perform in any of the four modes but we will perform more naturally in one or two, given the freedom to act.

Role Playing Group Process: After a brief lecture/discussion of the group process and roles played by members, students are selected to simulate roles as part of a "problem solving" group in front of the class. This brief exercise introduces students to roles and responsibilities of project team members. We also demonstrate brainstorming as a process to stimulate creative thinking.

Oral Presentation by Group: Each group is required to give a 15 minutes oral presentation in front of the class. Everyone is required to participate, and we give students guidelines and choices about what they will present. Because we know that students, for the most part, fear public speaking, we spend some time giving suggestions about effective speaking and practicing brief impromptu talks.

Out of Class Activities

Completion of Kolbe A Index Online: Students individually access and complete the Kolbe instrument through a Web facility.

Required Minutes, Reports: Each group is required to document meeting times, members present, and accomplishments. The preparation of an agenda is required for each meeting and students write notes of each meeting for a final report to be handed in at the end of the semester.

Reflective Process - Group and Individual: During the semester and at the end students are asked to reflect on the group process and the technical difficulties they had in designing their project. Class time is spent sharing information and discussing how to improve the group process. At the end of the semester students are asked to answer in writing a series of question about the problems and benefits of the team project.

Written Evaluation of Group Members: Students are asked to complete an evaluation form, asking them to rate the other members of their group as well as themselves.

VI. Conclusion

The importance of teaching communication and teamwork skills in engineering and computer science is well understood, but finding effective teaching strategies is challenging. Our earlier work demonstrated the value of carefully choosing teams to maximize synergy, but analysis of the natural action modes of software engineering students using the Kolbe instrument has shown that this collection of individuals lacks some of the problem solving approaches needed for productive synergistic teams. The challenge is to find ways of teaching some of the necessary group communication skills that may not come naturally for this group of students.

As we continue to explore effective pedagogy for improving the communication and teamwork skills of engineering and computer science students, we will design assignments that are practical and realistic. Use of the Kolbe index has provided an excellent positive way to raise students' awareness of their potential as well as their need to understand others' ways of doing things. When people strive toward a goal using their natural talents they will function most productively. We must design assignments that take advantage of their natural talents and encourage them to explore ways of expanding their capabilities.

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