TEACHING TEAMWORK SKILLS IN SOFTWARE ENGINEERING BASED ON AN UNDERSTANDING OF FACTORS AFFECTING GROUP PERFORMANCE

Robert Lingard[1] and Elizabeth Berry[2]

Abstract ¾ *Being able to work effectively in teams is an important learning objective for software engineering students. Although many programs today make team projects fundamental elements of their curricula, few actually teach teamwork and communication skills directly. Consequently, students may gain experience working in teams but may not learn the skills necessary to perform effectively in a team environment. In previous studies it was shown that both team synergy and basic software engineering knowledge correlated significantly with team project success. This paper examines additional factors that have the potential to affect group performance. In particular, this study looks at gender, age, cultural diversity, previous work experience, and the degree to which work is equitably shared among team members as possible factors affecting success. Based on the results of this study, suggestions are made for both team formation and designing appropriate assignments to enhance the teamwork skills of students.*

Index Terms ¾ *Communication, group projects, software engineering, teamwork.*

INTRODUCTION

This paper summarizes the recent activities associated with attempts to improve group project experiences among software engineering students at CSU, Northridge. The study described draws on data collected over the last three years regarding team composition and team achievement for students in an introductory course in software engineering. In particular, this study looks at gender, age, cultural diversity, group viability, and previous work experience in the field of software engineering as potential factors influencing team achievement. Additionally, the degree to which work is equitably shared among team members is evaluated as a factor contributing to success. Some background and motivational material are provided along with a summary of previous results. The approach taken and the important results from the current effort are described. Based on the study results, some guidelines are outlined for team formation and suggestions are made for designing effective assignments to enhance the teamwork skills of students.

BACKGROUND AND MOTIVATION

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 observed that employers felt that new hires did not know how to communicate and that they had insufficient experience and preparation for working as part of a team [1].

Unfortunately, as Simon McGinnes states in regard to teaching information technology, "the skills of communication and collaboration . . . have often been undervalued in computing courses." [2] "Computer science education too often focuses on individual contributions rather than on managed group efforts that depend on defined standards, methodologies, and software processes; however, such groups are the norm in the software industry," according to Hilburn and Bagert. [3]

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. Students do not learn much from participating on dysfunctional teams and often develop negative views about the value of teamwork. [4]

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.

SUMMARY OF PREVIOUS RESULTS

A study conducted two years ago [5] compared team success with both team synergy, as measured by the Kolbe A™ Index [6], and basic software engineering knowledge, as measured by classroom tests. 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

---

[1] Robert Lingard, California State University, Northridge, College of Engineering and Computer Science, Northridge, CA 91330-8281 rlingard@ecs.csun.edu
[2] Elizabeth Berry, California State University, Northridge, College of Arts, Media, and Communication, Northridge, CA 91330-8257 elizabeth.berry@.csun.edu

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 person who initiates in Fact Finder mode 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.

Figure 1 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
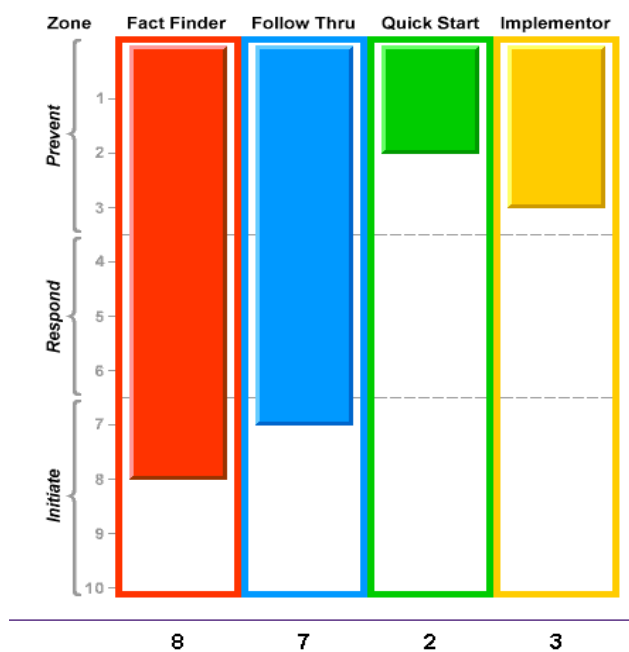

FIGURE 1
SAMPLE KOLBE RESULTS

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 accommodating or responding 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. [7] 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. There were three 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 at Brigham Young University (BYU) described by Swan [4], which showed that team process effectiveness was the major factor accounting for the success of group projects. 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 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. According to Kolbe, ideal group synergy results when the sum of the members' instinctive energy is distributed so that 25 percent is initiating 50 percent is responding, and 25 percent is preventing. 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 (initiate, respond, and prevent). Figure 2 depicts the synergy of one team in

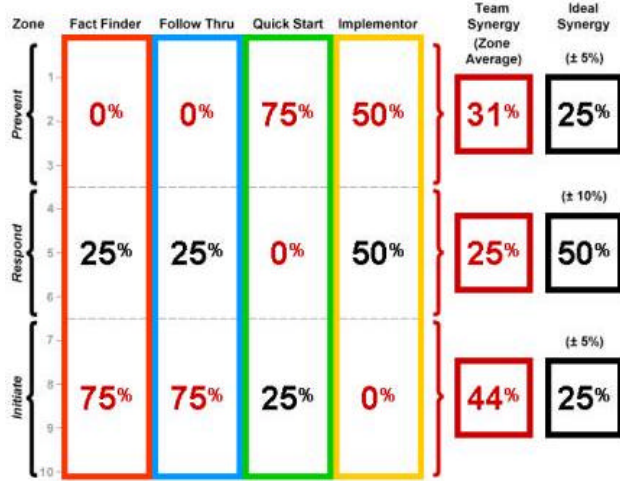relation to the ideal. In this case the calculated synergy of the team would be 50% (100% - 6% -25% - 19%).

FIGURE 2
TEAM 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 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. The current study examines this further.

CURRENT STUDY RESULTS

One purpose of the current study was to reexamine some of the same factors previously analyzed. This analysis included the data collected over a two year period. In all, 181 students comprising 39 teams were analyzed. Most of the conclusions from the original study were reinforced. The data are shown in Table I. The table is sorted by project score.

In the current study the correlation between project scores and combined test scores of team members was even more significant [r(37) = 0.549, p < 0.0005]. Similarly, the correlation between teams' self rating of effectiveness and project scores also showed a greater significance [r(37) = 0.472, p < 0.005]. In evaluating the relationship between project scores and group synergy the Kolbe measure of *viability* was used. *Viability* is a complex metric developed

by Kolbe analysts to measure how closely the combination of Kolbe scores for a group match those of an ideally synergistic team. The study results show that this measure of synergy correlates significantly with project scores [r(37) = 0.3247, p < 0.025].

TABLE I
STUDY RESULTS

Team Name	Project Score	Exam Scores	Effective-ness	Viability
F98-C	95.5%	85.3%	4	57.0%
S00-4	91.5%	87.0%	4.5	84.0%
F98-5	90.5%	81.8%	4.5	96.0%
F98-F	90.5%	85.6%	4	31.0%
F98-E	90.0%	78.2%	3	98.0%
F99-A	90.0%	85.4%	4	98.0%
F99-C	89.3%	77.8%	3.75	67.0%
S99-2	88.0%	87.8%	4.25	76.0%
S00-1	88.0%	87.1%	4.25	48.0%
S99-E	86.5%	78.9%	4.2	34.0%
S99-D	85.5%	78.6%	4.4	96.0%
S00-7	85.5%	76.3%	3.8	76.0%
F99-1	85.3%	79.3%	4	98.0%
S00-6	85.0%	81.0%	4.5	37.0%
S99-5	84.0%	84.3%	3.8	91.0%
F99-3	84.0%	80.9%	4.5	98.0%
S00-2	83.5%	78.4%	4.25	71.0%
F99-2	82.7%	81.8%	4	34.0%
S99-3	82.5%	83.3%	4	91.0%
F99-B	82.0%	77.1%	3.8	86.0%
F98-B	81.5%	77.8%	3	48.0%
S99-A	81.0%	75.1%	4.4	91.0%
S99-B	80.5%	74.9%	2.33	98.0%
F98-A	80.0%	81.7%	4.5	98.0%
S99-4	79.5%	79.2%	3.6	31.0%
F98-2	79.0%	72.9%	4	98.0%
F99-D	78.7%	81.1%	4.8	98.0%
F98-4	78.5%	77.7%	2.75	29.0%
S99-1	78.0%	76.5%	4	92.0%
F99-E	78.0%	79.4%	4.8	86.0%
F99-F	76.0%	80.6%	4.25	0.0%
S99-7	75.0%	81.1%	4	91.0%
S00-3	74.0%	72.0%	2.6	31.0%
F98-D	73.5%	76.8%	3.33	98.0%
S99-C	73.5%	77.9%	3.5	86.0%
S99-6	72.5%	79.6%	3.5	0.0%
F98-1	71.0%	81.0%	3.67	57.0%
S00-5	67.0%	76.3%	2.5	29.0%
F98-3	66.0%	76.1%	2.33	0.0%

ADDITIONAL STUDY RESULTS

An additional objective of the current study was to examine a number of facors potentially influencing team success that had not been previously analyzed. In the survey given at the

end of the semester to all students in the course, information is gathered as to their age, gender, native language, and work experience. It is natural to ask whether any of these factors affect group performance.

With respect to age it is interesting to note the wide range of ages among the students. The average age for a team ranged from 21.3 to 38 years. The somewhat surprising result was that there was no significant correlation between average group age and project scores. One might have thought that older, more mature students would have had more experience working in groups and, therefore, that older groups would have done better. This study showed no evidence that such was the case.

Among the students in these classes 25.8% were women. This is consistent with the overall percentage of women majoring in computer science at CSU Northridge. Among the teams studied the percentage of women on a team ranged from 0% to 60%. However, no significant correlation was found between the percentage of women on a team and the project score for that team.

A third factor analyzed was the cultural diversity on a team. In the survey students were asked to specify their native language. For each team a diversity number was calculated by determining the number of different languages spoken and dividing that number by the size of the team. For example, for a team of five with three different native languages among the members, the diversity value would be 60%. It is interesting to note that as many as 17 different languages have been identified as native within a typical class of 30 students,. It was thought that such a high level of language diversity might have contributed negatively toward project success. However, analysis of the data showed no significant diffferences in project scores based on the degree of team cultural diversity. It might be that since all teams were diverse, all teams were affected to a similar degree. Seventy-nine percent of the teams included three or more different native languages, and all teams included at least two. Because cultural diversity is still a likely issue with respect to group performance, this subject will be dealt with in the later section on teaching strategies.

This study also tried to determine whether there was bias that favored predominately English speaking teams. The percentage of native English speaking team members ranged from 0% to 80%, but there was no significant correlation between the teams' English speaking ability and their team scores. In fact, although not significant, the correlation was negative.

The last factor of this type analyzed was relevant work experience. Students were asked whether they were currently working in a computer related field. Again, it was thought that relevant work experience might contribute toward project success. Twenty-eight percent of the students indicated that they were currently working in a computer related job. The percentage of such experienced students on a team ranged from 0% to 75%. Suprisingly, there was no significant correlation between work experience as measured here and team performance even though work experience did correlate significantly with test scores.

ANALYSIS OF GROUP PARTICIPATION

One part of the survey given to students at the end of the semester asks them to evaluate the other members of their team. In particular, one question asks them to rate each team member's contribution to the team project as a percentage of the total effort. That is, they are to give each team member, including themselves, a value from 0% to 100% such that the sum of such numbers is 100%. If a student felt that all members of the team contributed equally, a value of 20% might be given to each person on a five person team.

A measure of equality of participation was calculated as minus the variance of the average scores of the individuals on a team. That is, the scores each team member received from the other members of the team were averaged and the variance among these average scores was calculated. Since the greater the variance the more unequal was the participation among team members, the variance was negated to serve as a measure of equality of participation.

This measure of participation correlates significantly with project scores [r(37) = 0.3276, p < 0.025]. Additionally, this measure correlates even more significantly with the teams' self ratings of their effectiveness [r(37) = 0.4691, p < 0.005]. This last results probably reflects the fact that team members see a relationship between team ineffectiveness and a lack of participation by one or more team members. Overall, these results suggest that team success might be increased if better participation among the team members could be achieved. The next section discusses teaching strategies to encourage greater participation by all team members during group assignments.

The somewhat related factor of group size was also analyzed in this study. Although most teams in this study consisted of five members, there were some three, four, and six member teams. Analysis of the data shows a significant negative correlation between team size and project scores [r(37) = -0.3435, p < 0.025] indicating that smaller teams do better. This may be due to the difficulties in coordinating group activities among the various group members. Some techniques for teaching groups to deal with such issues are discussed in the following section.

TEACHING STRATEGIES

In most courses in which group projects are required, students receive little, if any, guidance on how to be an effective team member. It seems evident that students need instruction in group process as well as how to interact effectively with members of their own team. The fact that the groups are composed of students from varying backgrounds and ethnicities makes it imperative that time be spent in helping students understand the importance of the social domain of group process. In our previous study [8]

we suggested a number of exercises to promote understanding of the group process, but it is also important for students to establish comfortable relationships with others in the group. During the beginning stages of the group projects, students benefit from activities which increase the ease with which they interact with each other. Throughout the semester students should have opportunities to analyze and discuss the group process as they are experiencing it. Following are activities which can easily be incorporated into a class in which a group project is required. The exercises below suggest activities that may be useful in addressing some of the specific problems uncovered by the current study. Further research is needed to assess the effectiveness of these techniques.

Sharing Commonalities

This activity should be used early in the semester, shortly after the groups have been formed. Instruct students that they will be meeting with their project teams and that each group is to come up with three things they all have in common. Explain that each thing they find in common must be specific rather than general. For example, it could not be, "We all have brothers and sisters;" however, it could be, "We all have two brothers and one sister." It could not be, "We all drive cars." It could be, "We all drive red Mazdas." Have each group chose a recorder and spokesperson. Allow the groups about 15 minutes to come up with their lists. Walk around the class and help any groups who are having difficulty by brainstorming ideas. At the end of the allotted time, have a spokesperson from each group share the group's list with the class.

This activity is a good way to get students talking to each other and asking questions they normally wouldn't ask. It helps in establishing cohesiveness in the group and serves to promote participation.

Team Retreat

In this activity, adapted from Silberman [9], the instructor provides each team with a stack of index cards (different sizes in each stack are best). Challenge each team to be as effective a group as possible by constructing a three-dimensional model of a "Team Retreat," a place where they could go to study, work on their project or just relax. They may use only the index cards, but folding and tearing the cards are permitted; no other supplies can be used for the construction. Encourage teams to plan their retreat before they begin to construct it. Provide marking pens so that teams can draw on the cards and decorate the team retreat as they see fit. Allow at least fifteen minutes for the construction. Do not rush or pressure the teams. Each group should have a successful experience. When the constructions are finished, invite the class to walk around the room and view their classmates' projects. Reconvene the teams and ask them to reflect on the experience by responding to this question: What were some helpful and not so helpful actions we did as a team and individually when

working together? Summarize the comments and emphasize the need for helpful actions when working as a team.

Team Meeting Reports

Requiring teams to produce written meeting reports can be helpful, not only for organizing and planning team activities, but also for improving team member participation. In the software engineering class of this study, teams were required to produce such reports when working on major projects. For each meeting one team member assumed the role of moderator and another served as recorder. It was a requirement of the course that each member of the team serve as the moderator at least once and also as the recorder once. This helped to insure participation in meetings by all team members. As Bean points out, a dominant individual in the role of moderator has to be quiet in order to get the team's help, and a quiet person in that role must practice speaking up. [10] This encourages individuals to improve their teamwork skills. Also, the meeting report form required that all members present at the meeting be listed by name. Although attendance at team meetings was not considered in determining course grades, the fact that their presence was being documented encouraged individual participation in team efforts.

The "Mine/Ours" Strategy

Another strategy used to encourage greater participation on group projects is what we called the "mine/ours" technique. This technique is applicable to a wide range of exercises. In the software design project, one of the required team tasks was to produce a high level design diagram for the system to be built. Without specific guidance teams often just assign this task to one team member. The others merely serve as reviewers of the diagram produced. Too often the reviewers are content to accept what has been produced without really learning how to produce such a diagram themselves. Furthermore, the diagrams produced are of lower quality if they have not had the benefit of a true collaborative effort. With the "mine/ours" strategy, each student is asked to independently produce a version of the required diagram as a homework assignment. Then, in a team meeting, the individual diagrams are compared and discussed, and the team produces a consensus diagram. Each team must submit not only their consensus diagram, but also the individual diagrams of each of the team members. This approach insures that each team member participates in this part of the project. This technique, which is a variation of Bean's "Evidence-Finding Strategy" [9], is applicable for any task where a team consensus is desired and where a good result depends on team members being individually well prepared before the collaboration begins.

Hypothetical Situation

Since it is difficult to devise projects in a classroom setting that match many real world situations, it is sometimes useful to have teams work on hypothetical problems. For example,

one of the important activities in software engineering is risk analysis. However, many of the risks present in real projects never appear in classroom projects. In a real project, employee turnover could be an important issue, but in the classroom, except for the case of an occassional student dropping a class in mid semester, this is not a serious project risk. The team can be given this as a hypothetical problem for their project, however, and asked to develop plans for risk mitigation, monitoring, and management. This activity can be combined with the "mine/ours" strategy described above by asking individuals to independently produce lists of project risks for a hypothetical situation, have teams arrive at a consensus prioritized list of risks, and then assign the team the task of developing a risk management plan for the highest priority risk.

Role Playing

Teamwork skills and team member participation can often be enhanced through role playing. One way to do this is by selecting an existing team, or by selecting any group of students in the classroom, and assigning specific hypothetical roles to each. The selected group would then hold a simulated meeting in front of the class in which they attempt to solve some project related problem. The problem might relate to a real situation facing the team or it might be a hypothetical problem of the nature discussed in the section above. For example, in the case of the problem of employee turnover posed above, each member of the group might be asked to play the role of an individual from a different organization in a hypothetical company. One student might play the role of a software project manger, one might represent the human resources department, and another might assume the role of a software developer. These students are then asked to conduct a simulated meeting to discuss the issue at hand. Role playing gives students an opportunity to interact with other team members in ways that would be unlikely in normal classroom project work and provides them another opportunity to improve their group communication skills.

SUMMARY AND CONCLUSIONS

This study reinforces the findings of the original effort regarding the significant correlation between team project success and both team synergy and team perceptions of their own effectiveness. The Kolbe A Index can be useful in forming synergistic teams since it provides an indication of people's problem solving styles. It has long been recognized that both cognitive and affecitve factors contribute to team productivity. The Kolbe A Index, however, provides new insights into how groups function. According to Hoffman, "this approach offers a fresh, 'third way' of measuring and optimizing individual employee and team achievement." [11]. Although it is rarely possible to form ideal teams, it is

helpful for students to understand the significance of team composition, and it is important that they receive the necessary instruction and assistance for dealing with any resulting problems relating to team dynamics.

The current study also reconfirmed the finding that team achievement correlates with knowledge of the course material as indicated by scores on exams. To the greatest extent possible, teams should be formed to equally distribute the software engineering knowlege and abilities present in the class among the teams. This helps to ensure fairness and minimizes the likelihood of having ineffective teams.

An important new finding of the current study is that team success is affected by the degree to which there is equal participation by all team members. Consequently, efforts to improve the participation by individuals toward accomplishing team goals can be beneficial.

In order for students to gain the maximum benefit from team experiences, it is important for them to be members of effective teams. Instructors can help insure that this happens by taking care to form teams that are most likely to be effective and by devising exercises that both help teams understand the group process and encourage individual participation in team efforts.

REFERENCES

[1] Denning, P. J., Educating the New Engineer, *Communications of the ACM*, 35 (12), pp. 83-97, ACM, 1992.

[2] McGinnes, S., Communication and Collaboration: Skills for the New IT Professional, www.ulst.ac.uk/misc/cticomp/papers/mcgin.html University of London, 1995.

[3] Hilburn, T. B. and Bagert, D. J., A Software Engineering Curriculum Model, *Proceedings of the 1999 ASEE Annual Conference*, ASEE, 1999.

[4] Swan, B. R., et al., A Preliminary Analysis of Factors Affecting Engineering Design Team Performance, *Proceedings of the 1994 ASEE Annual Conference*, pp. 2572-2589, ASEE, 1994.

[5] Lingard, R. and Berry, E., Improving Team Performance in Software Engineering, *Selected Papers from the 11th International Conference on College Teaching and Learning*, Chambers, C. (ed.), Florida Community College at Jacksonville, 2000.

[6] Kolbe, K., *The Conative Connection*, Addison Wesley, Reading, MA, 1990.

[7] Kolbe, K., *Pure Instinct*, Times Books, New York, 1993.

[8] Berry, E. and Lingard, R., Teaching Communication and Teamwork in Engineering and Computer Science, *Proceedings of the 2001 ASEE Annual Conference*, ASEE, 2001.

[9] Silberman, M., *Active Learning Strategies to Teach Any Subject*, Allyn and Bacon, Boston, 1996.

[10] Bean, J. C., *Engaging Ideas: The Professor's Guide to Integrating Writing, Critical Thinking, and Active Learning in the Classroom*, Jossey-Bass, San Francisco, 2001.

[11] Hoffman, E., *Psychological Testing at Work*, McGraw-Hill, New York, 2002.