Teams in Engineering Education

A Report Submitted on Work Completed Under Sponsorship of the

National Science Foundation

Grant Number USE 9156176
Student Teaming and Design

Submitted by

L. Bellamy, Chemical, Bio, and Materials Engineering
D. L. Evans, Mechanical and Aerospace Engineering
D. E. Linder, Psychology Department
B. W. McNeill, Mechanical and Aerospace Engineering
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Abstract

This report reviews the needs for teaming skills in the engineering workplace and discusses why these same skills can contribute to improving the educational process. The report also includes a Team Training Workbook that contains exercises designed to take teams of participants through the stages of team development and the principles of effective team performance. A Facilitator's Guide is included to provide instructors with additional information to help insure the success of the exercises in the Workbook.
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**Team Training Workbook**

*Facilitator's Guide for Team Training Workbook*
Introduction

The Slow Evolution of Teams in the Workplace

In 1966, Warren Bennis, a well-known business professor and consultant to multinational companies and governments throughout the world, published an essay entitled "The Coming Death of Bureaucracy" that contained the following predictions about the demise of the hierarchical structure then common to nearly all organizations [see Chapter 4 of Bennis (1993)]:

Organization
The social structure of organizations of the future will have some unique characteristics. The key word will be "temporary." There will be adaptive, rapidly changing temporary systems. These will be task forces organized around problems to be solved by groups of relative strangers with diverse professional skills. The groups will be arranged on an organic rather than mechanical model; they will evolve in response to a problem rather than to programmed role expectations. The executive thus becomes a coordinator or "linking pin" between various task forces. He must be a man who can speak the polyglot argot of research, with skills to be evaluated not vertically according to rank and status, but flexibly and functionally according to skill and professional training. Organizational charts will consist of project groups rather than stratified functional groups. . . .

Adaptive, problem-solving, temporary systems of diverse specialists, linked together by coordinating and task-evaluating executive specialists in an organic flux—this is the organization form that will gradually replace bureaucracy as we know it. . . . Organizational arrangements of this sort may not only reduce the intergroup conflicts mentioned earlier; they may also induce honest-to-goodness creative collaboration.

Motivation
The organic-adaptive structure should increase motivation and thereby effectiveness, because it enhances satisfactions intrinsic to the tasks. There is a harmony between the educated individual's need for tasks that are meaningful, satisfactory and creative and a flexible organizational structure.

I think that the future I describe is not necessarily a "happy" one. Coping with rapid change, living in temporary work systems, developing meaningful relations and then breaking them—all augur social strains and psychological tensions. Teaching how to live with ambiguity, to identify with the adaptive process, to make a virtue out of contingency, and to be self-directing—these will be the tasks of education, the goals of maturity, and the achievement of the successful individual."

Nearly 30 years of hindsight now make clear how profound Bennis' predictions were when the predictions are compared to current reality in the business world. Flatter organizations, movement to Total Quality Management (TQM) principles, more use of self-directed teams, and Senge's (1989) learning organization ideas are but a few of the signs of an emergence Bennis' perceived culture. Typical of the comments currently being heard from leaders in industry are the following:
"The task for us at Boeing is to provide a massive change in thinking throughout the company—this is a cultural shift, and it isn't easy!" Phil Condit, Executive Vice President, Boeing Commercial Airplane Group.

"If you can't operate as a team player, no matter how valuable you've been, you really don't belong at GE." John F. Welch, CEO, General Electric.

"Everyone has to work together; if we can't get everybody working toward common goals, nothing is going to happen" Harold K. Sperlich, President, Chrysler Corporation.

In today's "polyglot argot" of the workplace, the Bennis' terms of coordinator (or linking pin), task forces (and project groups), and organic-adaptive, have been replaced with the terms process owner (or sponsor), teams, and quality-based, respectively.

Implicit in Bennis' predictions is the need for each employee to possess the interpersonal skills that would enable task forces and project groups (i.e., teams) to work together. Teams are rapidly becoming ubiquitous in the workplace, as evidenced by the publicity surrounding the institution-wide commitment found at the Toyota/General Motors NUMMI plant, "Team" Xerox, the San Diego Zoo, and many others too numerous to mention. Also, the design and manufacturing of such products as the Chrysler Corporation H car, the Dodge/Plymouth Neon, the General Motors Saturn, and the Boeing 777, have made it clear that teams are the wave of the future, if not the present.

The Slower Evolution of Teams in Education

In spite of the now obvious trends in the workplace, education has seriously neglected "teaching how to live with ambiguity, to identify with the adaptive process, to make a virtue out of contingency, and to be self-directing" as identified by Bennis. Education has also all but ignored the concomitant interpersonal or team skills issue.

Current engineering graduates (and faculty) have little knowledge of team skills and dynamics. In fact, working together in academe is often regarded as cheating, an activity that is penalized severely. Engineering students compete for grades in the vast majority of their courses, removing most of the incentives that might exist for helping other students.

Recent studies of engineering education that have established desired attributes of graduates [e.g., Pister (1993), Evans et al. (1993), Evans and Shunk. (1992), ASTD (1988)] have used various phrases to describe the desire for skill in teaming, including: teaming ability, good interpersonal skills, effective in a group, and an ability to interact with others. The latest major report on engineering education [Pister (1993)] states as its vision that:
The engineering curriculum will have been redesigned so that it adequately prepares students to meet the demands of the present and future engineering workplace and life in a complex technological society. Specifically it will:

- emphasize teamwork as well as individual effort;
- instill a sense of the social and business context and the rapidly changing, globally competitive nature of today's engineering;
- ............

While it may be necessary and important to develop the interpersonal skills of engineering students so that they can smoothly transition into the workplace, the early development of these skills holds great potential for enabling improved academic performance. Many educational elements within the engineering curriculum are best experienced by the students when they work in teams. This is certainly true of capstone design courses where faculty try to simulate the engineering workplace, but with the recent interest in active learning pedagogies, it is also true on a much wider scale.

The traditional approach to team building in academe is to put three to five students together and to let them "work it out" on their way to solving a problem. A better approach is to prepare the students with some instructional elements that will generate an appreciation of what teaming (as opposed to just working in groups) involves, and to foster the development of interpersonal skills that aid in team building and performance.

**Purpose of this Work**

The purpose of this work was to explore the reasons behind the recent emergence of a desire on the part of employers to have the educational system develop students' skills in teamwork. With a better understanding of this need, the development team was to explore the role of teaming in the lower division engineering curriculum and to create modules that would be useful in educating students about the function and efficient performance of teams. This included developing students' interpersonal skills and using some of the tools that enable teams to function effectively.

This narrative section of the report provides some of the background concerning teaming and describes how teaming may fit into the engineering curriculum. The major sections that follow this narrative present exercises that cover the differences between groups and teams and explore some of the elements that are a part of effective teaming. The exercises, applicable in the classroom, will take teams of participants through the stages of team development and the principles of effective team functioning. The format is one in which the participants would form teams and actively engage the materials.
Preparation for this Work

In preparation for this work four members of the development team, three faculty from the College of Engineering and one faculty from the Department of Psychology in the College of Liberal Arts and Sciences, participated in two training sessions that were a part of the Continuous Quality Improvement (CQI) program of the Boeing Commercial Airplane Group in Seattle, Washington. The reasoning behind this participation was to try to understand, first hand, what industry was trying to accomplish with teams and why there have been increasing pronouncements from industry that new graduates need teaming skills.

The first of the sessions attended at Boeing was a two-day workshop entitled "Team Member Training for Quality Improvement." This workshop typically has about 20 to 30 people who are divided into teams of 5 to 6 persons. The format of the workshop involved the participants in an active team environment, and concluded with formal presentations by each team to the other teams. These formal presentations were to be designed as suitable presentations for management.

The second Boeing session in which the ASU team participated was a four-day workshop entitled "Team Leader." This workshop was intended for those employees who had taken the "Team Member" training, participated in one or more company-sponsored teams, and had shown some talent for leading a team. Format of this workshop was essentially the same as the "Team Member" workshop. The stated purpose was to 'Learn to lead a team to success' using a process that involved "Discussion, activity, and each participant." The stated payoff was "Confidence and self-knowledge."

Two members of the development team then visited Mt. Edgecumbe High School in Sitka, Alaska for the purpose of meeting and talking with the administration and some of the faculty (school was not in session at the time of the visit, thus preventing direct contact with students). Mt. Edgecumbe was one of the first schools to apply Total Quality Management/CQI principles to administrative operations and to planning and delivery of the curriculum [Tribus (1990)].

One member of the ASU team also attended a Boeing four-day workshop on "Continuous Quality Improvement Facilitator Training" that was offered to Boeing employees who desire to serve as a facilitator of teams within the company. Boeing generally recommends that a facilitator be appointed to each team in order to help make the collection of members a smoothly functioning team. The facilitator is an expert in spotting and correcting various process and personnel problems within the team.

During these preparatory visits the ASU team members began to understand the philosophy of and the need for the cultural change that industry has been undergoing. Indeed, this preparation opened this team's eyes to the whole of the Quality Culture that is now pervading many institutions in the United States.
More importantly, it caused the team to realize that the needs that are impelling non-academic institutions to this new culture are also needs that education has.

**The Nature of Most Modern Engineering Tasks**

The literature on group dynamics includes a typology for classifying tasks that are generally encountered by groups [Steiner (1972)]. The first classification in this typology distinguishes between whether or not a task being classified can be divided:

Can the task be subdivided? The task is referred to as:
- **Divisible**, if it can be divided so that team members may work on the parts, or
- **Unitary**, if it cannot be divided and must be accomplished by one person.

The second classification in this typology distinguishes between the goals of the task being classified:

What is the goal of the task? The task is referred to as:
- **Optimizing**, if the purpose is to produce the best possible product, or
- **Maximizing**, if the purpose is to produce as much as possible.

The third classification in the typology distinguishes between the various ways that members of the team contribute to the final outcome:

How are individual efforts combined to yield the team product? The task is referred to as a:
- **Conjunctive**, if all members must succeed in order for the team to succeed,
- **Disjunctive**, if, when one member succeeds, the entire team succeeds,
- **Additive**, if the sum total of all efforts is important,
- **Compensatory**, if one member's extra effort makes up for another member's reduced effort,
- **Discretionary**, if the team can decide how individual efforts relate to team performance.

The research of Katzenbach and Smith (1993) has verified the appropriateness of teams when "a specific performance objective requires collective work and real time integration of multiple skills, perspectives, or experiences," i.e., when the tasks are divisible, optimizing, and conjunctive. Indeed, many of the tasks encountered in the practice of engineering, such as managing, designing, and improving manufacturing processes and products, are divisible, optimizing,
and conjunctive. Thus, engineering tasks generally match Katzenbach and Smith's performance objectives, and require team-oriented approaches.

Indeed, most of the major problems facing society today are divisible, optimizing, and conjunctive group tasks. While it is true that there are disjunctive efforts (one person discovers a concept and all may share the insight) and additive efforts (e.g., brainstorming) that are a part of the solution process, full solution of most problems will require the expertise of a number of people, all of whom initially possess different pieces needed for establishing the solution. Thus, if society is to advance in any reasonable fashion, it is imperative that students, as a part of their formal education, learn and practice the skills required for effectively working together.

The Academic Link with Teams

In academe there is a need for:

- higher quality in the product (in academe's case this is the delivered education of the students);
- more ownership in the process by those who participate in the process (in academe's case, ownership by the students is needed);
- continuous improvements for all process (in academe's case the administrative and educational processes);
- data-driven decisions throughout the process.

These needs are all counterparts of the needs of industry, indeed of most institutions. Since there exists this direct parallel, there perhaps exists a direct correspondence between the methodologies that are used by industry and the methodologies that can be used by academe.

In the semester or two prior to the start of this work, several of the ASU team members were beginning to experiment with more active learning strategies in the classroom. One member of the development team had much earlier attended a seminar on the subject given by Karl Smith of the University of Minnesota, and several members of the team attended cooperative learning workshops offered through ASU’s Faculty Development program.

Active learning strategies are ones in which the students become dynamic, real-time processors of the material being taught, rather than recipients of the information in a very passive lecture environment. Cooperative learning, an active learning strategy, is a pedagogy that involves students working in groups to accomplish a common goal [see e.g., Karre (1994), Wankat et al. (1994), Kagan (1992), and Johnson et al. (1991)]. Group grades are not a necessary part of cooperative learning, but norm referenced grading (e.g., grading on a curve) and cooperative learning are incompatible since competition for grades hinders cooperating for a common good.

Positive interdependence (all members must cooperate to complete the task) and individual and group accountability (each member is accountable for the
complete final outcome) are important parts of cooperative learning. The pedagogy is supported by a large body of research that shows, relative to students taught traditionally (i.e. primarily with lectures and individual homework assignments), students taught by cooperative learning techniques tend to exhibit longer information retention, better performance on exams, higher grades, stronger critical thinking and problem-solving skills, more positive attitudes toward the subject and greater motivation to learn it, better interpersonal and communication skills, and higher self-esteem.

The pedagogy of cooperative learning yields less than optimum results when the tasks assigned to the groups are inappropriate and/or when the students do not possess the skills or attitudes to enable them to work with one another. Building the interpersonal skills of students enables them to benefit more from this active pedagogy.

Most students have experienced functioning in *compensatory task* efforts when they have worked in groups at some point in their education. Either they have done most of the work for the whole group or they have contributed less than their fair share to the group’s effort. For this reason, students are often hesitant about group activity—in fact, they may strenuously object to being asked to work in groups again. Industry is seeing the effects of this dislike. For optimum group performance in cooperative learning environments, the instructor should structure the group’s objective so that it involves the efforts of everyone on the team. In this way, interdependence within the group is built. In the typology of team tasks, this is closely related to designing *divisible, optimizing, conjunctive* tasks.

Design courses offer excellent opportunities for team activity on divisible, optimizing, conjunctive tasks. Good interpersonal skills of all members, combined with well-structured problems, are fundamental in bringing to fruition a good design.

**Links with the Quality Movement**

As might be obvious from the first section of this report, the evolution of teams in industry is linked to the acceptance and spread of the quality culture first started by W. Edwards Deming, Joseph M. Juran, and A. Feigenbaum. Although there are some cases in which the implementation of the quality movement has failed, there are several things that make the movement so persistent. First of all it espouses a philosophy that improvements can always be made—the search for these improvements never ends. Second, actions must be supported by data that verify that implemented changes are, in fact, real improvements. This requirement is intended to supplant the all-too-common "seat of the pants" approach to implementing a plan, wherein data are never collected to verify whether the implementations are working. Third, is the idea that process improvement teams must have representation from the people who participate in
the process. This requirement is intended to supplant the concept that people
do not plan and evaluate processes can be segregated from the people who actually
run and participate in a process. This latter and outdated concept originated with
Frederick Taylor, the industrial engineer who first proposed the hierarchical
management structure common in industry since the time of Henry Ford.

The link to the quality movement was clear in the visits to Boeing and to Mt.
Edgewise High School. It was further explored through the Deming Librarian,
a set of video tapes that covers the philosophy of the quality movement. At the
request of the development team, this expensive set of tapes was purchased by
the University for the team’s viewing and for the start of a permanent library on
quality.

At the invitation of the Phoenix Think Tank, one of the development team
members participated in a four-day workshop on Total Quality Learning which
further demonstrated how the quality movement can be applied in education.
Two of the team members later attended a related five-day Total Quality
Learning Facilitative Institute which included a focus on the role of the
computer in automating a tracking process to monitor student progress.

One of the important parts of the quality movement is a set of tools that
improves the performance of teams. These tools, described in detail by Brassard
(1989), improve the ability of teams of people to plan their course of action. The
tools break down hierarchical (i.e., Taylor-type) walls by giving all team
members the ability to contribute to the process. Through the use of these tools,
consensus decisions can be reached more easily.

The so-called "seven new quality tools" consist of the following:

- Affinity Diagram
- Interrelationship Digraph
- Tree Diagram
- Prioritization Matrices
- Matrix Diagram
- Process Decision Program Chart
- Activity Network Diagram

Descriptions of some of these tools can be found in the Appendix of the
Team Training Workbook included with this report. While not all of these tools
are necessary or appropriate for introduction and use in lower division courses in
academe, several are quite helpful. The helpful ones at this level include the
affinity diagram, the interrelationship digraph and, perhaps, the tree diagram.

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1. This tape library is available for purchase from Film, Inc., Chicago, Illinois.
2. The Phoenix Think Tank is a collection of prominent, Phoenix-area people from education,
government, and private enterprise, who are interested in K-16 education reform. The Think Tank
is supported by the Ford Foundation.
Coupled with a few other tools such as brainstorming, a code of cooperation, the deployment flow chart, the force field analysis, the issue bin, and the modified nominal group technique, these tools allow all members of teams in lower division courses to contribute to the process being used. These tools essentially redistribute control from those who are very articulate and/or domineering, thus empowering all members.

The remaining tools in the "seven new quality tools" above are useful in upper division courses (e.g., in capstone design courses), and should not be overlooked.

**Changes in the Engineering Core Curriculum**

Since the grant period began in the fall of 1992, the engineering core curriculum at Arizona State University has been extensively discussed and debated. It was originally planned that the development of teaming modules under this program would be used in a new sophomore-level course intended to follow an existing freshman-level engineering design course in which the students worked individually. However, as the development team gained knowledge about the teaming process and the role it could play in improving the educational experience, it soon became apparent that the freshman course could and should start the development of teaming skills. This did not rule out the inclusion of a sophomore-level course in the curriculum, but it was decided that teaming should begin in the freshman course.

During the 1992-93 academic year various modules that might be used to teach teaming skills were tested and improved in several courses and in an ASEE Annual Conference workshop conducted by members of the ASU team. The testing is briefly described in a later section. After each trial, the modules were improved to make them more effective and efficient to deliver.

During the fall semester of 1993, a team-based version of the freshman course was piloted. The pilot version of this freshman course retained most of the design elements that existed in the original version, for they lent themselves well to team-type tasks. These are discussed elsewhere [McNeill et al. (1990)].

The teaming elements used in the pilot course were the exercises that can be found in the Team Training Workbook included with this report and discussed in the next section. They included the jigsaw exercise on team dynamics, the survival exercise, the team role exercise and the exercise of anticipating potential problems and establishing corrective norms. The tools that were used in these exercises included brainstorming, the affinity diagram, the process check, and the modified nominal group technique, all of which are included in the Appendix of the workbook portion of this report.

The freshman students were able to understand this material and put it to use. They became aware that there will naturally be problems that arise as their teams advance and that there will be periods of performance and maintenance. In
addition, they had anticipated what some of these problems might be and had explored strategies for mitigating these anticipated problems. With this training they became better team members.

More detailed, faculty-involved, planning is currently proceeding for both the existing freshman course and for the new sophomore-level course. Both will be offered in the Fall Semester of '94.

The Workbook and Its Modules

Included in this report is a Team Training Workbook which contains materials for teaching teaming skills and knowledge in the classroom. The teaching materials are in the form of modules that can be used to involve students in an active, workshop-like environment that has been found to offer an efficient method of delivery to and learning by the students. The teaching materials may be reproduced for handout to the students and/or made into slides or overhead transparencies for presentation purposes.

To aid the instructor in the delivery of the teaching materials to students, a Facilitator's Guide is also included at the end of the report. The Facilitator's Guide gives instructions and support material for each part of the Team Training Workbook. The instructions and support material are in the form of annotations found on reduced versions of each of the teaching slides included in the Team Training Workbook.

The workbook is divided into four working parts and a supporting Appendix. The four working parts include (1) an introduction to the materials, and sections on (2) making teams out of groups, (3) individual performance versus team performance, and (4) additional exercises.

The first working section, entitled Introduction, covers the purpose and environment of the experience and discusses in particular:

1) the suggested format for delivering the instruction;
2) the outcomes that may be anticipated; and
3) some of the simple tools that will allow effective performance in the active environment to be established.

Section I of the workbook uses a cooperative learning activity called jigsaw to teach material on the formation and operation of teams. This active instruction pedagogy calls for the participants to be divided in groups, each one of which would study some part of team formation and operation. All members of each group are to become "experts" in the subject assigned to that group.

The authors have found that reinforcing the expert topics with a video is worthwhile, although the jigsaw can be completed without it (if the video is not shown, then the timing of the exercise will change). Two videos have been found to be satisfactory although both videos are set in a business, rather than academic, context. Sources of the two recommended videos are given in the
When the members of the expert groups have learned their group's material and prepared a lesson plan, the expert groups then disband. Each expert joins a collection of experts from other expert groups to form "functional teams," each member of which is an expert in a different aspect of team formation and operation. Each member of these new teams then teaches the material to the other members of the team. That is, each member of a functional team brings a piece of the jigsaw back from the expert groups to the functional team. Upon completion of the exercise, all team members should have some knowledge and understanding of all the topics.

There are five different pieces provided for the jigsaw in Section I, thus accommodating up to five different "expert" groups. The five topics are:

1) Stages of Team Development;
2) Six Types of Team Decisions;
3) Recurring Phases in Task-Performing Teams;
4) Sources of Power in Teams; and
5) Five Issues to be Considered in Team Building.

The instructional strategy for Section I calls for the instructor to carefully choose the number of participants to be placed into each expert group. Although expert groups can accommodate from two to about six people, the ideal size is four or five. When the expert groups are too small (less than three) or too large (above six), active participation and learning decrease considerably. It is preferable to cover only four of the expert topics with larger expert groups (say, five or six) than to have very small groups (say, one or two) cover all five. If the number of participants forces the expert group size above six participants, the facilitator should form two or more groups on each expert topic.

Section II of the workbook presents exercises that demonstrate that team performance can exceed individual performances. This section begins with an exercise that is done independently by each individual in the team. It next

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3 If these materials are to be used as a part of a class in which teams have already been defined and are expected to function later in the course, it is best to ensure that members of any one functional team not all become experts in the same subject. That is, the instructor should devise the expert groups so that each contains only one member from each of the functional teams that will be expected to perform later in the course. An easy way of accomplishing this is to have the members of each functional team count off (1 through \( n \), where \( n \) is the number of expert topics the instructor wishes to cover in the jigsaw exercise. If the number of members on a team exceeds \( n \), the count should recycle when the number \( n \) is reached.) At the conclusion of this counting exercise all of the people who are 1's would assemble in the same location, all of the people who are 2's would assemble in the same location, etc., in order to become experts in their appointed topics.
presents a mini-lecture on structure for meetings and role assignments, and moves on to anticipating problems that might emerge when people attempt to work together. The teams then revisit and redo the exercise that had originally been conducted by individuals. The section ends by comparing team performance with the individual performance.

Sections I and II of the workbook call for reporting of the team's process to all of the groups. This has been found to be an important function since it causes each team to be reflective about what just happened.

At the conclusion of each section, the teams are also requested to conduct a process check, an important part of continuous quality improvement. Suggestions for improvement should be "built" into future activities, both as they relate to the delivery of the learning experience and to team operation if the teams were to continue.

Several tools are introduced and used in the recommended processes for delivering the material to the students. These tools are all useful for improving team performance. Details on each tool are included in the Appendix of the workbook. Other more advanced tools, including the seven new quality tools, can be found in Brassard (1989).

Section III of the workbook is entitled Additional Exercises and presents several exercises that can be used to further demonstrate topics on task types (e.g., disjunctive and additive tasks) and team building (the RUSE and Traffic Jam games).

Piloting of the Modules

The modules found in the workbook section of this report have been tested in several classes and faculty/student workshop environments during the course of the project. This testing was done by using the modules with groups of participants, asking participants for feedback on the effectiveness of the modules (e.g., through process checks at the end of session 4), and then retaining the positive features of the modules as defined by the users and incorporating the improvements that were suggested and practical. The following forums were used to test the modules:

Senior-Level Course: A senior capstone design course in chemical engineering offered the first opportunity for using team training modules in a classroom setting. Due to their long exposure time to the traditional education environment, many students were somewhat uncomfortable and unreceptive to material that did not seem to be of a technical nature. Most wanted to get on with "technical content." Toward the end of the

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4 See the Process Check description on page 24 of the Appendix of the workbook portion of this report. Most often this procedure was in the form of the +Δ process check as described on page II-18 of the workbook.
semester, this attitude seemed to change as the students, in retrospect, saw the value.

Lessons learned: Begin the team work early in a student's academic career. Also, the use of a third party facilitator is valuable for helping dysfunctional teams.

Sophomore-Level Course: Several of the modules under development at the time were tested in a sophomore-level set of 3 courses that was taught using the NSF/Texas A&M University integrated engineering sciences courses [Erdman et al. (1992)]. Two of the courses in the sequence were taught in the fall of 1992 and one course was taught in the spring of 1993. Lessons learned: The modules improved the students' skills at teaming. The problems seemed to be greatly reduced, although some problems, such as strong personalities, seemed to persist. The need to continually reinforce the use of the material, especially in the second semester of the set of courses, was identified.

Freshman-Level Course: A new version of ASU's freshman design course, a curriculum element in the engineering program for the last 30 years (it was last significantly modified in 1985), was piloted in fall semester of 1993 as a course in which teaming was required. Three sections are being scheduled for fall of 1994. The pilot class of 14 students used all of the materials found in the workbook portion of this report. The students benefited from an introduction to the development of teams. Only one of the four teams had major problems in the final project at the end of the semester. Other teams were able to work together to get the project done. Lessons learned: Beginning early in the program is the correct philosophy. Also, the materials in the workbook portion of this report are appropriate for freshmen.

These modules have also been used in faculty workshops for the purposes of (a) making faculty aware of team skills and how these develop and (b) providing them with exercises that they could use in the classroom to improve the performance of their students. These workshops are listed below:

Team Building Workshop (Session 0453), ASEE, 100th Annual Conference and Centennial Celebration, University of Illinois, Urbana/Champaign, June 21, 1993. 19 attendees from 19 institutions.

Special Teaming Workshop for the Foundation Coalition, Mission Palms Hotel, Tempe, AZ, July 22-24, 1993. About 40 attendees (total) from all member institutions participated in this training. These institutions are:
Arizona State University, Mesa Community College, Rose-Hulman Institute of Technology, Texas A&M University, Texas A&M University at Kingsville, Texas Women's University, and the University of Alabama at Tuscaloosa.

Special TQM training for ASU upper administration (the team building exercises from this work were used in this training), ASU Downtown Center, Phoenix, AZ, September 1-2, 1993. 28 attendees consisting of the University President, Provost, all Vice Presidents, and all but three Deans.

Special Teaming Workshop, College of Engineering, University of Alabama, Tuscaloosa, Alabama, October 1-2, 1993. 16 faculty attendees from science and engineering at the University of Alabama.

Special Teaming Workshop, College of Engineering, Penn State University, State College, Pennsylvania, December 4, 1993. 24 faculty attendees, 12 engineering faculty from the main campus and 12 from the Commonwealth Campuses.

Special Teaming Workshop, College of Engineering, Arizona State University, Tempe, Arizona, January 20 and 22, 1994. 13 faculty attendees from the college.

(Scheduled) Texas A & M University, Kingsville, Texas, April 4-6, 1994.

(Scheduled) Texas A & M University, Texas, Spring Semester 1994.


**Synergisms Spawned by This Work**

This project has led to many synergisms being developed both inside the University and outside. For example, the training workshop for the ASU upper administration that is listed above started when contact was established with the office of Vice President for Administrative Services. This office is charged with
establishing a TQM environment in the administrative and business areas of the University. The original contact came simply from an inquiry about the availability of the Deming Library video tapes. It evolved into a group of eight people (five were participants in the funded work reported here) from different parts of the University who assembled the TQM training sessions for the upper administration (listed in the previous section) and who have continued to work with them as ASU attempts to grow its own new culture.

ASU's knowledge of teaming and active learning strategies contributed greatly to the successful coalescing and funding of the Foundation Coalition under the NSF Engineering Education Coalition program. This Coalition consists of Arizona State University, Mesa Community College, Rose-Hulman Institute of Technology, Texas A&M University, Texas A&M University at Kingsville, Texas Women's University, and the University of Alabama at Tuscaloosa. The pre-award workshop listed in the previous section has done much to make the management and operation of the Coalition more efficient and effective.

The visit to Mt. Edgecumbe High School led to one of the development team members spending the Fall Semester 1993 at this high school. The purpose was to better understand how quality principles are being applied there so that similar programs might be accelerated in other places.

Several of the workshops attended by the development team were also attended by K-12 teachers and administrators, leading to linkages being established that would not have been possible otherwise. For example, relationships with at least three Phoenix-area schools have been established, resulting in joint projects being initiated between the University faculty and the schools.

Summary

Although the exercises in the workbook portion of this report demonstrate the importance of teams and impart some of the skills and knowledge that are necessary for good team performance, these skills and knowledge are not sufficient to cause teams to operate at a high level of proficiency. Sufficiency requires, in addition, performance challenges that are "clear and compelling" (Katzenback and Smith [1993]) and tasks that are divisible, optimizing, and conjunctive. As stated previously, most engineering design is now recognized as an activity fitting these latter requirements, implying that it is done best by using teams of specialists who apply their skills concurrently rather than sequentially by each specialist in turn throwing the design "over the wall" to the next specialist. With the U.S. trying to become more competitive in the global economy, the "clear and compelling" nature of engineering design and
production is also self evident. Thus, presuming the knowledge and skills of teaming are present in the participants, the conditions for sufficiency are present.

The experience of the team responsible for this study has shown that knowledge of and attention to the team process lead to a greater percentage of teams being successful in academe. This conclusion seems to be independent of whether the “teams” are short-term groups actively learning together in content-oriented classes or long-term teams working on design projects in capstone courses. Although knowledge of and attention to the team process lead to a higher probability of success, the exercises in this book do not, by themselves, insure team success. The problems on which the teams work must be designed to involve compelling and suitably structured tasks. In addition, students must be willing to participate in changing the culture of the classrooms in which they learn and the workplace that they will eventually enter.
References
Brassard, M., (1989); The Memory Jogger Plus+, GOAL/QPC, Methuen, MA.