UTILIZING TEAM BUILDING SKILLS IN ENGINEERIG PROJECTS

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ABSTRACT

Fundamental elements of Group Dynamics can be the basis for successful engineering projects. A tested process for selection of team members is presented. In case of national or regional competitions, the potential for success of a small program entering the competition for the first time may be significantly different than that of a larger institution which has entered the competition several times previously. The success rate of the projects depends heavily on successful team building. Interest and enthusiasm level of the team members plays an instrumental role on the success of the project. These elements may play an even larger role in the team's success than previous academic performances. The preliminary measure of the interest level of the potential members may be achieved by inviting underclassmen volunteers to participate in the current year's activities. Such members should be taken to the current year's competition to gain experience and to decide if they have the interest and motivation to bring a future project to a successful completion. The goals of the team must be set as early as possible. This will enable the team to identify the potential need for the addition of a member(s) early in the process. The role of the advisor of the team is examined. His/her role in the initial inception of the team is both critical and instrumental. The team must function in such a way that each member will benefit from all other members. Project management activities of the advisor must gradually be taken over by at least one of the members who have been selected/recruited based upon their management skills. The advisor must make certain that all members bring good group management skills to the project, and any deficiencies in these skills must be taught again. The success rate of the proposed approach may be measured by the performance record of three different group projects that have been on going in The College of New Jersey (TCNJ) over the past two decades.

I - INTRODUCTION

Over the past twenty years, The College of New Jersey (formerly known as Trenton State College) has developed and prepared many vehicles for competitive events. In 1983 we built our first Mini-Baja vehicle as part of our Senior Design Project activity. We have had new groups of students building completely new and distinct vehicles for SAE's "Mini Baja East" every year since 1983. In 1992 we started a second group building a solar/electric car to participate in NESEA's "American Tour deSol". These two groups were working side-by-side when in 1995

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we added a third group whose task was to design a Lunar Rover to compete in NASA's "Great American Moonbuggy Race". When the advisor for the solar/electric car retired, the faculty felt that the department needed to maintain several opportunities for students to become involved in "group senior design activities". Based upon the department's history of success in national competitive events, it came as no surprise that in 1998 we organized a group to design and fabricate a solar/electric boat with which to compete in ASME's 1999 "Solar Splash". All of these groups continue to operate within our relatively small program, without funding from the department.

We like to think that the successes that we have realized over this 20-year period are because of good engineering and preparation. If the truth were known however, in many cases, we were just lucky. We approach each competitive event with several goals in mind. First is to win the event with the best engineered, most finely prepared vehicle possible. The second goal is to finish every event that we enter. The third goal is to bring the vehicle, and driver(s), back in one piece. We have come to recognize that winning any one of these events is often, in large part, a product of "racer's luck". The best engineered, most finely prepared vehicle does not guarantee a win. Conversely, a poorly engineered and haphazardly prepared vehicle will almost always guarantee a placement with the "also entered". The common denominator, the basis for any success that we may enjoy, and the reason why all these activities were organized in the first place, is the involvement of students in a cooperative learning environment – a team effort. Edgar Dale relates an "ancient proverb" that states, "Tell me, and I forget; Show me and I remember; Involve me and I understand." (1) It is this involvement that has led us to formalize the active group learning experience, and equate this team structure with the recognized "Cooperative Learning Experience". (2)

II – STRUCTURE

In their work, *"Strategies for Improving the Classroom Environment,"* (3) Cynthia Finnelli, Allen Klinger and Dan Budny raise some interesting issues regarding the potential parameters that may have a contributing negative effect on the popularity of engineering and science disciplines on some potential candidates. In one specific area, they refer to the monograph of Shiela Tobias, *They're not Dumb, They're Different: Stalking the Second Tier*; pointing out that the "classroom culture" and the general environment of science and engineering fields suffer from a lack of community (both between the instructor and the students and among the students themselves) and that many students desire this relationship and are more successful when it is incorporated in the classroom (4).

We propose that this (potential) deficiency may be overcome by incorporation of projects that team work is an integral part of them. In fact, such an approach has been successfully implemented in the engineering programs at The College of New Jersey. Starting from their first semester, and throughout their sophomore, junior and senior years, students are involved with projects that involve them with group activities. They are assigned to teams of two, three, four or more students depending on the nature of the project/activity at hand.

The first discussions of group dynamics, of team development, and the interdependence of team members is held in the first engineering course in the first semester. These concepts are further developed and repeatedly exercised and further polished in future classes. To illustrate the typical level of "Team Work" activities incorporated throughout the curriculum, the authors have selected the format of the *mechanical specialty* as an example of where team work is a fundamental organizational element in this program. This format is shown in Table (1). In some cases, a competitive event is employed at the end of the semester. In most cases, each team must generate a professional final report (meeting industry standards) and make a formal team presentation. Since students in more than half of these courses represent several engineering (as well as non-engineering) concentrations, opportunities exist for assigning group members from different disciplines. As shown in table (1), students are involved in team work activities in twelve different courses <u>*prior*</u> to their senior year.

Course Title	Year Taken	Term Taken	Nature of the Design Activity/Project				TEAM WORK
			Lab. Experiment.	Reverse Engineer.	Mini-Design Project(s)	Final Design Project	
Fund. Eng. Design	**1**	**1**		✓		✓	✓
Creative Design	**1**	**2**				✓	✓
Manufacture. Process	**2**	**1**		✓			✓
Engineering Materials			✓				✓
Mech. of Materials	**2**	**2**			✓	✓	✓
Mech. Lab I	//	//	✓		✓		✓
Society, Ethics & Tech.	**3**	**1**				✓	✓
Mech. Design Anal. I	//	//			✓	✓	✓
Thermodynamics. II	**3**	**2**				✓	✓
Fluid Mechanics	//	//				✓	✓
Kinematics & Mech.	//	//		✓	✓	✓	✓
Mech. Lab. II	//	//	✓				✓
Heat Transfer	**4**	**1**				✓	✓
Control Systems	//	//			✓		✓
Control Sys. Lab.	//	//	✓				✓
Mech. Lab III	//	//	✓		✓		✓
Senior Project I	//	//				✓	✓
Mech. Lab IV	**4**	**2**	✓		✓		✓
Mech. Elective	//	//			✓		✓
Senior Project II	//	//				✓	✓

Table 1: Associated Team Work in the Mechanical specialty of the Engineering Program at the College of New Jersey.

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Finally, in their two-semester "senior design project" (the capstone engineering design course), students review, reinforce, and tie together all the previously learned concepts of their education (including team work concepts). They use the full two semesters to work on one design project of their choosing. *These projects are primarily group efforts with students drawn from several different engineering disciplines.* These design teams often include students from such fields as physics, business, art, and computer science. One member of the group is usually from the engineering management concentration and serves as the team manager. This provides structure, organization, and time management of the group's efforts. There are at least two technical faculty advisors, and often a third advisor offering assistance specifically in team management.

III– ESSENTIAL ELEMENTS OF TEAM DEVELOPMENT

According to Carl Smith, "Base groups are long-term, heterogeneous cooperative learning groups with stable membership whose primary responsibility is to provide each student the support, encouragement, and assistance he or she needs to make academic progress". (5) Formal cooperative learning structure (we call it Team Building) then, is more than the members of the group simply discussing ideas with each other. It is more than sharing technical materials with each other, or even helping each other. It is the transformation process that changes a group of individuals into fully functioning, cohesive group. Within our faculty then, it is generally agreed that our team building structure generally follows the essential elements that makes the "Formal Cooperative Group" work.

Although table (1) indicates that instruction on team building begins in the first semester of the freshman year, it also indicates that the culminating team building experience is the Senior Design Project. The authors would like to focus the following discussion on the demanding elements of forming Senior Design Project Teams with the specific intention to participate in a national or international collegiate competitive event.

First of all, in our team building structure, members are selected from a group of interested applicants. Many of these applicants have volunteered, as underclassmen, to help earlier senior design teams prepare for an event. They know what is involved in participating in such an activity. They have witnessed that the success of the team depends upon the efforts of all the team members. It is this common purpose that compels each individual to "dig in" to accomplish more than any one of them could accomplish alone. They understand that they are linked together in such a way that one of them cannot succeed unless all of them succeed. Johnson, Johnson, & Smith (2) call this element "Positive Interdependence".

Secondly, all of our teams have at least one formal meeting scheduled each week. These meetings are structured so that each of the members not only presents the status of their part of the project, but also explains the nature of the concepts and strategies utilized in the process. The group then gets to react, encourage, and promote each member's accomplishments. These informal presentations culminate in a formal presentation at the end of each semester. It is worth noting here that our senior project experience extends over a two-semester period. Again Johnson, Johnson, and Smith characterize this element of team development as *"Face-To-Face Promotive Interaction"*.

One of the most telling outcomes of these weekly meetings is that the group begins to develop an awareness of those members who need help. The group needs to know who needs assistance in accomplishing their part of the project. It is the opportunity for the group to assess the accomplishments of its members, and to assure that each member is held accountable for their part of the project. Johnson, Johnson & Smith call *this "Individual Accountability/Personal Responsibility".* It is this process that causes the team members to develop the realization that none of them can "hitch-hike" on the work of others.

It is the area of *"Teamwork Skills"* (leadership, decision making, trust building, communication, and conflict management (2)) where a management member of the team becomes invaluable. Each group has one member from the "Engineering Management" concentration in the engineering program. This member presides over the meetings, and with critical path network scheduling, insures that all elements of the project come together in an organized fashion. The social skills of team membership have been reasonably well taught in the beginning engineering classes, and this experience is the opportunity to hone these skills.

The *"Group Processing"* element cited by Johnson, Johnson, & Smith (2) is also accomplished at these meetings. This is the opportunity for the group members to discuss which member actions are being helpful, which are being distractive, which to continue, and which to avoid. The atmosphere of these meetings begins to change, as the team becomes more cohesive. The members seem to feel comfortable discussing personal actions in this setting – the atmosphere is like a family discussion.

The entire structure of these groups/teams is considered as being based on the accepted practices utilized in the development of Formal Cooperative Learning Groups (2). Although not occurring in the normal classroom setting, the accepted practices still apply.

IV – STAGES OF TEAM DEVELOPMENT

As the group of individuals come together to begin forming a group, they will pass through several predictable phases as they progress from separate individuals to a cohesive group. In 1965, Bruce Tugman (6) published his "Forming, Storming, Norming, and Performing" team development model. This elegant model has served as the basis for a host of similar models that have been developed in the almost three decades since its original publication. The Forming, Storming, Norming, and Performing stages of team development form a basis for understanding the team developmental process. A team must be able to identify which stage they are in, and manage the transition form one stage to another adeptly.

The *"Forming"* stage initially involves the introduction of team members, and the sharing of personal expectations and goals. The members will be highly dependent on the advisor for direction and guidance. The advisor must be prepared to answer lots of questions about the project's background, purposes, and objectives. The members will usually be excited about the project, but at the same time anxious about the expectations that are being placed upon them. The group discussions at this point may seem irrelevant to the project, and a waste of time. In reality however it is the members learning about each other, their work habits and styles. This stage is nothing more than the first stages of transition from the individual to the group.

As the group begins to feel more confident in their understanding of the task at hand, they are likely to enter the *"Storming"* phase. Virtually all teams pass through the Storming phase, and many visit it more than once. This phase is characterized by the tension that arises as members begin to recognize the need to reconcile the differences in opinion and the differences in working styles that surface. This tension may not be loud or obvious. Task resistance and hostility may appear as quietness and missed meetings. This second phase ends when the group acknowledges and confronts the conflict openly and regains focus on the task at hand.

When the team emerges from the conflict of the storming phase, they will enter the *"Norming"* stage. At this point the group is settling into a sense of cohesion where they feel that they are a part *of the group*, not just *in a group*. The commitment to group unity is strong, and they may well organize fun and social activities. It is important, during this phase, to formally recognize the achievements of the group to further enhance the developing cohesion of the group. Finally collaboration and cooperation will replace the conflict of the previous stage.

The overriding goal of team development is to get to the *"Performing"* stage as quickly as possible. Teamwork can now be characterized by trust, open communication, and support. Friendships will develop and team members will build a loyalty to each other. The group feels that positive work is being done, and the team will have a high degree of autonomy. It is in this stage that the team becomes what Johnson, Johnson, & Smith (2) might identify as a truly high performing cooperative learning group.

V – THE ROLE OF THE ADVISOR

There are probably as many different types of advisors as there are faculty members willing to fill that roll. Some remain intimately involved in every step of the project, while others are content to sign the entry form and quickly turn over the process to the team members. What works best? George Ettenheim suggests that there are pitfalls involved in both cases. From his observations of the development of the Sun Race Competition, and presently Solar Splash, "If a faculty advisor holds the reins too tightly, the students may lose interest. If the students are without an advisor, the lack of experience may hurt". (7) In either case, there are several common tasks that each advisor must perform.

As stated earlier, many of these projects lead to national and international collegiate competitions. It is up to the advisor then to analyze the rules and regulations of the competitive event to determine the number and type of engineering design activities that warrant academic credit at the senior design project level. This then dictates the number, and background, of students required to carry off the project. In our case, team sizes average from four (4) to six (6) members. In almost every project, there always seems to be a myriad of little design problems that do not fit into the above classification. These are excellent problems that can be assigned to underclassmen volunteers. They are always eager and willing helpers. Fortunately, for the advisor, it is from this group that future team members are selected.

Also stated earlier was the fact that these students were "selected from a group of applicants." Being a small engineering program, where all of the courses are taught by full time faculty, there are several advantages to this process. By the time the students are seniors, the faculty knows them very well. Their academic performance, their problem solving skills, their motivation, and their work ethic are well known to the project advisors. The advisor's task then becomes matching the requirements of the project with the potential candidates.

Note here, that students are selected from a group of applicants as opposed to the students choosing their partners. This process is based on the fact that in industry, we usually do not have the luxury of choosing with whom we work. In the beginning stages of team development (freshman and sophomore) several teams may be developed in any given class. Several rotations of groups or group members will screen out individuals who are not contributing/making an honest effort at the expected level.

Through a series of interviews and meetings, the Senior Project advisor assembles the project team. This often happens during the spring of the junior year, and often includes some of the underclassmen volunteers to the project. When funds are available, many of these future members of the team accompany a current senior project team to the competition. This process has proven to be one of the greatest motivators of future team members.

The first organizational meetings, of a new team, are critical to group development. The advisor must clearly define the elements of the project, as well as the interrelationship of the various elements. Each member of the team must be critically aware of their personal responsibility, how their part relates to the other members' parts, and how all of the elements are dependent on one another – positive interdependence and individual accountability. It is necessary that the advisor meet individually with each member of the team to develop a personal contract with the student. This contract lists specifically each element that the student is going to accomplish, to what extent, and under what conditions. This then becomes the basis for grading the student's progress at the end of the semester. *"The Senior Project Proposal form"* along with the Grade Weighting Criteria (used at TCNJ) is attached in Appendix: 2 for potential adaptation or modification.

As the group develops, the advisor takes on a less and less dominant roll. The advisor never completely absents himself from the group, but takes on a role more like that of a team member, offering input and advice in the areas where they have the greatest resources. Only occasionally might the advisor find it necessary to intervene in the technical direction of the group, in avoiding pitfalls and traps observed in previous experience, or in the social aspects of team development. The intervention is always aimed at the successful completion of the project.

One might reasonably assume that the final task of the advisor (other than competing successfully in an event) might be grading the performance of the students involved in the group. In reality however, the properly conceived contract mentioned above (what the student will do, to what extent, and under what conditions) will specify precisely the grade that the student has earned. And, it is never tied to "winning an event", because we all know that winning is almost always a product of "racers luck". Table (2) provides some suggested strategies that the authors have found helpful in the successful development of teams.

Planning the Project	
1.	Evaluate the feasibility of conducting the project with regard to its required finances, human resources, equipment, facilities, deadline for completion, etc.
2.	Recruit members that their interpersonal and intellectual skills complement each other.
3.	Set realistic expectations and challenge each the members at a level that they may succeed.
4.	Prepare a preliminary timetable for major activities involved in the project.
5.	Establish a clear grading policy that is consistent with project objectives and its requirements for success.
Conducting the Project	
1.	Plan a comprehensive first meeting, reviewing all objectives, rules and regulations and logistical issues related to the project.
2.	Review the role of each member as an individual contributor and make it clear that the success of the team depends on the performance and dedication level of each of the members.
3.	Provide sources of information for conducting research and obtaining related literature.
4.	Inform the new team about the existing network of support for obtaining financial and professional assistance.
5.	Discuss the synergistic nature of the design and team work activity and provide examples of success and failure using prior experiences, etc.
6.	Set up a regular weekly time for group meetings that is compatible with every member's schedule and emphasize on the importance of participation of all members.
7.	Make them aware that a later change of design in one of the components/subsystems of the product may create a "Domino Effect" on many other components/subsystems.
8.	Have the entire team work with the project manager to generate a Gantt chart and a Critical Path Network.
9.	Have all members provide a progress report on weekly-basis and discuss/brainstorm the potential solutions for the newly encountered/unforeseen problems.
10.	Encourage members to finalize a (seemingly) flawless and promising design before they start fabrication.
11.	Encourage/require the team to test the functionality/practicality of their proposed designs by computer simulations and actual prototyping.
12.	Establish ample hours for the project, and make yourself available for all team members.
13.	Have the entire team make a presentation to previous year team members and all involved supporting individuals/collaborating advisors at critical stages of the project.
14.	Encourage the previous year team members to provide support and advice for the young/inexperienced team.
15.	Establish a rewarding and appreciation system for all the parties involved.

Table 2. Suggestions for Improving the Chances of Success for a Team Based Project.

VI- METHOD OF MEASUREMENT

As stated earlier, the elements of group dynamics are introduced earlier in the education of the students and continuously emphasized from the first course to the last. An integral part of each group's performance record is the completion of the evaluation sheet for assessing the performance and contribution of each of the group members in a confidential manner. The form used by this faculty is *"The Group Activities Evaluation Form"* (found in Appendix: 1) and is offered here for potential adaptation or modification.

VII – CONCLUSIONS

It is the purpose of this paper then, to suggest that *a sequence of progressively more complex Team Work projects* be established as part of each level of academic preparation. Further, it is suggested that these activities be based upon *a well-founded cooperative learning environment,* and that the team work experiences reflect this foundation. It is further suggested that *the essential elements of team development* be firmly established, and that each team work experience recognizes the validity of this process as it progresses. Early analysis of the graduates of this program seems to indicate that they are measurably better prepared for engineering leadership and management positions, and, those who wish, are accepting the most sought after graduate study fellowships. As the program develops, the view from the inside is that it can only get better.

Table A-3, (Appendix: 3) displays the performance record of the students in the mechanical specialty of the engineering program at The College of New Jersey in regional, national and international student design competitions. The effectiveness of what we have proposed in this paper may be measured through the results shown in this table.

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APPENDIX: 1

Group Activities Evaluation Form

Group activities provide settings where students can be both intellectually active and personally interactive. Evaluate your group's performance on each of the five essential elements of a well-structured learning group.

I. ***Was this a* Lab. Group_________ *or a* Design Group_______*?***

Group meeting schedule:

	YES	NO
1. Did your group meet on a regular basis		

Positive Interdependence:

	YES	OCCASIONALLY	SELDOM	NEVER
2. Did your group discuss, and eventually agree on an answer and/or solution strategy for each problem?	100-75%	75-50%	50-25%	25-0%
	YES	**SOME DID**	**A FEW DID**	**NO**
3. Did each member of the group fulfill their assigned role responsibilities?	100-75%	75-50%	50-25%	25-0%

Face-to-Face Promotive Interaction:

	YES	SOME DID	A FEW DID	NO
4. Did each member of the group share their knowledge with the rest of the group?	100-75%	75-50%	50-25%	25-0%

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Teamwork Skills:

	YES			NO
5. Did you or a member of your group take over *leadership* responsibilities?	100-75%	75-50%	50-25%	25-0%

	YES			NO
6. Were team *decisions* based upon discussion and consensus?	100-75%	75-50%	50-25%	25-0%

	YES			NO
7. Did the members of your team develop a *trust* in one another?	100-75%	75-50%	50-25%	25-0%

	YES			NO
8. Did each member of your group feel comfortable expressing their views and opinions?	100-75%	75-50%	50-25%	25-0%

	YES			NO
9. Did your team deal effectively with *conflict* and differences?	100-75%	75-50%	50-25%	25-0%

Group Processing:

	YES			NO
10. Did your group's discussions include topics focusing on teamwork skills, and collaborative skills? (see #5 thru #9 above)	100-75%	75-50%	50-25%	25-0%

Individual Accountability/Personal Responsibility:

11. List the members of your group, and indicate your perception of the ***percentage*** of contribution each member provided in the completion of your group project. Be sure to include ***YOUR OWN NAME.***

NOTE: Your *% contribution* column must total 100%

Your name________________________________ % Contribution_______________

Name____________________________________ % Contribution_______________

Name____________________________________ % Contribution_______________

Name____________________________________ % Contribution_______________

Name____________________________________ % Contribution_______________

TOTAL = 100%

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APPENDIX : 2

Date Received: _______________

Proposal Accepted: _______________
Chair's Signature

The College of New Jersey
Department of Engineering

Senior Project

Project Proposal

Title of Project: ____
Semester: _____________

Student
Name (print): ________________________
Contact Phone #: ____________________
E-mail:______________________________
Group Members____

Advisors
Primary (print):________________________
Collaborating: ________________________

Grade Weighting Criteria (%)

SP1

Preliminary Design Report (40-70)	[ ]
Preliminary Design Presentation (10-30)	[ ]
Project Notebook (10-30)	[ ]
Other Pertaining Criteria (10-30)	[ ]

SP2

Final Design Report (40-70)	[ ]
Final Design Presentation (10-30)	[ ]
Project Notebook (10-30)	[ ]
Working Model (0-30)	[ ]
Other Pertaining Criteria (10-30)	[ ]

Formulation and Statement of Design Problem:
(continue on a separate sheet as necessary)

Planned Approach to Design Activity:
Include proposed outcomes and deliverables
(continue on a separate sheet(s) as necessary)

Appendix: 3

Year	Competition Title	Competition Level			# of Schools	TCNJ Placement
		Regional	National	International		
1999	Mini-Baja, Eastern Region	✓			40+	Top Ten Overall
1999	Solar Splash Solar/Electric Boat Regatta			✓	20+	Rookie Team with Best Overall Score, 2nd Place; Technical Report
1999	6th. Annual Great Moon-Buggy Race		✓		30+	AIAA's 1999 Best Engineering Design Award
2000	Mini-Baja, Eastern Region	✓			40+	Top Ten Overall
2000	Solar Splash Solar/Electric Boat Regatta			✓	20+	1st Place; Technical Report and Best Visual Displays
2000	ASME Student Design Contest Region III	✓			15+	2nd Place
2000	7th. Annual Great Moon-Buggy Race		✓		30+	1st Place; National Championship
2001	Mini-Baja, Eastern Region	✓			40+	Top Ten Overall
2001	Solar Splash Solar/Electric Boat Regatta			✓	20+	1st Place; Technical Report and Best Visual Displays
2001	8th. Annual Great Moon-Buggy Race		✓		30+	3rd Place
2002	Mini-Baja, Eastern Region	✓			40+	Best Engineering Design, 2nd. Place Overall
2002	Solar Splash Solar/Electric Boat Regatta			✓	20+	Best Technical Report, 2nd Place; Visual Displays, Outstanding Electrical Design, & Outstanding Workmanship
2002	9th. Annual Great Moon-Buggy Race		✓		30+	AIAA's 2002 Best Engineering Design Award

Table A-3: Performance Record of the Students in the Mechanical Engineering Program at TCNJ in Regional, National and International Competitions.