

A Comprehensive Model for Student Design Team Formation and Performance in the Engineering Classroom

Authors:

Stephanie G. Adams, University of Nebraska-Lincoln, 175 Nebraska Hall, Lincoln, NE 68588-0519, sadams2@unl.edu

Gül E. Okudan, Pennsylvania State University, 0213T Hammond Bldg, University Park, PA. 16802, gek3@psu.edu

Abstract—In the rapidly changing markets of today, the survival of a company may depend on their ability to respond to customer needs with new or improved products. To achieve the level of responsiveness required to remain competitive, the formation of product design teams is helpful. In theory, these teams should function as a cohesive unit to successfully facilitate product ideas. There are two causes of inadequate yield from team focused work organizations. First, the team may lack the necessary knowledge and skills required. This problem is remedied by adding to the team people who are specially trained in the necessary area. The second issue causing poor performance within a team can be interpersonal dynamics. Finding and implementing a remedy for this issue can become more complex. It is possible, for instance, to reassign individuals to other projects and thus eliminate tensions, or to recruit members from other projects. However, either solution to this problem will cost time and money. In product design teams, these issues may result in delayed product launches and lost market shares. Similar problems also occur in classroom settings, where increasingly team-learning focused approaches are implemented to better prepare engineering students for industry. One additional concern in classroom settings is the hindrance in student learning when faced with a dysfunctional team. Therefore, the initial team formation is crucial to ensure a high probability of success. One major component of the proposed comprehensive student team formation and performance model is the team formation. This paper discusses a comprehensive model which focuses on team formation, performance management and improvement issues to prevent dysfunctional teams.

Index Terms—Product Design Teams, Team Effectiveness, Team Formation

INTRODUCTION

The objective of this article is to present a model currently in development to facilitate and measure the effectiveness of teams in education. The need for a model of this nature is driven by an increase in organizations moving toward a structure based on teams or groups rather than the traditional emphasis on individual contributors. Employers expect college students to possess these skills and often complain that recent graduates have not learned the team approach to problem solving [1]. In response to employers' pleas for graduates prepared to work in teams, the Accreditation Board for Engineering and Technology (ABET) has redefined program outcomes to include (Item d) the ability to function on multi-disciplinary teams. This modification of need has sparked a growing movement within the engineering community to incorporate more teaming activities into the engineering classroom. This movement can result in a number of challenges for students and faculty.

Buckenmyer observed that in a classroom setting, an announcement of a team project was frequently received with moans, complaints, or other indicators of displeasure [2]. Upon further discussions with classes of students, the following reasons for their negative attitudes toward teams were provided:

1. Teams did not work well together; they were a collection of individuals rather than a united entity.
2. Members were unclear about expectations for the team.
3. Some members became free riders or social loafers.
4. Group members did not know how to build a team and maintain team efforts.
5. Team members did not know how to handle conflict within the team.
6. Teams did not know how to choose a leader.
7. Teams failed to establish definite work assignments for members or create specific due dates.
8. There was no recourse for dealing with noncontributing or dysfunctional members.
9. Inclusive meeting times were difficult to set.
10. Multiple team assignments were given during a semester.

Jones indicates that a well-structured, robust system for developing teams can overcome the flaws in the traditional classroom model and can energize the learning process, while an improperly structured team system can undermine the goals of education [3]. Furthermore, the inappropriate use of teams can not only undermine the educational process but also foster an attitude of contempt amongst students towards future teaming experiences. Buckenmyer states that, "What is taught poorly in college may contribute later to poor performance on the job." [2]

It is well reported that organizations that effectively use teams spend long hours and millions of dollars training individuals, teams, team leaders, and managers. For example, Motorola has reported spending about \$30 million a year on training, mostly on teams [2]. Unfortunately, very little formal training has been provided in the engineering classroom. Teams in the business world develop the ability to deal with their internal problems, but this takes time, and time is precisely what a student team does not have.

Unlike business teams, students have a limited time in which to form teams and complete their task. Whereas, in the business environment, team members are typically with the same company or department for quite some time which allows for the existence of personal interconnections that precede and supercede teams [3]. In addition, there are typically incentives to foster high commitment and actions taken to deal with non-performers immediately. Furthermore, people are allowed to build reputations as team players. Conversely, in educational teams many students don't build reputations or relationships and there is a lack of continuity to the teaming process.

Therefore it is important that a model be developed to assist faculty with successful implementation of teams in the engineering classroom. The model should be independent of the student in the classroom and deliver both effectiveness and efficiency regardless of the diversity of students in the classroom. Without a model of this nature, faculty and students will continue to experience the negative attitudes articulated by Buckenmyer. Furthermore, a model for the development, facilitation, and measurement of effective teaming will promote patterns of behavior that support the goals of teaming in the classroom and aid the faculty member in their introduction, management and assessment of teams. Researchers at the University of Nebraska-Lincoln and Pennsylvania State University have developed a conceptual model to address this need.

BACKGROUND

During the last 15 years scholars and researchers in academia and industry have studied, evaluated, and recommended changes in the field of engineering education. A consistent finding has been the need for graduates to demonstrate their ability to work in teams, communicate effectively, provide leadership, and demonstrate a basic understanding and proficiency with financial and economic matters [1], [4]-[9]. Also, the Accreditation Board for Engineering and Technology (ABET), expect better preparation in these areas to be incorporated into the engineering curriculum at the college and university level [1], [10]. ABET stated in EC 2000, Criteria for Accrediting Programs that one program outcome and assessment measure for engineering programs is to demonstrate that their graduates have an ability to function on multi-disciplinary teams [10].

Unfortunately, many colleges and universities have not been able to show that the use of teams is enhancing teaming skills and learning. This ABET requirement and industry's need for teamwork bring to light a series of questions for engineering educators. The first question is what does it mean to function on a multi-disciplinary team? Second, what should be used to measure students' ability to do so? Next, how will teaming in the classroom be used to enhance this ability? And finally, what effect does teamwork have on the enhancement of learning? The answers to these questions are paramount if engineering educators are to successfully incorporate teams into the engineering classroom.

To address these concerns, a number of scholars have called for a paradigm shift in teaching methods. The most common shift has been moving from instructor-centered to student-centered methods. One method of creating this shift has been active learning. Active learning has been defined as anything students do in the classroom other than watch, or listen to the instructor.

Cooperative learning, the most common approach to active learning, is a pedagogical approach that involves students working together in small groups to accomplish shared learning goals and to maximize their own, and each other's, learning [11]. Research on the use of cooperative learning at the college level has focused on three broad categories of outcomes: individual achievements, positive interpersonal relationships, and psychological health.

Previous studies show that cooperative learning encourages the development of positive relationships and promotes a significantly higher level of individual achievement than either competitive or individual learning. Springer found that small-group learning had a significant and positive effect on undergraduates' achievement, persistence, and attitudes [12].

The Johnson, Johnson, and Smith model of cooperative learning is the most commonly referenced and used model in the engineering education environment [11]. Their model, which requires a substantial amount of structure, is centered on five basic elements: positive interdependence, individual accountability, face-to-face interaction, interpersonal and small group skills, and group processing.

The first element, positive interdependence, deals with the individual students' belief that he or she cannot succeed unless the other group members do (and vice versa) and that their team members' work benefits them just as their work benefits the others. The second element, individual accountability, comes in when educators assess individual students' performance and give feedback to the individuals and to the other group members. The group needs to know which of its members need more assistance, support, and encouragements to complete assignments. The third element, face-to-face interaction, involves group members helping, supporting, and praising each other's efforts to learn. The fourth element, interpersonal and small group skills, deals with the students' need to possess good social skills to function effectively. Those skills include: leadership, decision-making, trust-building, communication, and conflict management. The last element, group processing, involves students' assessment of how well they are maintaining effective working relationships within their groups and how well they are achieving individual and group goals.

Cooperative learning can occur through peer instruction or teamwork [13]. For many faculty, teamwork has become the vehicle for implementing cooperative learning. Unfortunately, many faculty lack the necessary skills to lead, manage, evaluate, or train students working in teams [7], [14]-[15]. In the case of most faculty, their expertise rests in their technical specialty. Consequently, students do not receive sufficient training, or feedback, to learn or master teaming skills. In many cases faculty stick 3-5 students together, call them a team, assign a task, and expect results. If lucky, students will complete their task, but it is unlikely they will develop good teamwork skills.

What exactly constitutes good teamwork skills? Many scholars have tried to identify the skills that yield an effective team. Researchers have generated multiple lists of skills constituting effective teams in areas ranging from business to the engineering classroom. Skills and factors identified include: team empowerment, clear mission/purpose, role clarity, team size, rewards, open communication, group task, group composition, group process, accountability, interdependency, feedback, autonomy, and conflict resolution [16]-[20].

Furthermore, several models have been proposed and used to improve our understanding relevant to: (1) how teams function, and (2) how their performance can be improved. Input-Process-Output Model [21], Normative Model [22], Time and Transition Model [23], General Model of Group Effectiveness [24], Team Evolution and Maturation Model [25], Conceptual Model of Team Performance [26], Integrated Model of Team Performance and Training [27], and a Heuristic Model of Group Effectiveness [20] are among these models.

All of these models aid in the understanding of team performance. Perhaps the most widely accepted is McGrath's Input-Process-Output Model [21]. This model categorizes the factors that influence team performance into three major classes: input variables, which determine the givens associated with the composition and the characteristics of the team as well as the task and the situational requirements of the environment in which the team operates; process variables, which include the behavioral processes through which team members interact, communicate, and coordinate activities in order to complete their mission; and output variables which include the measures of team performance and cohesion and other outcomes that result from the actions of the team. According to this model input variables are further subdivided into three groups: environmental factors, individual characteristics level, and group level or team difference variables which serve to define the nature and characteristics of the overall team.

Hackman's model contributes by emphasizing organizational context as well as the effort, skills, and strategies of team members in performing tasks [22]. The Gersick model highlights the dynamic and evolving nature of team performance [23]. Nieva et al. emphasize that individual characteristics cannot be ignored in team functioning [26]. The task-oriented model conveys the criticality of task and work structures in understanding team performance. Salas et al.'s model is an integrated version of the above models [27]. Cohen and Bailey's model moves away from the "input-process-output" approach by depicting design factors, which have an indirect impact on outcomes via group processes and psychological traits, as also having a direct impact on outcomes [20]. It suggests that group psychological traits are real group level phenomena. These traits directly influence them through shaping internal and external processes.

Most of these models have only been tested in the business sector. McGourty and DeMeuse developed the Team Developer (TD) as an electronic assessment and feedback system designed to help students and team members grow [7]. When used properly, the TD enhances communication and improves team performance.

The TD was developed based on the premise that there exists a set of internal and external factors that affect team performance. Internal factors, those under direct control of a team member, are communication, decision-making, self-management, and collaboration. External factors are structure, rewards, task, resources, and culture. Team performance as a part of the TD includes quality, quantity, innovation, meeting deadlines, and so forth.

The TD is administered as a computer survey to team members who rate themselves and fellow team members on internal team factors. Each student receives a rating summarizing their self-view along with perceptions of them by their team members. Results of the TD can be used to construct and individualize an action improvement plan.

Although the TD has been used by students at the undergraduate and graduate level in disciplines such as engineering and business, it has limitations. The developer reports that unless students make a concerted effort to improve their own skills, the improvement plan is not useful. Another limitation as identified by this researcher is that effectiveness is measured

only by performance. Adams found that effectiveness was more than performance and should also consider the satisfaction of the team members [28].

Models of team effectiveness developed with a business emphasis suggest that performance is only one component of effectiveness. Researchers introduce a number of variables related to effectiveness, such as: design (autonomy, interdependence), process (e.g. helping behavior), context (adequate resources); satisfaction; cost savings; and productivity improvement [16]-[17], [20], [24], [28]. With an increased focus on teams in engineering education and the desire to produce graduates proficient in skills beyond the technical realm, a broader definition of team effectiveness is needed.

Engineering educators should strive to show that results from teaming initiatives are more than outcome oriented. Teaming initiatives should also examine the process of getting work done. Furthermore, teaming initiatives should impact both students' attitudes about teams and their behavior while working on teams as well as enhance their learning.

The model, presented here, is different from the models in the literature in the following ways: (1) this model looks at both the team's output and the process of getting the work done, and (2) the model examines team performance as a function of an individual member's perception of other members. The remainder of this paper describes this new model and presents results of several pilot studies.

THE MODEL

This section of the article provides detailed information on the model. Included are the goals of the model, the theoretical foundation on which the model has been developed, an explanation of the model, and the outcomes of the model.

The goals for the model depicted in Figure 1 are as follows:

1. to assist with the facilitation of teamwork in the classroom;
2. to assist with the measurement of individual growth with regards to learning a subject and learning how to work in a team; and
3. to assist with the measurement of teamwork effectiveness.

Insert Figure 1 about here

Measures of effectiveness should include both the individual and team level of analysis, capture the process as well as the outcome, describe and diagnose performance, and help to provide knowledge of the results to the team for developmental feedback [29]. An alignment of the needs of the individual, the dynamics of the team, and the requirements of the task will produce a high-performing, synergistic team.

According to Brannick and Prince, before a group of individuals can function effectively as a team, the members must have the technical knowledge and skills to perform their own tasks [29]. After all, effective teamwork requires team members who have positive attitudes toward the team and its task, have been provided adequate direction and support for accomplishing team goals, and know their responsibilities and those of other team members with whom they interact. Therefore, efforts to improve team performance must focus on the performance of individuals [29].

The model begins with the pre-assessment of individual members. The pre-assessment is being administered to establish a baseline for training purposes and growth measurement. It is important, when trying to understand team behavior, to remember that a group is a system of associations and that if the nature of those associations is changed, the behavior of the group has no choice but to follow the directions dictated by those associations, and that no individual in the group has to change to elicit a new behavior [30].

The next step in the model is the formation of teams. Successful team formation takes into account various perceptions of the individuals. Individual perceptions are influenced by member characteristics, team structure, task characteristics, and organizational context. Member characteristics are shaped based on their experience, tenure, gender, cognitive skills, personality traits, task relevant skills and knowledge. For example, in a team where individual recognition is emphasized and a hierarchical team structure is chosen, the ideal individual characteristics of team members may be very different than in a team environment in which each member has an "equal say" and the recognition is collective. This is illustrated with the Team Formation Sub-Model shown in Figure 2 below.

Insert Figure 2 about here

The argument is that task relevant or social behaviors of members within a team are shaped by each member's perception of other team members' characteristics; and further this perception is a function of each interacting pair's (the person who is forming the perception and the person who is being perceived) differences in individual characteristics. Therefore, in addition to behaviors of members (communication, conflict and its resolution, etc. which are considered as team processes), individual characteristics of team members and interacting pairs' differences should be analyzed as they relate to the performance of the team.

Once the team is formed an additional pre-assessment is conducted on member attitudes regarding teaming, their experiences with teaming, and their proficiency with the characteristics leading to an effective team experience. As individuals and teams complete the pre-assessment period, training should be provided to all teams prior to their work on the task. The convener of the teams sets forth the task to be completed. Training is recommended in subjects such as: role clarification, effective communication, conflict resolution, running effective meetings, decision making techniques, setting goals, and proper evaluation techniques.

At this point the task is assigned. When assigning a task, important characteristics to consider are domain, gender orientation, complexity, and interdependence. Each of these may affect the performance of an individual within the team environment in relation to other team members. Monitoring should begin in conjunction with task assignment.

During the monitoring process team facilitators, conveners, coaches, instructors, etc. should observe the dynamics of the team, the attitudes of the members throughout the teaming process and the stages of development the team exhibits. Monitoring should be objective and done qualitatively. The team convener should observe the teams in action as well as query members via focus groups and interviews as to their experiences. This information will be beneficial in evaluating the behaviors and attitudes of team members.

Also, during this time it is important to reward team members. Rewards are typically given upon completion of a task or a project. However, this model promotes rewards throughout the teaming process for meeting major deadlines, meeting them ahead of schedule, or other acts that demonstrate success by the team. Rewards might consist of a "pat on the back" for a job well done, a certificate of achievement, a pizza party for all team members, verbal acknowledgement, or some other motivational event. Once the task is completed, a post-assessment should be conducted to measure the effectiveness of the team.

Highly effective teams exhibit certain characteristics. A review of the literature produced numerous characteristics for consideration. The hypothesis for this model is that the following seven characteristics (to be referred to in the remainder of this article as "constructs") are the most critical for an effective teaming experience: common purpose, clearly defined goals, psychological safety, role clarity, mature communication, productive conflict resolution, and accountable interdependence. A description of each construct follows:

Common purpose is the main objective of the team. This should be understood and shared by all team members. Common purpose should lead to the development of the team's goals. Successful teams shape their purposes in response to a demand, or opportunity, put in their path [18]. This helps teams get started by broadly framing the convener's expectation.

Clearly defined goals are quantifiable and commonly agreed upon statements that define the actions to be taken by the team. The attainment of specific goals helps teams maintain their focus.

Psychological safety is the shared belief that the team is safe for interpersonal risk taking [31]. Psychological safety is a sense of confidence that the team will not embarrass, reject or punish someone for speaking up. Psychological safety leads to a team climate characterized by interpersonal trust and mutual respect in which people are comfortable being themselves.

Role clarity is the team members' common understanding of each individual's expected role. The presence of role clarity minimizes misunderstandings regarding task assignments.

Mature communication refers to team members' ability to:

1. articulate ideas clearly and concisely
2. give compelling reasons for their ideas
3. listen without interrupting
4. clarify what others have said
5. provide constructive feedback

Mature communication among team member ensures a higher level of understanding.

Productive conflict resolution refers to the procedures and actions taken when a conflict occurs. Productive conflict resolution leads to results such as:

1. facilitating the solution of the problem,
2. increasing the cohesiveness among team members,
3. exploring alternative positions,

4. increasing the involvement of everyone affected by the conflict and
5. enhancing the decision-making process [32].

Accountable interdependence is the mutual dependence that all team members have regarding the quality and quantity of each individual's work within the team. Mutual dependence generates a shared sense of security.

In order to measure these constructs we must look at the process of completing the task and the satisfaction of the team members. Task completion and satisfaction can be further studied by examining the relationship between performance, behavior, and attitude to effectiveness. The hypothesis of the model regarding team effectiveness is that effectiveness (E) is defined as a function of *team performance* (P), *members' behaviors* (B), and *members' attitudes* (A) and can be represented by the equation, shown in Figure 3. Future work will allow the team of scholars to quantify the relationship that performance, behavior, and attitude have with effectiveness.

Insert Figure 3 about here

Performance considers the extent to which the outputs meet the standards of quantity, quality, and timeliness according to those who use the product or receive the service [28]. Behavior considers the extent to which the team experience contributes to the growth and personal well being of team members [28]. Attitude is concerned with examining how the process of carrying out the work enhances the capability of members to work together interdependently in the future [28]. For the purposes of this model, the outcomes for performance, behavior, and attitude, along with the tools for measurement, are shown in Table 1.

Insert Table 1 about here

WORK TO DATE

The material previously presented in this article in explanation of the model was formulated based on reviews of the literature and the experiences of the authors. In order to validate the work presented here the authors have begun a series of experiments to test the proposed concepts. To date several independent studies have been conducted in an educational environment. The initial results are presented below.

In the first study an instrument, the Team Performance Questionnaire (TPQ), was developed as a self-report measure of performance. The TPQ utilized seven characteristics including Productive Conflict Resolution, Mature Communication, Role Clarity, Accountable Interdependence, Goal Clarification, Common Purpose, and Psychological Safety as a means to measure the performance of students working in teams. To date two studies have been conducted, one in spring 2001 and the second in spring 2002. After the results were analyzed, modifications were made to the instrument and the name was changed to the Team Effectiveness Questionnaire (TEQ). This change reflected the idea that effectiveness encompasses performance, behavior and attitude. The modifications included a rewrite of a number of questions and the addition of questions focused on obtaining information about the attitudes of team participants.

The TEQ is divided into two main parts. The first part is used to collect demographic data and information on individual preferences regarding teaming and previous team experiences. The second part of the questionnaire is used to measure the student's ability to effectively work in teams. This part also measures their understanding of each of the characteristics identified by the researchers as vital for the performance of the team. Between five and nine questions were included in each of the categories.

The team effectiveness questionnaire was constructed using both nominal scales and interval scales. Nominal scales are used in the first part of the questionnaire to collect demographic information and student preferences towards teaming. A five-point Likert scale ranging from "Strongly Agree" (1), to "Strongly Disagree" (5) was used as the interval scale for the second part of the questionnaire. Interval scales are used for most questionnaires for several reasons: variables measured in interval scales can be analyzed using parametric statistics that are based on the assumption that the scores represent a normal distribution around the population mean. These scales also provide the most variation of responses lending themselves to better data analysis.

In the spring 2001 study, 162 engineering students who were enrolled in senior design courses at the University of Nebraska-Lincoln completed the Team Performance Questionnaire. Using the data collected from the questionnaire, several

analyses were performed. The first analysis was to test for internal consistency using the Cronbach coefficient. Cronbach's coefficient alpha is used if the items are scored as continuous variables (strongly agree to strongly disagree), which in this case they were. Cronbach's alpha provides a coefficient to estimate consistency of scores on an instrument. The results from the internal reliability analysis are shown in Table 2.

Insert Table 2 about here

The self-performance items presented the highest internal reliability with a standardized alpha equal to 83%. The remaining reliabilities ranged from 65% for conflict to 75% for goal clarity.

The next analysis was to use factor analysis to test the adequacy of the questionnaire in measuring team performance. The factor analysis produced 7 factors which account for 58.167% of the variance. Unfortunately the items did not load on the factors as expected due to the limited sample size. Therefore, the validity of the results is limited. Future work will be done with an increased sample size.

Pearson Correlation coefficients were computed among team self-performance and the seven team constructs created. Using the Bonferroni approach to control for Type I error across the 28 correlations, a p-value of less than .0018 (.05/28=.0018) was required for significance. The results are shown in Table 3.

Insert Table 3 about here

The results of the study showed that the self-performance items presented the highest internal reliability with a standardized alpha equal to 83%, while conflict presented a very low reliability. The remaining reliabilities ranged from 65% for conflict to 75% for goal clarity. The results from the Pearson-product moment correlation analysis indicated high positive correlations between self-assessed performance and the seven constructs identified in the team effectiveness model.

In the spring 2002 study, 188 engineering students who were enrolled in senior design courses at the University of Nebraska-Lincoln completed the TEQ. The same analyses as used in the 2001 study were performed. As a measurement of reliability, Cronbach's coefficient alpha was calculated for each of the factors considered in the study. As Table 4 shows, all of the factors produced alpha values greater than .5 indicating a high internal consistency. In other words, items assigned to each construct are measuring the same characteristic making the instrument reliable.

Insert Table 4 about here

From the factor analysis 10 factors were identified as the fewest possible constructs needed to reproduce the original data, explaining 67.7% of the variation. However, the loading distribution was not as expected. The expectation was to obtain seven factors (constructs of the study). The analysis showed that five factors accounted for a significant part of the items loading. A new analysis was run forcing the analysis to use 7 factors in order to evaluate the instrument on the original conditions (measurement of the seven constructs). The variance explained by the 7 factors was 61.5% and once again the loading was not as expected. However, there was an improvement as the items distribution showed a loading more consistent with what was expected.

Once again, Pearson Correlation coefficients were computed, using the Bonferroni approach to control for Type I error across the 28 correlations. A p-value of less than .0018 (.05/28=.0018) was required for significance. Table 5 shows the correlation values between the variables of the study. These results showed high values with statistical significant correlation between variables.

Insert Table 5 about here

The result of this study showed that attitude toward teamwork is highly related to each of the seven characteristics considered essential for a team to become effective. However, all of them did not account for the explained variance in attitude. In fact, only six of these characteristics (mature communication, accountable interdependence, psychological safety,

common purpose, role clarity and clear goal) were shown to contribute to the explanation of the variance on attitude toward teamwork. The explained variance accounted for by the variables was of 72.4%.

The most recent study conducted occurred during the fall 2002 semester. The objective of this study was to develop a protocol to observe and measure the behavior of a team based on this model. Observation was used as the main tool to assess team behavior. A checklist form was designed to aid in observation along with a protocol that details the requirements and instructions on how to organize and prepare the observation of a team, as well as a description of how to fill out the forms, and obtain and interpret data. A pilot study was conducted to test the reliability of the tool. A total of nineteen students enrolled in an Engineering Management course were observed on a teamwork experience. Data was collected using three different observers with the protocol and checklist designed in this study. Inter-rater reliability was calculated using Cohen's Kappa for statistical analysis of the data. The results indicate that the tool is 62% reliable. Creswell states the 80% is necessary to ensure reliability [33]. With proper training on the use of the instrument the reliability can be improved. Additional studies are currently underway to improve the reliability.

SUMMARY

A conceptual model has been developed to assist in the development of effective teams, to assess team effectiveness, and to measure the growth of individuals working in teams. The model shows the essential components in building teams and determining whether or not teams are effective. Development, testing and validation of the model will occur in three phases. The first phase consisted of the development of the Team Effectiveness Questionnaire (TEQ), a questionnaire to measure performance and attitude. To date, the TEQ has been tested with three groups of engineering students working on design teams. Results of these tests can be found in the proceedings of the 2002 American Society of Engineering Educators Conference.

The second phase of the validation of the model was to develop and test a protocol for behavioral observation. A checklist form was designed to aid observation, along with a protocol that details the requirements and instructions on how to organize and prepare the observation of a team. Additionally, instructions on completing the forms, obtaining, and interpreting data were included. This tool provides an assessment of the extent to which each of the seven constructs of the model is present in a team, based on the behavior exhibited by the team members. A pilot study was conducted to test the reliability of the tool. New studies are currently underway.

The third phase of the model will be to develop a methodology for determining if students working in teams learn more than those who do not. While implementation of the final phase is not yet underway, a plan has been developed. The initial plan consists of offering introduction to statistics in two sections: one taught utilizing teams and the other taught utilizing the traditional individualist method. In both courses, material content will be identical. However in team based course homework, tests, and projects will be in a team based manner. At the end of the course students will be asked to demonstrate what they have learned via concept maps, vee diagrams, and knowledge tests. The hypothesis at that point will be: Students completing the course in the team based environment will learn more and be able to demonstrate it at a level greater than those in an individual based environment. Funding has been awarded by National Science Foundation to support this work.

If this model is successful it should reveal: a) individually, team members grew in their understanding of the team constructs; b) the team as a whole grew in their understanding of team constructs and c) proper synergy of task and team process occurred.

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FIGURES AND TABLES

FIGURE 1

MODEL FOR THE DEVELOPMENT AND FACILITATION OF EFFECTIVE TEAMING

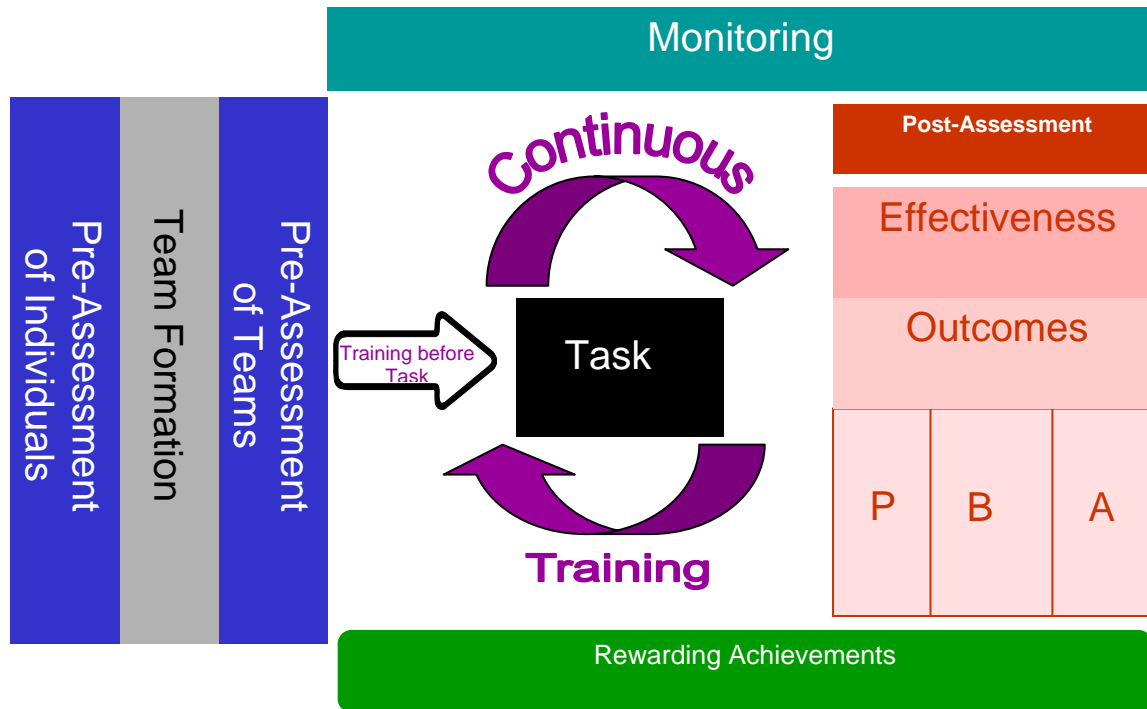


FIGURE 2
TEAM FORMATION SUB-MODEL

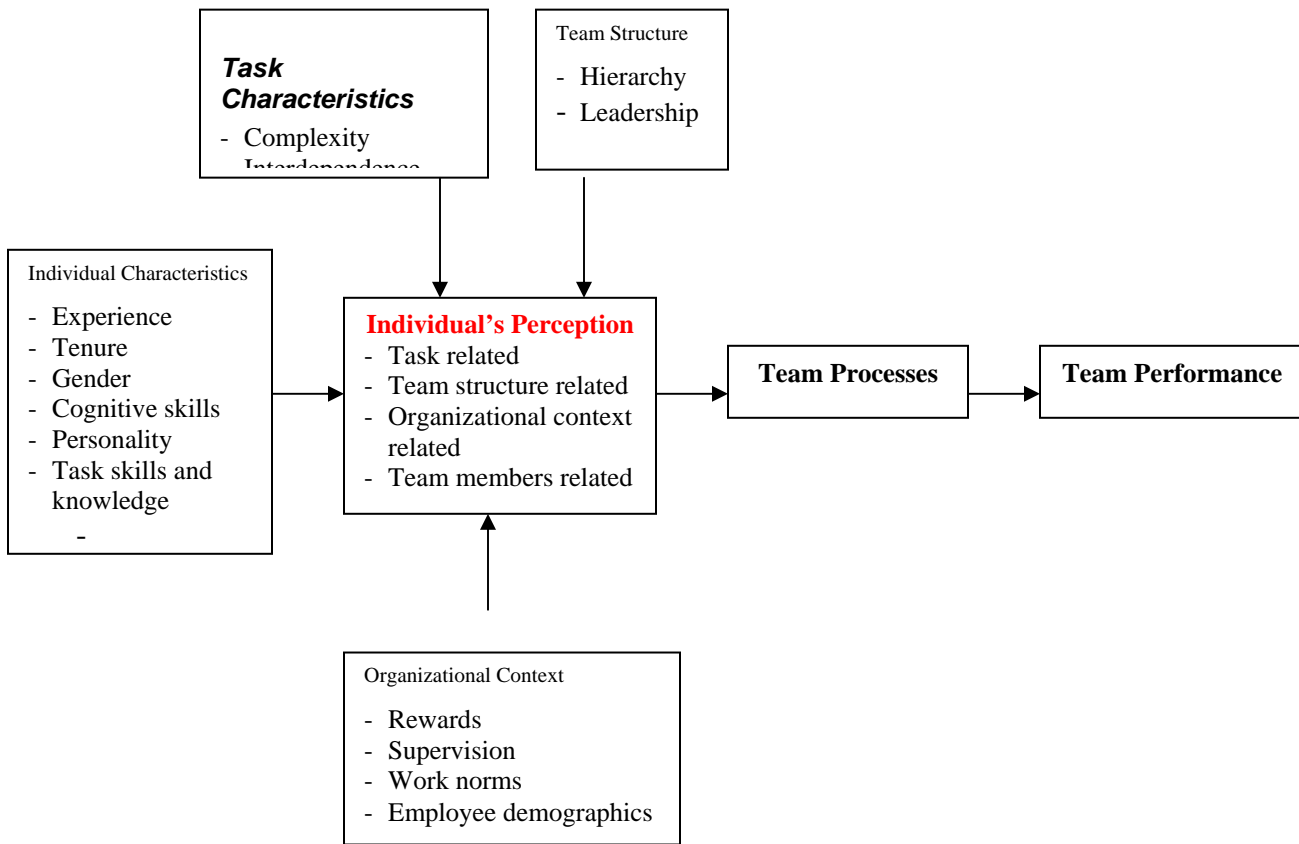


FIGURE 3
MATHEMATICAL REPRESENTATION OF EFFECTIVENESS

$$E = f(P, B, A)$$

TABLE I
OUTCOMES OF MODEL

Outcomes	Measurement	Tools
Performance (P) (on the assigned task)	<ul style="list-style-type: none"> • Knowledge about the subject • Quality of the results • Timeliness • Quantity of the results • Skills mastery 	<ul style="list-style-type: none"> • Project report • Project presentation • Knowledge test (for declarative and procedural knowledge) • External assessment

		<ul style="list-style-type: none"> • Concept map • Vee diagram • Case studies
Behavior (B) (as a team)	<ul style="list-style-type: none"> • Behaviors identified with each of the construct contributing to team effectiveness 	<ul style="list-style-type: none"> • Direct observations • Interview • Video tapes
Attitude (A) (toward teamwork)	<ul style="list-style-type: none"> • Willingness of continuing working in team • Satisfaction for the teamwork experience and the work done 	<ul style="list-style-type: none"> • Questionnaire • Interview • Video tapes

TABLE II
INSTRUMENT RELIABILITY (CRONBACH'S COEFFICIENT ALPHA)

Variable	Number of cases	Reliability coefficients	Alpha	Standardized item alpha
Conflict	162	5 items	.6532	.6519
Communication	151	7 items	.7553	.7538
Role clarity	161	5 items	.6800	.6854
Interdependence	161	6 items	.7324	.7296
Goal	161	6 items	.7462	.7506
Purpose	160	5 items	.7250	.7354
Psychological Safety	162	6 items	.7184	.7353
Self-performance	162	5 items	.8331	.8319

TABLE III
CORRELATIONS AMONG THE CONSTRUCTS IN THE TEAM PERFORMANCE QUESTIONNAIRE

	Perform	Conflict	Communication	Role Clarity	Interdependence	Goal	Purpose
Conflict	0.734						
Role Clarity	0.682	0.629					
Communication	0.573	0.543	0.648				
Interdependence	0.766	0.703	0.755	0.619			
Goal	0.677	0.677	0.741	0.614	0.702		
Purpose	0.738	0.685	0.719	0.696	0.727	0.750	
Psychological Safety	0.614	0.560	0.703	0.548	0.623	0.583	0.600

TABLE IV
INSTRUMENT RELIABILITY (CRONBACH'S COEFFICIENT ALPHA)

Variable	Number of cases	Reliability Coefficients	Alpha ^a	Standardized Item Alpha
Attitude	188	15	.9142	.9181
Conflict	188	8	.7238	.7342
Communication	184	8	.8136	.8174
Goal	188	6	.7958	.7932
Purpose	188	7	.8745	.8774
Psychological Safety	187	7	.7547	.7647
Role Clarity	186	5	.7920	.7955
Interdependence	187	8	.8451	.8436

a. Cronbach's Coefficient Alpha.

TABLE V
CORRELATIONS AMONG THE CONSTRUCTS IN THE TEAM EFFECTIVENESS QUESTIONNAIRE

Variables	Attitude	Psychological Safety	Interdependence	Conflict	Communication	Role Clarity	Purpose
Attitude							
Psychological Safety	.790*						
Interdependence	.782*	.807*					
Conflict	.726*	.790*	.778*				
Communication	.751*	.833*	.762*	.788*			
Role Clarity	.543*	.694*	.579*	.625*	.683*		
Purpose	.800*	.797*	.830*	.754*	.793*	.726*	
Goal	.726*	.708*	.735*	.680*	.762*	.696*	.839*

* $p < .001$.