BUILDING AN ENGINEERING TEAM:
PEER ASSESSMENT PROVES A USEFUL INSTRUMENT
TO GAUGE PROGRESS

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Abstract – Successful team operations rely on several functions that team members assume throughout the life of a project. The National Training Laboratory in Group Development developed a method describing team success based on task and team functions. At the 2004 ASEE Conference, we presented findings indicating that undergraduate teams spent the entire semester developing both a quality product and a satisfied team. We have prepared statistics based on historic information as the foundation for comparing observations during each phase of the project, as described by Tuckman. The statistics demonstrate that team dynamics changed significantly throughout the phases, achieving a balance as the team approached the end of the project.

In an ever increasing technological industry, the emphasis on team relations continues to grow. More and more industries are using teams to solve problems and to generate solutions. In addition to this, as many industries become more global, the make-up of the team is changing to include various disciplines. For example, it is not unusual for a team to be composed of engineers, business majors, and scientists, as well as other varying experts. In short, it is imperative, with the increase of team based productivity and mixed discipline teams in an ever increasing global market, to find out what strategies successful teams utilize to solve problems and make decisions.

Educators have long been aware that industry needs people who can work well together, primarily because the knowledge base for decision-making is frequently broader and deeper than one person can provide. Although scholars differ in their views about phases that teams go through during decision-making processes, they agree that task and team functions are critical for success in the team decision-making process (Jones and Bearley1; Bales2; Bales & Strodtbeck3; Bennis & Shepard4; Tuckman5; and Fisher6).

The Design EPICS (Engineering Practices Introductory Course Sequence) Program at the Colorado School of Mines (CSM) guides teams of first and second-year engineering students through an authentic design experience that calls on decision-making to address technical, open-ended, client-based projects. Mentors guide students through these creative, interactive, and complex processes. Teams practice these processes as they synthesize information, their skills, and client values. Project solutions are showcased in written reports, oral presentations and graphics demonstrations. Past projects include designing interactive playground equipment for
children with disabilities, lunar mining equipment that received NASA’s attention and water treatment systems for rural communities.

Success for any given team relies not only on individual contributions of team members but also on interactions between team members. Team building occurs simultaneously with the development of the project as teams grow and bond through technical interaction. Teams need to balance the task and team skills to establish an effective communication network that leads to efficient engineering design. To create effective design solutions, a team with diverse expertise must be brought together in a social setting. Their solution is dependent upon the members’ ability to become learners, teachers, and analyzers of the team solution. Since the fields of engineering and science increasingly demand the use of team decision-making in order to meet the needs of a rapidly developing technological society, we need to examine the makeup and functions of successful teams.

According to Hare, Blumberg, Davies, Kent, a team role is a function identified with a set of responsibilities associated with the position in the team. They clarify how the term role should not only refer to formal positions in a group, such as “chairperson, secretary, or member, but also to informal positions, such as joker or scapegoat, or to identify a person by a predominant type of behavior, such as silent member or nonconformist”. The two most common roles, identified in our study and supported by research (Hanna & Wilson; Eberhardt; Benne and Sheats; Pfeiffer and Jones), are a “task leader” whose primary concern is for group productivity, and a “team leader” whose concern is for inter-member relations. Although scholars emphasize that team (or process) behaviors are viewed as critical for team success (Mayer, Hawkins & Power), the task functions are the ones commonly associated with team leadership (Bales).

After the Second World War, the National Training Laboratory in Group Development developed a method for describing team performance based on a balance of task and team functions. Task functions, critical to producing a quality product, focused on activities aimed at the project goal. Team functions, critical to maintaining team unity, focused on a team-centered approach to problem solving. These functions, defined in Table I, initially developed by Benne and Sheats were refined over the years by Schein and Eberhardt as training instruments. The EPICS program used this instrument to assess the operations of a team throughout the life of the project. Knecht reported that student teams took the entire semester (the life of the project) to

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EPICS program used this instrument to assess the operations of a team throughout the life of the project. Knecht reported that student teams took the entire semester (the life of the project) to
achieve a balance between task and team functions. As observed by Applbaum\textsuperscript{16} and Jones and Bearley\textsuperscript{1}, the balance of these functions leads to successful problems solving.

Effective teams often follow a predictable developmental process, described by Tuckman\textsuperscript{5}: forming, storming, norming, and performing. Forming is the early stage in which members become familiar with each other and set ground rules for how the team will operate. Storming comes next as team members brainstorm ideas about how to solve the proposed problem. Team members may encounter tensions in this stage as different personalities conflict and then learn to resolve their disagreements. In the norming phase, teams reduce tensions as they gather information and refine their options into workable solutions. In the performing stage, the team polishes and perfects its work to deliver a finished product.

EPICS teams conduct a series of teamwork exercises at various phases of the project, reinforcing the impact of task and team functions on the performance of the team. During these exercises, half of the teams perform the exercise, and the other half observe the functions of performing teams using an observation sheet based on functions proposed by Eberhardt\textsuperscript{9}. Observations are compiled for each team member and then summarized for each team. Observations, collected for each function for each exercise, were statistically evaluated using a t-test in which $\alpha=0.1$ was marginally significant and $\alpha=0.05$ was significant.

All of the stages Tuckman describes are equally important. Our hope is that using research to identify differing team stages will give mentors the advantage of being able to provide more differentiated instruction specific to individual team needs. Another goal is to ensure that our students are learning both task and team functions, which will promote not only a higher quality product, but a more satisfied team.

**Teamwork Exercises as Teams Move through Project Phases**

**Forming Phase**

During the forming phase the curriculum focused on forming 1) an understanding of the project, 2) needs of the client, and 3) the team. The team building exercise, Rope Geometry, required the team to build a geometric shape while blindfolded. The goal of the exercise promoted initiating and communicating to successfully build the geometric shape. This exercise created a situation in which students relied on their ability to develop a communication network in order to operate effectively as a team.

Lacking information about each other, the team focused their energy on task functions. Nearly 75 percent of the observations, shown in Figure 1, were attributed to task functions with an emphasis on initiating, followed by an exchange of information. Teams forged a network of information exchange to clarify issues. Over 35 percent of the observations occurred in the area of information seeking and giving. These

![Figure 1: Distribution of Task and Team Functions during the Rope Geometry Exercise](image-url)
interactions resulted in clarification activities (another 15 percent) necessary to achieve the goal of the exercise (and project). Clarifying also kept members in touch with each other’s progress. The observations highlighted the need to build a communication network within the team.

This exercise demonstrated that the traditional engineering focus on task functions needed to be enhanced with an equal attention to the team’s cohesion. The exercise provided a tool early in the semester to discuss with students the importance of team functions during the design process.

**Storming Phase**

The second phase of the project evolved as the team began to feel comfortable with each other and to storm. Storming activities generated options and clarified specifications for the project as well as identified team strengths and weaknesses. During this phase, team building and project development occurred simultaneously as team members grew less timid and began to voice their opinions and to compromise. Although no exercise was performed for the purposes of this study during this phase, it is a vital part of team and project development. The team is beginning to identify strengths and delegate responsibilities, essential team functions. They are also researching alternative options for the project, essential task functions. Much of the curriculum during this phase is composed of research and of activities that prompt the students to share opinions and options and to become involved in team discussion. During this phase it is not uncommon to see students ‘trying on’ various team roles.

**Norming Phase**

During the norming phase, curriculum highlighted a balanced analysis of 1) individual systems, 2) system components, and 3) systems integration. The timing coincided with the start of the implementation phase of the project, when teams addressed design issues associated with subsystems. The Atomic Popcorn exercise reinforced values of integrating individual skills into the team’s design strategy. Teams not only planned but also used their unique skills to meet the goal of the exercise. The exercise, however, required a great deal of harmony and gate keeping working the ropes and elastic band necessary to transfer the popcorn.

Team dynamics changed as teams settled into a normal routine. Task functions (65 percent of the observations) with an emphasis on initiating dominated the teams’ attention, as depicted in Figure 2. The exchange of information decreased, possibly indicating an increase of trust among team members. Team functions increased to 35 percent of the total observations. Team members devoted more time to harmonizing and encouraging each other as they worked to remove the toxic popcorn.

![Figure 2: Distribution of Task and Team Functions during the Atomic Popcorn Exercise](image-url)
Moving from the forming to the norming phase, the team expects everyone to pull their own weight and in doing so enhance the ability of the team to be successful. We observe significant decreases in information seeking ($\alpha=0.05$, $P<0.00$), clarifying ($\alpha=0.05$, $P<0.01$) and summarizing ($\alpha=0.05$, $P<0.02$) that suggest a greater confidence in team members to use their unique skills in the solution of the problem. Team members trust that other members competently perform the responsibilities of their position. This confidence carries over into the project as team members approach the integration of their systems. We observe a significant increase in encouragement ($\alpha=0.05$, $P<0.04$), an important function to team unity. These observations characterize reliance and confidence within the team. The exercise, which requires each team member to operate as an individual but as an integral part of the team, demonstrates that the consequences of each member’s commitment contribute to the outcome of the project. If a member threatens this relationship, the consequences can be disastrous to the member or to the team.

**Performing**

The performing phase concluded the project life cycle. Teams brought together all the components to showcase their product. They worked together to 1) complete the design report, 2) assemble the graphics portfolio, 3) construct the prototype and 4) prepare the market presentation. By the end of the project, teams performed with little guidance from the mentors. Teams ended the semester playing Jenga against other teams. To construct the tallest structure within the time constraint, each member responded to the exercise quickly and efficiently to assure timely decision and smooth movements.

Teams on average exhibited a balanced distribution of task and team functions. Emphasizing information seeking, 55 percent of observations were task functions. Team function, (45 percent of the observations) highlighted the significance of encouragement as observed frequently when teams approach the end of a successful project. We observed a balance of task and team functions, displayed in Figure 3. Team performance during this phase of the project relied on the plan. If the team adequately developed the plan, they supported each other as they implemented the plan.

As teams moved into the performing phase, they significantly changed their mode of operation. The need for initiation dramatically decreased ($\alpha=0.05$, $P<0.09$), while information transfer including clarifying and summarizing significantly increased ($\alpha=0.05$, $P<0.01$ for all). Teams concentrated much of their attention on team unity, recognizing the need to work together to be successful at both the exercise and the project. We observed significant changes ($\alpha=0.05$, $P<0.02$) in all team functions as teams moved from the norming to the performing phase.

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*Figure 3: Distribution of Task and Team Functions during the Jenga Exercise*
Summary

The three exercises complement the content of the course and help students to visualize the value of balance between task and team functions. The distribution of functions for each exercise, illustrated in Figure 4, demonstrates the progression toward a balance of functions as the project evolves. Moving from forming to performing, we observe a significant decrease in initiating functions ($\alpha=0.05$, $P<0.01$) and a significant increase in information giving ($\alpha=0.05$, $P<0.00$). Although confirming the obvious, all team functions increase significantly ($\alpha=0.05$, $P<0.00$) except gate keeping, which commands the attention of teams throughout the semester.

The exercises also provide mentors with a resource to convey essential engineering design methodologies that are vital to many disciplines. Some examples include the need for compromise, communication, delegation of responsibility, and commitment. Partaking in these exercises gives mentors an opportunity to observe team interaction and can provide chances to identify a team in crisis. It should be noted that students appreciate, and should be told why they are participating in the exercises and the relevance of the exercises both to the development of the project and to the development of their teams.

As teams progressed through the project they maintained a high regard for the activities necessary to generate a quality project for the client. In general, teams developed a useful decision making methodology through a communication network of information transfer. They recognized the value of fostering team unity through activities that engaged and supported these team decisions.

Production of a quality product and team satisfaction depends on a balance of both task and team functions. The rope geometry introduces teams to the value of assuring that all members participate in the process. As the team divides the work into individual pieces, team members develop norms, conducting their individual research and integrating the results into a quality product. The atomic popcorn exercise reinforces the importance of initiating action and information transfer with greater emphasis on supporting and encouraging each other. Members support and encourage each other to develop this quality, ensuring satisfaction. By the end of the semester, team performance relies on a balance of task and team skills, reinforced by their performance during the Jenga exercise. The series of exercises underscores the balance of task and team functions and documents progress throughout the semester.

These data promoted our hypothesis that team dynamics change throughout the duration of the project. They further supported the contention that student teams required almost the entire life cycle of the project to develop a balance of task and team functions. Several authors asserted

![Figure 4: Change in Task and Team Distribution during Teamwork Exercises throughout the Semester](image-url)
that this balance was key to the success for these teams. On average, teams demonstrated this balance at the completion of the performing phase of the project.

Future Studies

We should have an observer assess teams’ attention to task and team functions during an exercise such as the “brainstorming” exercise. This study would document team behavior for technical activities that take place during the project. In addition, the findings would inform the integration of team process into the design process.

We propose to continue the research by identifying teams that are successful or that disintegrate during the project. Since some teams may not have achieved this balance, we should assess the relationship between team performance and the distribution of task and team functions. The intent of the research would be to correlate the success or failure of a team to their ability to work as a unit.

Bibliography:

5. Tuckman, B.W., (1965), Developmental Sequence in Small Groups, Psychological Bulletin, 64, 384-399
Biographical Information

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Robert Knecht’s 23 years of experience in the engineering industry focuses on technical and management support for minerals, energy and waste projects. He currently directs an engineering design program based on a curriculum that focuses on projects from industry. His projects require students to implement a design methodology in teams to solve open-ended problems and to communicate these solutions both in written and verbal forms.

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