Development of a Protocol to Measure Team Behavior in Engineering Education

Stephanie G. Adams, Carmen R. Zafft, Maria Carolina Molano, Kumar Rao

University of Nebraska Lincoln

Introduction

In recent years business publications and corporate recruiters have reported that businesses are increasingly looking for college graduates who work effectively in teams. However, employers report that engineering graduates--although astute and well-prepared technically--lack the ability to function effectively in teams. Consequently, educators in engineering face the new challenge of providing students with the necessary management skills in the context of team activities. As a result, the identification and measurement of team behaviors in engineering education are necessary. The identification of team behaviors will provide the appropriate teaming activities for students to develop teamwork skills.

Despite the well-recognized significance of team behavior in team effectiveness, few studies have examined behaviors specific to teams in engineering education. Instead, studies have focused on team behaviors in environments such as, the military (14, 10) and business organizations (12, 16). Although these studies provide useful information in measuring team behavior, they measure teams with different characteristics and compositions than those found in engineering educational environments. The lack of a well-developed team behavior measurement tool for engineering education makes it difficult to understand the team process. Measurement techniques in this area are necessary for the assessment and implementation of effective teaming skills. Therefore, a fundamental gap remains in the understanding of team behaviors that affect team effectiveness in engineering education.

In this project, the researchers set out to develop a protocol to measure team behaviors in engineering education. The objective of this paper is the result of the attempt by the researchers to observe teams in the engineering classroom. The focus is the development of the protocol to measure team behavior and lessons learned from implementing this protocol in the engineering classroom.

In summary, this project was primarily created for the following reasons:

- The Criteria 2000 of Accreditation Board of Engineering and Technology. ABET has asked United States engineering programs to modify their curriculum to teach teamwork skills in the classroom.
- Increase in the need of engineering students who are prepared to work in teams in the engineering industry.
- The need to develop a protocol to measure team behavior in order to assist engineering educators in identifying team behaviors that will be useful in teaching teamwork skills in the classroom.

Observing Teams in Education

Role of Observation

Observation has been widely used in education as a tool to assess teacher performance and teaching techniques. Classroom observation is an intentional, methodical process that is planned and focused (8), and has been classified as the foremost method for gathering data regarding teaching and teachers' behavior. Because observation has the capacity to disclose the climate, compatibility, interactions, and operations of the classroom, which are available from no other source (5), observational assessment is frequently used singularly or with other assessment techniques.

Two types of observation techniques were considered for this project. The first type is direct observation which studies an event, institution, facility or process in its natural setting (9). This approach provides a richer understanding of the subject. Kumar outlines an eight-step process to plan and conduct studies using direct observation. These steps include:

1. Determining the focus of the observation
2. Developing direct observation forms
3. Selecting the sites
4. Deciding on the best timing
5. Conducting the field observation
6. Completing the forms developed
7. Analyzing the data
8. Checking for reliability and validity

This general procedure can be applied to any field study when direct observation is utilized.

In addition to direct observation, indirect

observation was also considered. Indirect observation techniques include those in which the observer is not actively present or involved with the natural setting and development of the activity being observed. The observation is done with the use of instruments that allow the observer to record activities and further analyze them, such as the use of a video camera.

A combination of both techniques, direct and indirect observation, was chosen for the purposes of this project. Direct observation was used because the observer was actively present during the observation process. Indirect observation was also used through the use of a video camera. This technique was chosen so that the researchers could ensure the validity of the observation process by further analyzing the team activities.

Protocol to Measure Team Behavior

In determining how to develop the protocol to measure team behavior, the researchers looked to Kumar's (9) eight-step process to plan and conduct studies that use direct observation. Further description of each step follows, along with the action taken by the researchers for this project.

Step 1: Determining the Focus of the Observation

Teams in engineering education were the focus of the observation. In this project, it was proposed that by assessing the presence of the different constructs in a team through the measurement of behavior, the effectiveness of the team can be evaluated. The Effective Team Behavior Checklist would provide an assessment of the extent to which a team exhibits each of the seven team constructs.

Step 2: Develop Direct Observation Forms-Effective Team Behavior Checklist

Morgan, Glickman, Woodward, Blaiwes, and Salas' (14) study was used as a guide in preparing the Effective Team Behavior Checklist. In this study, the researchers defined two categories of behaviors that can be distinguished throughout the life of a team; task work and teamwork. They developed the Critical Team Behaviors form (CBT), used to record data during team observations. The study looked to develop a method to measure team behavior in a Navy environment. A brainstorming session with several naval instructors was conducted to identify a list of every possible behavior from previous training sessions. As a result 90 critical elements were identified and categorized within seven dimensions. Based on this, forms were developed which listed the effective or ineffective behaviors characterizing each dimension. During observations an x was placed under the name of every individual involved in a critical incident and an x surrounded by a circle under the individual who initiated it. Notes were taken when an external individual participated in the incident. This study observed that good teams tend to exhibit a relatively higher number of effective behaviors and a relatively lower number of ineffective behaviors than poorer teams.

This same procedure was used for this project in order to determine the behaviors to observe in engineering education teams. The observable behaviors were based on the constructs defined by the Team Effectiveness (TE) Model, developed by researchers from the University of Nebraska-Lincoln, Effective Teaming Lab (1).

Based on Adams'TE model, team behaviors are categorized into seven distinct constructs:

1. Common Purpose
2. Clearly Defined Goals
3. Psychological Safety
4. Role Clarity
5. Mature Communication
6. Productive Conflict Resolution
7. Accountable Interdependence

These constructs have been defined as characteristics a team should encompass in order to be effective and will be the foundation for the behaviors identified in the development of the protocol to measure team behavior. Definitions of each construct are provided below.

1. **Common Purpose** is the main objective of the team; understood and shared by all team members. Common purpose leads to the development of the team's goals.
2. **Clearly defined goals** are quantifiable and commonly agreed upon statements that define the actions to be taken by the team.
3. **Psychological safety** is the shared belief that the team is safe for interpersonal risk taking. An environment is created in which people are comfortable being themselves.
4. **Role clarity** is the team members' common understanding of each individuals expected role.
5. **Mature communication** refers to team members' ability to: articulate ideas clearly and concisely; give compelling reasons for their ideas; listen without interrupting; clarify what others have said and; provide constructive feedback.

6. **Productive conflict resolution** refers to the procedures and actions taken when a conflict occurs that lead to results such as: facilitating the solution of the problem; increasing the cohesiveness among team members; exploring alternative positions; increasing the involvement of everyone affected by the conflict and; enhancing the decision-making process (3).
7. **Accountable interdependence** is the mutual dependence that all team members have regarding the quality and quantity of each individual's work within the team.

Step 2.1 Detailed Development of the Checklist

The first step taken in the creation of the checklist was to develop a list of the effective behaviors that could be displayed by team members based on the seven constructs previously defined. The next step was to sort the behaviors under each of the seven constructs and eliminate those that were repeated. The remaining constructs were reworded and organized to ensure that all aspects of the definition of a construct were covered without redundancy.

Seven different forms were created with each listing the behaviors that represent one of the constructs. The forms are designed to allow each behavior to be rated as it is exhibited by each of the members of a team. The results will be given as a function of the behaviors exhibited by all the team members. This is achieved by having a matrix that included behaviors in rows and a team member in very column.

Space is also provided to record the discipline of each team member, the name of the person performing the observation, and the observation length, which are factors that can affect the results of an observation and should be recorded for analysis. A team code and observation number should be assigned to every team observed and to all observations performed, and recorded on the checklist in order to match the forms and the tape containing the team meeting observed. The last column in the forms of the checklist was provided as a space to calculate the results of every observation. Given the wide spectrum of behaviors that can be displayed it is possible that a behavior that describes a construct was not included in the corresponding form. Extra space was given in each form for these behaviors to be recorded if a rater finds any during an observation.

Step 2.2 Scale Development

In order to develop the scale, the researchers used a variation of the procedure used in the Pre-School Behavior Checklist (PBCL) (11). Using this procedure, the behaviors observed are described using four different choices. These include: not exhibited, somehow exhibited, highly exhibited, and non-applicable behaviors. Each was rated with 0, 1, 2 and N/A respectively. This type of rating is used because the behavior exhibited is a variable that depends on the frequency of the occurrence of the behavior. Using zero as a score would indicate that the team members lack the ability to exhibit this behavior when applicable. The non-applicable (N/A) score should be used to score behaviors that are not exhibited because the situation does not account for it.

Effective Behaviors for Accountable Interdependence	Member 1	Member2
1. Honestly expressed abilities, capabilities and limitations		
2. Completed a task by the time agreed		
3. Changed the way he/she performed a task if the team's needs required it that way		
4. Additional behaviors observed		
5. Additional behaviors observed		

Table 1: Behaviors for the Effective Team Behavior Checklist

Step 2.3 Scoring Methodology

After the scale to score the behaviors is defined, a method to calculate the final scoring should be determined. The main purpose of the score is to measure the extent to which each of the seven constructs is exhibited by a team. Taking this into consideration, the final score needs to be a result given for every team

Date:		Observer:	Team's Code:
Team Members	**Discipline**	**Starting Time:** **Ending Time:**	**Observation:**
1. *2.* *3.* *4.* *5.*			

Place a score under each member for behaviors listed below. Rate 0,1,2 or N/A for non-exhibited, somehow exhibited, highly exhibited and non-applicable behaviors respectively. Use the blank spaces to provide a description of other critical behavior that effectively show psychological safety and mark the boxes accordingly.

Effective Behaviors for Psychological Safety	Member 1	Member 2	Member 3	TOTAL
1. Used we not me or I when referring to the team				
2. Spoke out to propose an idea				
3. Encouraged another team member to voice their opinion				

Table 2: Effective Team Behavior Checklist

Effective Behaviors for Accountable Interdependence	Member 1	Member 2	Member 3	SUM	SCORE
1. Honestly expressed abilities, capabilities, and limitations	2	2	2	6	2
2. Completed a task by the time agreed	NA	NA	NA	NA	NA
3. Changed the way he/she performed a task if the team's needs required it that way	0	1	0	1	0.333

Table 3: Example of Score Calculation of Single Observations

in each of the constructs. Each team observed will have seven different scores. Since each of the seven checklist forms lists a different number of behaviors, depending on the construct, it was decided to assign the final scores in terms of percentages to keep all seven scores in the same scale between 0-100%.

To obtain the results of a single observation, the rates (0, 1 and 2) should be totaled for each behavior. In this manner a sum will be obtained for every behavior (row) in each of the seven forms. The score for every behavior is obtained by dividing the sums by the number of members in the team. Behaviors that were rated N/A should be assigned a total score of N/A.

Once all observations have been performed, it is necessary to summarize all the scores recorded in each observation using the Score Calculation Sheets. One of these sheets should be used for every team and each construct.

Step 2.4 Select Research Sample/ Participants

The Effective Team Behavior Checklist is most useful for teams of approximately three to five people. It is not recommended for teams of five or more members. To determine the number of teams to observe there are two options. The first is to observe all teams for one or two meetings, determine the variation and select the sample size depending on the variation of this data. This method could prove complicated if the population is too large. It is also possible to study three or four randomly selected teams. If the results obtained have a very high variation and all teams' exhibit very different traits it is necessary to increase the number of teams being observed. In the same manner, if the traits exhibited are similar and the teams selected seem to represent the behavior of a whole population fairly well, working with three teams should be sufficient (13).

For this project engineering students enrolled in an engineering management course were asked to voluntarily participate. The participants were grouped in five teams of three to four members.

Step 3: Select the Site

When selecting the site, the natural setting where the team will most likely be encountered should be taken into consideration. It is important to consider how the environment affects the team's natural development and which environment provides the conditions that are closest to what the study intends to observe. It is important that the site selected reflects a typical case and represents the real conditions in which the team would usually meet.

Step 4: Decide on the Timing

It is important to select the right timing for observations to take place. Wrong timing can distort findings given that the teaming experience is a process and the conditions and characteristics of a team vary as it goes through different stages. In general, it is recommended that teams be observed throughout the whole process because the type of behaviors team members' exhibit tends to be a reflection of the developmental stage the team is going through. Observations should be able to reflect these changes.

It is important to organize a schedule for the observations making sure all team members agree to it. The ideal way to decide on times is to plan observations each time the teams plan to meet. When considering the length of the observations, take into account that the observation may have some effect on people's behavior. Longer observations offer the opportunity for people to become less self-conscious and gradually start behaving naturally.

Step 5: Conducting the observation

The following is a brief description of the methods that should take place when conducting the actual team observation:

- Arrive at the observation site at least an hour early to perform setup of the equipment, along with test shots to ensure that the video camera is properly set up and working correctly.
- If using a video camera, set up an external microphone. Check the videocassette and the battery and make sure to have a

replacement for both in case changes are necessary during the observation.
- Fill out the information forms.
- In front of each of the team members' number write a single unique characteristic of the person. This will allow you to recognize each team member during the observations.
- Fill out the team's code and observation number on the top left side of the form. Make sure you mark the videocassette with the team code and observation numbers to be able to match the observations with its corresponding forms later in the analysis.

Begin to record as team members arrive. Attempt to be as unobtrusive as possible, allowing the meeting to flow naturally. Do not interrupt the meeting; restrict yourself to making sure all equipment is running as expected. If any problems occur with the equipment try to solve it with the resources you have available without interrupting. Remember the less conscious team members are of an observation taking place, the more naturally they will behave. While videotaping, the observer should pay attention to the events taking place in the meeting. Having an idea of what occurred during the meeting will make it easier to complete the forms later while watching the video. Once the meeting is resumed, the observer should provide some feedback to the team members, confirm their next meeting, and thank them for their cooperation.

Data Collection Procedure

For this project the five teams were videotaped during two of their group sessions. Three different raters followed the procedure given in the protocol to observe all ten of the teamwork sessions. Each rater used the Effective Team Behavior Checklist in identifying behaviors. Each observation performed included scores for each team member. Raters conducted the observations individually; information was not shared among the raters during the process.

Step 5: Complete forms

To fill out the checklist, complete one form at a time. Each observer/rater should be provided 7 forms for each construct to complete for each team member. Before each form is completed, the observer should first read through the definitions of the constructs corresponding to the form that will be completed. Having a clear understanding of the meaning of the constructs allows the observer to detect any relevant behaviors related to the construct that might not be listed on the form. If any, the observer should note them in the extra room provided or on the back of the form if more room is required.

Next, the videotape should be played while the observers complete the Effective Team Behavior Checklist. Data should be collected in a quantitative way that allows the calculation of results from which it is possible to draw conclusions. While observing the videotape the observer should assign a 1 once a behavior is exhibited. If the member seems to show this behavior consistently throughout the observation, a 2 should replace the 1. It is important to understand that the consistency of a behavior depends on the kind of behavior that is being rated.

In general, each behavior is rated in terms of the frequency with which it is exhibited in relation to the specific situation or observation. It is important for the rater to determine when a behavior should be exhibited as well as the criteria by which the behavior is rated according to its frequency. This is only possible if the rater understands the underlying concepts of each construct and the way each behavior contributes to its definition.

The seven forms can be completed at once but the observer needs to be cautious. While this strategy may seem more efficient, it requires the observer's attention of many factors at the same time. This reduces the level of awareness of the observer on each specific item and results in a higher chance of missing relevant behaviors during the observation. Make certain to rewind the tape and watch it as many times as necessary for the observer to be comfortable and secure with the scores provided.

Step 7: Analyze Data

The results provided by this checklist are percentages relative to each of the seven constructs. These percentages represent the extent to which each of the seven constructs is present in a team. For example, 70% of the students who score in mature communication indicate that there is still room for improvement in this area. The tool can be described as an assessment of the extent to which each of the seven constructs is present in the team based on what is exhibited by the team member's behavior.

Step 8: Check for Reliability & Validity

An assessment of the reliability of this tool was conducted through a pilot study in which three raters observed five teams of three and four members from an engineering management course. A total of nineteen individuals were observed for two different tasks. The inter-rater reliability rate was calculated as the most representative estimate of reliability for this type of instrument. Using Cohen's Kappa coefficient, the statistical analysis was designed in order to consider the different variables present in this

Effective Behaviors for Common Purpose	Observation 1	Observation 2	Observation 3	SUM	SCORE
1. Agreed on a main purpose for the team	2	2	NA	4	2
2. Questioned what the main purpose was when not clear about it	0.333	NA	1	1.333	0.667
3. Stated how a task relates to the common purpose of the team	0	0.333	0	0.333	0.111
4. Exchanged ideas to reiterate and make sure there is a clear understanding of the common purpose	0	1.667	2	3.667	1.222

Table 4: Final Score Calculation Example

TOTAL SUM	4
AVERAGE	1
TOTAL SCORE	(1X100)/2
FINAL RESULT	50%

scenario. The findings resulted in a 62% inter-rater reliability. According to Creswell (4), acceptable rates should be above 80%. Because of the low rating, the raters and the researcher convened to discuss the findings and uncover the hindrances of the tool.

Having the Kappa values for each of the items in the checklist allowed the raters and researcher to identify the problematic items and approach them individually. Reasons for discrepancies in the ratings were identified and improvement methods were proposed. The outcomes of this discussion are presented below:

- The tasks assigned to the teams were not substantial enough for the team members to exhibit most of the behaviors.
- It was difficult for raters to identify the behaviors within the teams and interpretation of the behaviors varied amongst the raters.
- The raters justified low scoring because what they expected to see from an effective team was not exhibited during the sessions.
- Raters did not have a clear understanding of how to proceed with the ratings due to a lack of a clear definition of each of the behaviors that allowed them to interpret and relate the behaviors observed with those listed in the checklist.

In the development stage of an instrument, items with 50% proportion of agreement or below are considered problematic. The results showed that one in eighteen items were problematic for the first observation, while in the second observation only seven were. Raters agreed that after the first two or three observations, rating the behaviors became simpler and scores were more consistent. Results show higher Kappa values for the second observations with an almost 10% increase in reliability rates between the first and second observations. These findings suggest that practice and training are a determining factor for the improvement of inter-rater reliability.

What Engineering Educators Should Know

Measuring behavior should be an important aspect of establishing team effectiveness. However, it can be a very cumbersome undertaking. First there are no universal instruments available for use by educators to capture behavior. So unless an educator shares the previously defined definition of team effectiveness they will need to start anew and follow a procedure such as the one identified. If they subscribe to a similar definition then this work provides a foundation for observing teams.

Educators should also know that measuring behavior using established methods such as observation are very time consuming activities. Observation is also a very costly option. One must have high-end, often expensive equipment (video cameras, computer equipment, software and microphones), special lighting and sound sensitive rooms in which to conduct observations. Direct observation is susceptible to observer bias and the very act of observation can also affect the behavior of those being studied. For instance, the Halo Effect (7) is the tendency to evaluate based on the overall positive impression the observer has of the subject from previous experiences. When the subject is scored negatively given the observer's overall impression, the error or source of bias is called prejudice. Another example is the Heisenberg Principle. This principle is when a distortion of a measurement is created with intrusion. This occurs when the act of measurement alters what is being measured (15). Lastly, the Hawthorne Effect could also come into play. The Hawthorne Effect found that workers productivity tends to improve or increase as they receive attention from the researchers who express an interest in them (6).

Measuring behavior is also labor intensive. First any individual who will rate the team should be trained to identify the behavior one is looking for to ensure consistently amongst the

behaviors observed. Without training the raters may end up with different definitions of the behaviors and how they should be interrupted. Most discrepancies are due to the raters' differing interpretations given the lack of common definitions and training. In addition to providing training for raters they should also be allowed to perform practice observations before the actual rating.

Conclusions

This project produced the Protocol to Measure Team Behavior, along with the Effective Team Behavior Checklist - both with the objective to measure team behaviors in engineering education. From the work done up to this point, these final conclusions can be offered. Initial testing of the tool shows that it is not reliable given its low inter-rater reliability rate. This limits the usefulness of the tool at this time. Nevertheless, the tool is in its initial stage of the developmental process. Implementing the changes previously suggested is expected to improve the reliability of the tool and make it useful for engineering education. It was found that the discrepancies in the interpretation of the team behaviors' definitions were identified as the main cause for observer's disagreement. Training was identified as a remedy to improve the reliability of this instrument and is the next logical step in the development process of this tool.

Overall, this project presents a great advancement in the development of a tool to measure team behavior in an educational setting. It also offers results that show the way to improvements and future work that should produce a useful and reliable tool for engineering education.

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Dr. Stephanie G. Adams is currently the Associate Dean for Undergraduate Education in the College of Engineering and an Associate Professor of Industrial and Management Systems Engineering at the University of Nebraska-Lincoln (UNL). She received her Ph.D. in Interdisciplinary Engineering from Texas A&M University in August of 1998. Dr. Adams is an honor graduate of North Carolina Agricultural and Technical State University, where she earned her BS in Mechanical Engineering, in 1988. In 1991 she was awarded the Master of Engineering degree in Systems Engineering from the University of Virginia. Her areas of concentration were Industrial Engineering and Management. Her research interests include Team Effectiveness, Collaborative and Active Learning, Engineering Education and Pedagogy, and Quality Control and Management.

Carmen R. Zafft is currently a Trainer and Curriculum Designer for a financial services company in Omaha, NE. She received her M.S. from the University of Nebraska-Lincoln in Leadership Education. She holds a B.S. in Criminal Justice from the University of Nebraska-Lincoln.

Maria Carolina Molano is currently a Senior Supplier Process Engineer for Abbott Diabetes Care in Alameda, California. She received her M.S degree in Industrial and Management Systems Engineering and a B.S. degree in Industrial Engineering from the University of Nebraska, Lincoln.

Kumar Rao is currently the Director of Panel Analytics at the Gallup Organization in Omaha, NE. He holds a M.S. degree in Survey Research and Methodology from University of Nebraska, Lincoln, a M.S. degree in Industrial Engineering from Wichita State University, and a B.S. degree in Industrial Engineering and Management from Bangalore University, India.