Session 2330

Assessing Team Functioning in Engineering Education

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Abstract

The present study used a series of team process checks modeled on those developed at Arizona State University to assess team functioning. Team members completed these forms individually and then collectively the members assessed the team as a whole. These process checks were compared to faculty ratings of the teams. The students' individual knowledge about teaming skills was also assessed and the relationship of these various measures to performance was examined. Two distinct dimensions of team functioning appear to be measured by the team process check: agency and affiliation. The process checks were positively correlated with faculty ratings, and the agency dimension of the scale predicted team project scores in one of the classes evaluated but not in the other two.

Introduction

With the growing prominence of the use of teams in education and business, the need for systematic, well-validated assessment of team functioning is clear. Previous assessment efforts have ranged from hastily constructed and poorly validated instruments to rigorously developed and empirically tested assessment processes. The difficulty with several of the better constructed and empirically validated systems such as those suggested by Cannon-Bowers and Salas[1] is that they are so complex and comprehensive that they become impractical in anything but the most rigorous and resource-rich environments (which universities often are not). The present study pursued the less ambitious, but perhaps more practical, goal of attempting to develop and validate a relatively simple self-report instrument, The Team Process Check (TPC), for assessing the functioning of teams in an educational setting.

A number of researchers within the engineering field have been working on defining outcomes in teaming and developing multi-source feedback systems[2,3]. These researchers point out that many of the assessment instruments in use in engineering education have not been well validated. They suggest what they refer to as triangulation or multiple measurements of an outcome to begin to improve the validity of the assessment process. McGourty and De Meuse[4] propose a four-dimensional model of team behavior (collaboration, communication, conflict management and self-management) and use a 24-item self-rating scale to assess these theoretical dimensions. Data

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are being collected in a number of settings to explore the relationships among this and other methods of measurement of team behavior[5]. Thompson[6] identified six core team skill areas and used peer ratings of these areas to demonstrate changes in team skills over time.

Often the dimensions of team functioning that have been assessed in prior research have been rationally defined rather than empirically verified. Our goal was to develop an instrument that could provide differentiated feedback on two general dimensions of team functioning, agency and affiliation, and to establish the empirical validity of such an instrument. These two dimensions have repeatedly surfaced in the teaming literature[7]. Furthermore, agency measures appear to be better correlated with performance than affiliation measures[8]. Thus, we revised the Team Process Check, developed at ASU, so that each item apparently measured only one dimension and so that there were an equal number of items on each dimension. In addition, we reversed approximately half of the items to prevent students responding the same way to all questions.

Pilot research revealed two possible problems that appeared to limit the effectiveness of our assessment strategy[9, 10]. First, our students were not sufficiently motivated to engage in the assessment process. Although the participating faculty were supportive of the process, the students tended to see it as separate from their engineering education. Second, it appeared as though the students simply did not understand enough about teaming to answer in any meaningful way. If students do not understand that there is such a thing as team process, they can hardly be expected to give differentiated responses, and the responses they give may be largely focused on the social environment of the team. Information about effective team behavior and/or team training might help to clarify the constructs to the point where self-assessments would be more likely to produce accurate evaluations.

In the present study, the faculty teaching introductory engineering courses agreed to incorporate the team assessments into the course structure and points were allocated to the students for completing the assessments in a thorough manner. Likewise, a team training website was developed and reading assignments were given to the students. The site was developed to provide a cognitive framework from which the students could provide more meaningful self-assessments. We anticipated that our first round of assessments, which were conducted prior to reading the team training material and prior to any substantial team experience, would yield weak, ambiguous and perhaps somewhat inflated self-assessments, consistent with our pilot data. We also expected that the increased knowledge and awareness provided by the training material and increased experience would produce more meaningful and more accurate self-evaluations at the second and third assessment periods.

Method

Subjects

The sample was comprised of 118 predominantly male undergraduate students enrolled in the freshmen engineering program at the University of Massachusetts Dartmouth. These students were configured into 32 teams of 3-4 members. The students met in these teams in their physics, math, and engineering classes throughout a semester, but they were assessed in the engineering classes only.

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Measures

Teamwork Knowledge Test (TKT)

The Teamwork Knowledge Test was developed by the researchers and was loosely based on the format used by Stevens and Campion[11] for their Teamwork KSA Test. The current test, however, was designed to be suitable for use with an undergraduate college population rather that an industrial or corporate population. The test consists of 21 multiple-choice items constructed to assess individual knowledge regarding a variety of teaming issues. The correct answers to all of the questions appear in the team training website. Each student was asked to complete The Teamwork Knowledge Test prior to any of the assessments and prior to exposure to team training materials. The students were then asked to complete the test again at the end of the semester, after exposure to team training materials and their team experience.

Team Process Check (TPC) (see Appendix A)

Each team member was asked to fill out Team Process Checks modeled on those developed at Arizona State University, but substantially modified after pilot testing indicated important empirical weaknesses. The TPC consisted of a 20-item scale assessing a team member's evaluation of his/her team's functioning across a number of domains (e.g., communication, task management, etc.) using 5-point rating scales ranging from *never* to *always*. The measure was constructed to cover two broad dimensions of team functioning, namely team agency and team affiliation. The team agency dimension attempts to assess areas such as team process and team decision making. The affiliation dimension is intended to assess interpersonal functioning, particularly communication and conflict resolution. Preliminary item analysis of the TPC administered during the first assessment period led us to include 2 additional items to the scale; therefore, the TPC at time 2 and time 3 consisted of 22 items. The process check also included a free-response section completed by the team as a whole in which the team was asked to indicate the one thing that their team does best, the one thing they would most want to improve in their teamwork, and one thing that the team could do to bring about that change. The TPC was administered three times during the course of one semester (t1, t2 and t3).

Faculty Ratings

At the end of the semester the faculty members teaching the engineering classes were asked to evaluate each of the teams on several dimensions of team functioning similar to the team process checks. The faculty used 5-point scales ranging from *never* to *always* to evaluate the teams on these dimensions.

Procedure

The time-line of the procedure was as follows:

1. TKT pre-test (administered on-line during first month of classes)
2. TPC t1 (administered in class at end of the first month of classes)

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3. Assignment 1 of team training material posted on a website (assigned at beginning of second month of classes)
4. Assignment 2 of team training material posted on a website (assigned at the end of second month of classes)
5. TPC t2 (administered in class at the beginning of the third month of classes)
6. TPC t3 (administered in class at end of the semester)
7. Faculty Ratings (provided by faculty at the end of the semester)
8. TKT post-test (administered on-line at the end of the semester, with some students completing on paper at the final exam, due to a glitch with the web administration)

Results

Team Knowledge Test (TKT)

Means and standard deviations for the TKT pre-test and post-test can be found in Table 1. The results show the students scoring on average between 70%-80%, suggesting a marginal command of the teaming issues being assessed. The results did show a statistically significant increase in TKT scores from pre-test to post-test (t (1, 70) = -5.02, $p < .01$). A factor analysis of the scale items failed to produce any meaningful factor structure.

Table 1. Means and standard deviations of assessment measures.

Type of assesment	Time	Mean	Std. Dev.	n
TKT	pre-test	14.99	3.13	87
	post-test	16.61	3.12	89
TPC	time 1	3.66	.50	116
	time 2	3.49	.53	91
	time 3	3.51	.49	91
	average over three times	3.55	.45	118
Agency	time 2	3.29	.60	91
	time 3	3.27	.59	91
Affiliation	time 2	3.51	.54	91
	time 3	3.55	.50	91
Faculty Ratings		3.94	.66	118

Team Process Checks (TPC)

The means and standard deviations for the TPC t1, t2 & t3 can be found in Table 1. In this paper we will report only the analyses of the closed-end data; we will report the free-response data at a later time**.** The mean scores ranged from 3.49 to 3.66, suggesting a reasonable self-assessment and a moderate level of team functioning. As expected, the results indicated what might be considered somewhat inflated self-evaluations at t1 with the mean score significantly higher than at t2 or t3 (t (1, 87) = 4.44, $p < .01$ and t (1, 87) = 3.84, $p < .01$, respectively). The mean scores at t2 and t3 were not significantly different from one another (t (1, 78) = -1.10, $p > .05$).

An exploratory principal axis factor analysis with varimax rotation was performed on the 20 items of the TPC t1, which yielded no distinct factors. The same analysis was performed on the 22 items of TPC t2. The analysis yielded 6 factors with eigenvalues over 1, explaining 63.8% of

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the variance after rotation. Then the number of factors was constrained to two in the attempt to verify the capability of the questionnaire to depict the two dimensions of agency and affiliation as intended by the researchers. After excluding nine double loading and weak loading (< .3) items, the analysis yielded two factors, which explained 42.48% of the variance after rotation (see Appendix A).

The exploratory factor analysis performed on the TPC t3, yielded 5 factors with eigenvalues over 1, explaining 59.2% of the variance, after rotation. When the number of factors was constrained to two, and after excluding nine double and weak loading items, the explained variance after rotation was 42.2%. This procedure resulted in one 6-item agency subscale and one 7-item affiliation subscale (see Appendix B). The two factors were similar to the factors found on TPC t2, but the TPC t3 structure was chosen because the factors were more conceptually clear. The subscales showed adequate reliability with alphas of .72 and .72 for agency and .76 and .72 for affiliation, at t2 and t3, respectively. Their intercorrelations are shown in Table 2.

Table 2. Intercorrelations of factor scores on TPC

	Agency t2	Affiliation t2	Agency t3	Affiliation t3
Agency t2		.64**	.65**	.35**
Affiliation t2			.43**	.64**
Agency t3				.51**

** p < .01

Faculty Ratings

The mean and standard deviation of the faculty ratings can also be found in Table 1.
The mean faculty rating was 3.94, which is moderately high and somewhat higher than the students' self-evaluations using similar dimensions and also using a 5-point scale.

Correlations

For the purposes of validation, correlations among the TPC, the TKT and the faculty ratings were calculated. Significant correlations were found between TPC t1, TPC t2 and TPC t3 and the faculty ratings provided at the end of the semester (r (109) = .39, p < .001; r (88) = .29, p < .01 and r (87) = .3, p < .01, respectively). The only significant correlations between the TPC and the TKT were found between the pre-test TKT and the TPC t2 and TPC t3 (r (73) = .29, p < .05 and r (87) = .27, p < .05, respectively). The TKT was not correlated with the faculty ratings.

The factor scales were significantly correlated with professor ratings (agency scales r (88)=.23, p <.05 and r (87) = .28, p < .01 and affiliation scales r (87)=.28, p < .01 for both times 2 and 3).

Outcome

A series of analyses were conducted to explore the relationship between team functioning and outcome, as measured by scores on team projects that were completed by the students at the end of the semester. The project scores for one of the three classes were significantly lower than for either of the other two classes, F(2,102) = 35.63, p < .01, and therefore the analyses performed with these scores were performed separately for that class and aggregated for the other two.

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For the two aggregated classes, the team project scores were significantly correlated with the faculty ratings r (52) = .36, p < .01. In the other class, the correlation between project scores and faculty ratings was not significant; however, the correlation between the team project scores and the TPC Agency factor on t2 was significant r (25) = .42, p < .05.

Regression analyses were performed for the single and combined classes to examine how well the two factors, Agency and Affiliation, TKT and faculty ratings predicted performance on the team projects. A hierarchical regression with four blocks was performed with team project scores as the predicted variable. The variables in each block were in sequential time order. Therefore, block one was Pre TKT, followed by block two TPC Agency t2 and TPC Affiliation t2, block three with TPC Agency t3 and TPC Affiliation t3, and block four with TKT post-test and faculty ratings.

The regression model was not significant for the combined classes, F (7,49) = 1.16, p = ns. However, the second block approached significance for the single class, with an R^2 of .34, F (3,18) = 2.61, p = .09. The TPC agency factor at t2 positively predicted the project scores, beta = .94, p < .05.

Discussion

The use of self-report assessments, while certainly limited, can provide a simple and economical means of obtaining useful insights into the functioning of student teams. This study offers evidence supporting the efficacy of one such measure and suggests a possible process by which measures such as these may be incorporated into an ongoing system of team training and assessment.

The Team Process Check assessments in this study were positively correlated with faculty ratings of the teams, providing evidence supporting the validity of the scale. The TPC also yielded two meaningful factors, one that appears to assess what may be termed the team's sense of agency or ability to get the job done well, and the other an affiliative or interpersonal factor, including communication and conflict resolution. The results regarding the prediction of team performance as measured by team project scores present a mixed and somewhat inconsistent picture. The assessment of affiliative interpersonal functioning did not predict performance in this study, which is consistent with the findings of Carless & DePaola[8]. The self-assessment of agency was predictive of outcome for one of the classes studied but not for the other two. Likewise, faculty ratings predicted outcome in two of the classes but not the other. The reason for these differences is unclear; however, in the class where agency did not predict project scores, the mean project score was significantly lower and the range of scores was larger. The restricted range of scores in the other two classes may have substantially decreased the possibility of finding a relationship between the TPC and project scores. In addition, the lack of correlation between the faculty rating and the project scores in the single class may be suggesting that the professor in that class was somehow scoring the projects differently than the other professors, and specifically scoring them irrespective of the team functioning. These are, of course, speculations and a more in depth analysis of the differences in scoring would be required to draw substantive conclusions. It is also worth noting that project scores are probably a weak

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measure of the outcome of teaming since they measure multiple aspects of course work in addition to the effectiveness of the team functioning.

The results of this study compared to our pilot research suggest that providing a motivational and a cognitive structure for the team members may have an important contextual influence. Since both factors were changed together in the present study, however, it is impossible to determine which of these factors was most influential or how they might interact. There does, however, appear to be an important lesson here for both researchers and educators, which is that providing an incentive and some cognitive understanding is necessary for engaging the students, improving their ability to adequately self-reflect and improving the validity of the assessment process.

Although the present study provides some evidence that these students are in fact functioning as they report they are, additional work also needs to be done to further validate the TPC. Corroborating evidence might be gathered through the use of direct observations of the teams or coded videotapes, for example, to support the validity of the instrument. The use of these methodologies can also provide subtler and more in-depth analyses. The use of multiple sources of information did not improve the prediction of outcome in our sample, but that does not preclude the usefulness of such a strategy. For example, we did not assess team members' individual self-evaluations or their evaluations of other team members. These sources of information may have improved our predictive capabilities. The work of Besterfield-Sacre et al[12] and others has begun to explore this possibility. The TPC is a simple, inexpensive, and user-friendly tool, but it is limited in its scope.

What is essential in any case is that the assessment tools employed by educators be well validated. Only well validated measures can produce useful assessments. Initiating improvement strategies on the basis of specious or questionable assessment data is unlikely to produce meaningful change. Only valid assessments as part of an ongoing assessment and training process can produce the continuous improvement educators seek.

The assessment of team functioning is a difficult, time consuming and expensive undertaking. The very nature of group process itself makes assessment complex. There are multiple forces in operation simultaneously at any given time. Defining, disentangling and measuring those forces is indeed complicated. One of the fundamental obstacles to achieving accurate and useful information about the teams that we have been studying involves the element of "buy-in" from both students and faculty. Students and faculty must have an essential conviction that team work and subsequently team assessment have value. To that end it must be demonstrated that the use of teams adds something to either the educational or work process, that successful team functioning leads to more successful team products, and that the assessment process itself can support the effective functioning of teams. Certainly, the literature is replete with evidence on the usefulness of teams. The current research adds some evidence to support the notion that effective teams may create better products. Perhaps future research can explore the use of the assessment process itself as a tool for enhancing the functioning of teams as part of an ongoing continuous improvement loop.

Efforts have been underway at a number of engineering campuses to use assessment as an intervention by making the assessment process an occasion for real discussion regarding change

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and improvement[13]. The functioning of teams may be enhanced by periodic meetings between the teams and the faculty, using an instrument such as the process check as the focal point for a structured conversation about the team in each of the areas assessed by the measure. The assessment process itself then becomes an opportunity for intervention and, therefore, real improvement. Systematic empirical verification of the efficacy of such a process presents an important avenue for continuing research.

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Appendix A
Factor Loadings for TPC t2 and TPC t3

items	TPC t2		TPC t3	
	factor 1	factor 2	factor 1	factor 2
10. We are careful to assign tasks to each of the team members when appropriate.	.39		.66	
18. My team can assess itself and develop strategies to work more effectively.	.63		.64	
11. My team tends to start working without an explicit plan.	.62		.63	
7. We have a difficult time staying focused and on track.	.45	.33	.55	
14. My team is able to generate potential solutions and evaluate them in an effective and systematic fashion.			.55	
13. Some people seem to do the bulk of my team's work.		.37	.35	
17. When conflict arises in the team, it is likely to be a battle, or at best, a waste of time.		.66		.66
2. When arguments break out, my team members are able to step back, calm down, and work out our differences.		.65		.64
19. As a team we find it difficult to accept criticism openly and non-defensively.		.55		.59
16. My team encourages differing opinions to be expressed.	excluded			.53
1. My team may agree on a solution but not every member "buys into" that solution.		.46		.37
4. My team members criticize ideas not each other.	excluded			.33
8. My team ignores conflicts among team members.		.35		.32
15. Our team operates according to clear rules.	.74		excluded	
21. When someone is struggling to express his or her ideas, our team helps to get the ideas out.	.63		excluded	
6. My team members have troubles expressing their ideas clearly.		.38	excluded	
9. My team members are clear about what is expected of them.	excluded			
22. We have difficulty completing our work efficiently.	excluded			
5. My team tries to get everyone's ideas before making a decision.	excluded			
3. My team members have difficulty listening to one another's ideas.	excluded			
12. My team members make helpful and constructive comments on other's ideas.	excluded			
20. We have a difficult time coming to decisions as a team.	excluded			

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Appendix B
Final Factor Structure

Agency	Affiliation
My team can assess itself and develop strategies to work more effectively.	As a team we find it difficult to accept criticism openly and non-defensively.
We are careful to assign tasks to each of the team members when appropriate.	When conflict arises in the team, it is likely to be a battle or, at best, a waste of time.
My team is able to generate potential solutions and evaluate them in an effective and systematic fashion.	My team encourages differing opinions to be expressed.
My team tends to start working without an explicit plan.	When arguments break out, my team members are able to step back, calm down, and work out our differences.
We have a difficult time staying focused.	My team members criticize ideas, not each other.
Some people tend to do the bulk of my team's work.	My team may agree on a solution but not every member "buys into" that solution
	My team ignores conflicts among team members.

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