A Methodology for Studying Team Performance: The Aircraft Maintenance Environment

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Abstract

Research methodology in the area of teamwork, has relied extensively on subjective evaluation rather than the use of objective performance measures. This approach has often failed to draw links between subjective measures that lead to improvements in performance based on objective performance measures. To address this issue, this paper initially outlines a framework for understanding team performance, then defines an integrated methodology to measure team performance. Following this step, the paper reports on the use of this methodology in understanding teamwork and team performance in the aircraft maintenance domain.

Keywords
Team training, performance measures, aircraft maintenance environment, computer-based training.

1. Introduction

Teams are critical in the work setting since they allow for successful execution of tasks that sometimes exceed the capabilities of single individuals [1]. Starting in the mid 1980s, research efforts were made to examine whether the effectiveness of teams increases as a result of team training. Working primarily with military organizations, Morgan et al. and Glickman et al. studied team training and the effects of training on team behavior and team performance [2,3]. Later, Swezey and Salas began to develop guidelines for team training [4]. But the obstacles faced by these researchers, as well as training professionals in general, was the lack of a well defined methodology to measure the impact of training on team performance.

In their work on team training, Wexley and Latham describe 4 ways to measure the effectiveness of training: 1) reaction criteria - or how the participants liked or disliked the trainer, training content, methods of training, etc., 2) learning - usually done with a test which measures the knowledge gained as a result of the training, 3) change of work behavior - measuring the extent to which the participants apply the knowledge gained during training to their work setting, and 4) measurement of cost related benefits [5]. The measurement of benefits is the most difficult of the four aforementioned criteria to measure, but Stelly and Taylor measured significant financial improvements after instituting team training among aviation maintenance personnel [6]. This paper describes a methodology that uses both subjective and objective measurement tools to

measure the effect of team training on team performance. A brief description of the study is provided along with examples of the tests and forms that were used.

2. Measuring Teamwork - Background and Theory

2.1. Definition of a Team

There are a number of definitions for "team" throughout the team literature. One of the early definitions was provided by Nieva et al. who worked on identifying the nature of team performance and the factors that affect performance [7]. Others have added the concepts of interdependency, knowledge of membership, and valued team goals to the definition of team [8,9,10,11].

In more recent work, Johnson and Johnson combined these concepts to defined a team as:

> two or more individuals who are (1) aware of their positive interdependence as they strive to achieve mutual goals, (2) interact while they do so, (3) are aware of who is and is not a member of the team, (4) have specific roles of functions to perform, and (5) have a limited life-span of membership [12].

2.2. Teamwork Skill

Recent research in the area of team skills has attempted to identify team factors/skills that affect team performance [3,4,13,14,15]. Knowing the skills involved in teamwork can guide us in the understanding of their effects on team performance.

Burke et al. generated a list of team skills that were distilled from over 103 identifiable team skills taken from the team literature [13]. According to the authors, the skills of adaptability, shared situation awareness, performance monitoring and feedback, leadership/team management, interpersonal, coordination, communication and decision making comprise a core set of skill dimensions common to all (or most) investigations. In their measurement of the team process, Brannick et al. used a similar classification of team skills [14]. Through a process of literature review, critical incident technique, and rating procedures, they selected the following six critical team dimensions: assertiveness, decision making/mission analysis, adaptability/flexibility, situation awareness, leadership, and communication. In a more recent study, Schmidt reported about seven common behavior skills that were critical to flight related mishaps [15]. These seven skills include: communication, assertiveness, mission analysis, decision making, situation awareness, adaptability/flexibility, and leadership.

2.3 Team Model

To conduct research on teams, one needs to understand the team environment, the factors impacting team performance, measures of team performance, etc. Literature on teams has put forth various "team models" and "team frameworks." Gersick developed the Time and Transition Model which described the modification of behavior and performance strategy that occurred in a team over time [16]. The Team Evolution and Maturation model, developed by Morgan et al. describes a series of nine informal, indistinct, and overlapping stages through which a team evolves [8]. The core of this model consists of the four stages of team growth:

Forming, Storming, Norming and Performing [17]. Tannenbaum et al. examined team building and its effects on team performance and effectiveness [18]. They developed the Team Effectiveness model for examining team building interventions. This model attempted to integrate previous research and theory on team functions.

Building on Tannenbaum's model and drawing from the task analysis of aircraft inspection and maintenance activities [19,20], site visits to repair facilities, observations with training personnel and A&P school instructors, Kraus et al. developed the Team Training Model for the Aircraft Maintenance Environment [21]. This model illustrates the interaction between internal factors, external factors, the team process, training strategies, and outcome measures. According to this model, the output of the entire team activity can be measured by considering it as consisting of changes in process measures and changes in task performance measures. The process measures are considered to consist of individual process measures, team process measures, and task performance measure (see Figure 1).

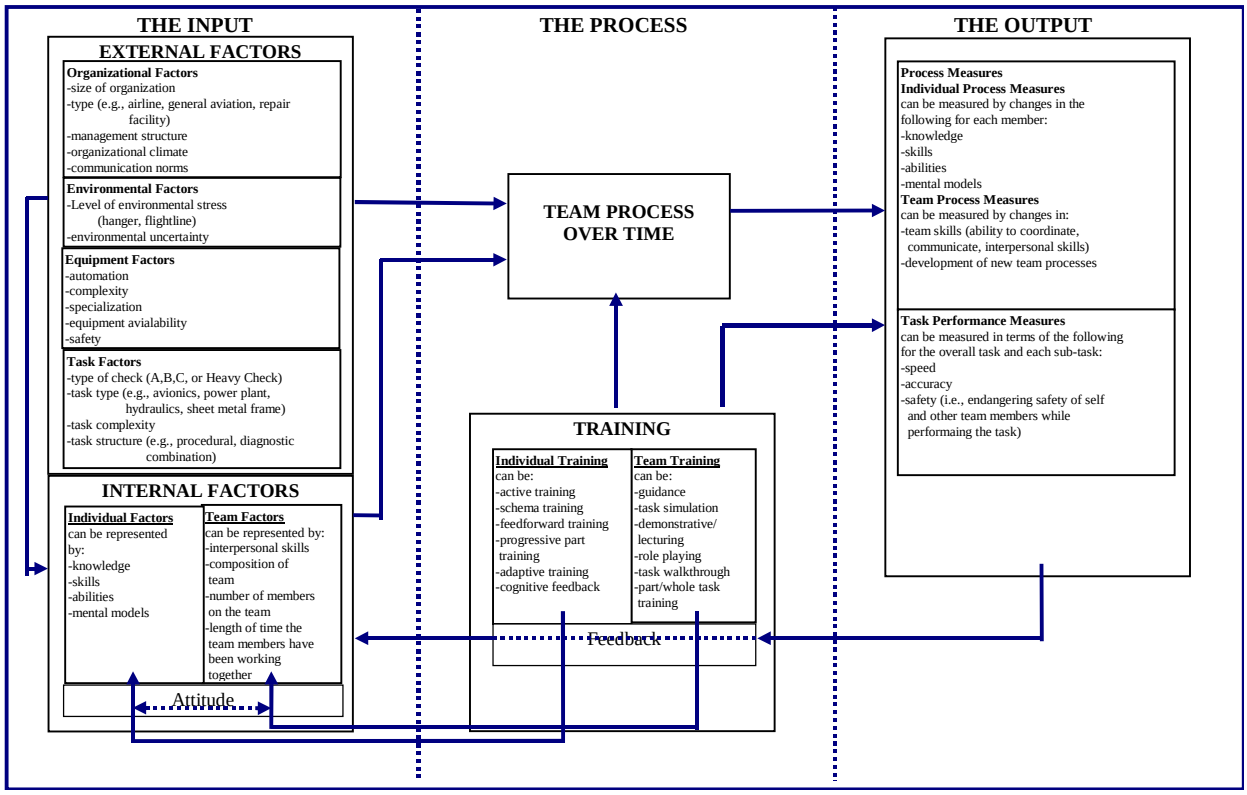

Figure 1. Team training model for the aircraft maintenance environment (Kraus et al. [21])

3. Measuring Teamwork Skills - The Aircraft Maintenance Example

3.1 Background

The importance of teamwork in the aircraft maintenance environment has previously been identified [19,20,22,23]. Because teamwork is important, a study was conducted to evaluate the

effect of team skills training on aircraft maintenance technicians (AMTs). To conduct the study, a computer-based team training software -- The Aircraft Maintenance Team Training software (AMTT) was developed. The program provided training in four team skills (communication, decision making, interpersonal relationships, and leadership) which were identified following a detailed task analysis of the aircraft maintenance environment conducted at various sites ranging from large airlines to fixed based operators associated with general aviation [23].

The general objective of this study was to demonstrate the potential effectiveness of advanced technology to accomplish team training. AMTT provided the Aircraft Maintenance Technicians (AMTs) instruction on team skills that would help them to function cooperatively and effectively in the aircraft maintenance environment. The specific objectives of this research were to evaluate the usefulness of computers in assisting AMTs in acquiring knowledge on team skills, and to determine if computer-based team training was as effective as traditional instructor-based training. Ultimately, the results of an experimental study conducted to determine the effectiveness of computers in delivering team skills instruction are reported.

3.2. Methodology for Measuring Team Performance

The controlled study used 36 subjects (AMTs) who were randomly assigned to two groups (IBT and CBT) such that each group had equal number of subjects. During the instructional phase, the IBT (Instructor-based Training) group received traditional instructor based training whereas the CBT (Computer-based Training) group received computer-based multimedia training (provided through the AMTT software). Every effort was made to maintain a constant curriculum and presentation sequence for both the groups. The only difference in the training between the two groups was the type of delivery system. During the evaluation phase, the subjects in each group were randomly assigned to three member teams (each group had six teams) and were tasked with completing a routine (RM) and a non-routine aircraft maintenance (NM) task.. The teams performance was evaluated as they completed the RM and NM tasks. The order in which the teams performed the RM and NM tasks was balanced within each group. Table 1 summarizes the data collection instruments administered during the instructional and evaluation phases of the study. It also identifies the type of measure, the type of analysis conducted and links the instruments to specific output measures as identified by the team training model for the aircraft maintenance environment [21]. The following, describes in detail, the measurements made in each phase.

3.3. Instructional Phase

Before the training was initiated, all subjects completed a Team Skill Perception Questionnaire for each team skill being taught (communication, decision making, interpersonal relationships, and leadership). An example of this questionnaire is provided in Figure 2. The questionnaire used elements from Crew Resource Management/Technical Operations Questionnaire (CRM/TOQ), a modified version of Taggart's questionnaire [24], Taylor's questionnaire [25], and the Critical Team Behavior Form (CTBF) [3]. Each questionnaire consisted of 10 questions on a seven point Likert scale, and was designed to measure the subject's perception of a particular team skill.

In addition to the Team Skills Perception Questionnaire, each subject completed a 20-question multiple choice Knowledge Test before training (see Figure 3). The objective of the Knowledge Test was to measure each subject's knowledge on the different team skills before training.

After completing the Team Skills Perception Questionnaire and the Knowledge Test, the subjects received team skills training using the appropriate delivery system. Upon completion of the training, the same Team Skills Perception Questionnaires and the Knowledge Tests were re-administered to the subjects. The purpose in repeating the same perception and knowledge tests was to measure the changes in perception and knowledge that had occurred during training.

Each subject also completed two sets of usability questionnaires. The questionnaires collected subjective satisfaction ratings on the training delivery system using a seven-point Likert scale, where seven indicated strong agreement and one indicated strong disagreement. The first questionnaire, referred to as the General Questionnaire (see Figure 4), contained questions relevant to both the training delivery systems, and was completed by subjects in both the groups. The General Questionnaire addressed usability issues related to: content, mechanics of presentation, format, and usefulness. The second part of the usability questionnaire was training delivery system specific, and addressed usability issues related to presentation and format.

Table 1
Team Training Model for the Aircraft Maintenance Environment (Kraus et al., 1995)

Phase of Research	Data Collection Instrument	Administration of Data Collection Instrument	Type of Measure	Analysis Conducted	Output Measure
Instructional Phase	Knowledge Test	Pre and Post Training	Objective	ANOVA	Individual Process Measure
	Perception Questionnaire	Pre and Post Training	Subjective	ANOVA	Individual process Measure
	Usability Questionnaire	Post Training	Subjective	ANOVA and t-test	Individual Process Measure
Evaluation Phase	Self Evaluation	Post Task	Subjective	ANOVA	Team Process Measure
	Instructor's Evaluation	Post Task	Subjective	ANOVA	Team Process Measure
	Accuracy	On-line	Objective	ANOVA	Task Performance Measure
	Speed	On-line	Objective	ANOVA	Task Performance Measure
	Safety	On-line	Objective	ANOVA	Task Performance Measure

1. Good communication and team coordination are as important as technical proficiency for aircraft safety and operational effectiveness.

Very strongly disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Very strongly agree**

2. Crew leaders and supervisors should encourage questions during work and in special situations

Very strongly disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Very strongly agree**

3. The start of shift team meeting is important for safety and effective team management

Very strongly disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Very strongly agree**

Figure 2. Sample questions from the team skills perception questionnaire - communication

Your crew chief is talking to the team and when he says something significant and you nod your head in agreement…

A. It displays a lack of desire to communicate.
B. You are communicating with body language.
C. You should keep very still so as to not confuse the speaker
D. You should remain quiet since verbal and non-verbal communication do not mix.

When a supervisor summarizes what he said and then asks several questions of the team member, he is…

A. Grading the team members.
B. Using an investigative management technique.
C. Using reverse psychology to get his team to work harder.
D. Looking for feedback to see if he got his message across.

Figure 3. Sample questions from knowledge test - communication

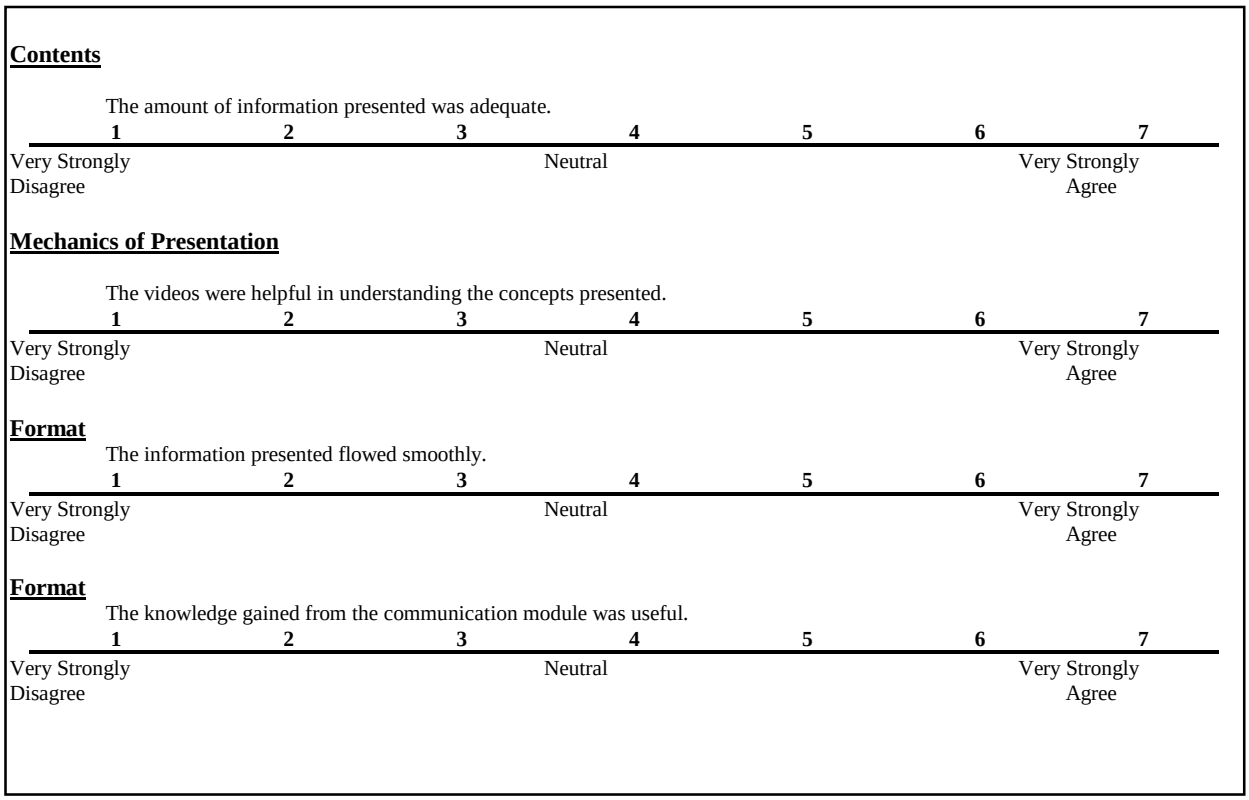

Figure 4. Sample questions from general usability questionnaire - contents

3.4. Evaluation Phase

As the teams performed the routine maintenance (RM) and non-routine maintenance (NM) tasks, three evaluators monitored the teams and independently evaluated their performance. The categories used to measure performance on the routine and non-routine maintenance tasks are shown in Tables 2 and 3.

Table 2
Routine Maintenance Task

Accuracy	Number of errors or number of times the team's procedure differed from the work card
	Number of times an improper tool was used
	Number of times that the equipment was handled incorrectly
Safety	Number of times the safety of the aircraft was in jeopardy
	Number of times the safety of an individual was in jeopardy
Speed	Time to complete the sub-task (in minutes)
	Percent of task completed within time constraint

A total of 120 minutes was allotted for the completion of the routine task. If a team was unable to complete the task within the allotted time, the evaluators estimated the percentage of the task that was completed. The percent completed was then used to estimate the task completion time.

Table 3
Non-routine Maintenance Task

Accuracy	Was the problem diagnosed correctly?
	Did the team locate the problem?
	Did the team fix the problem?
Speed	Time taken to diagnose the problem
	Time taken to locate the problem
	Time taken to fix the problem
	Total time
Safety	Number of times the safety of the aircraft was in jeopardy
	Number of times the safety of an individual was in jeopardy

Similarly, the teams were given a maximum of 60 minutes to complete the non-routine maintenance task. If a team was unable to complete the task within the allotted time, an estimate was made of the percentage of task completed. Based on the estimate, the task completion time was estimated.

Upon completion of the routine and non-routine maintenance tasks, the evaluators completed a questionnaire evaluating the teams on various team performance measures (communication, decision making, interpersonal relationships, and leadership skills). The evaluators rated each team on its application of each team skill by responding, using a seven point Likert scale (see Figure 5).

Upon the completion of the RM and NM tasks, all subjects completed a questionnaire that was identical to the evaluator's questionnaire. This allowed the individual team members to rate the performance of their team on the application of team skills (communication, decision making, interpersonal relationships, and leadership).

4. Summary and Discussion

The goal of this research was to understand the role of team training in the aircraft maintenance environment. As part of the research, a multimedia computer-based team training software -- Aircraft Maintenance Team Training (AMTT) software--was utilized. The study used a variety of measurement techniques to determine the effect of team training on knowledge, perception, and team behavior. Following is a list of the 5 most significant findings.

1. The Knowledge test provided a definitive means of measuring the effectiveness of team training on the acquisition of team skills knowledge. The Knowledge test showed that team training enhanced the knowledge of individuals on team skills. However, the type of training delivery system (instructor-based or computer-based) did not have a significant effect on the individual's ability to acquire team skills knowledge.
2. Use of the Team Skills Perception Questionnaire revealed no significant changes in the perception of team skills as a result of team training. Team skills perception scored high prior to training, indicating that the subjects understood the importance of team skills prior to receiving training.
3. According to both the General Usability and Delivery Specific Questionnaires, there were no significant differences between IBT and CBT in terms of user satisfaction. Recipients of both training delivery systems reported a high level of user satisfaction on the general and delivery-specific portions of the usability questionnaire.

4. Use of performance measures (speed, safety, and accuracy) effectively demonstrated the application of knowledge from team training to team performance. Correlation analysis showed that team and task performance increases with an increase of knowledge in select team skills.
5. The Instructor's Evaluation and the Subject's Evaluation were effective measures of the use of team skills behavior learned in the instructional phase. Teams which exhibited superior team behavior also exhibited superior performance on a select set of task performance measure. The correlation analysis showed that the results approached significance for a large number of variables.

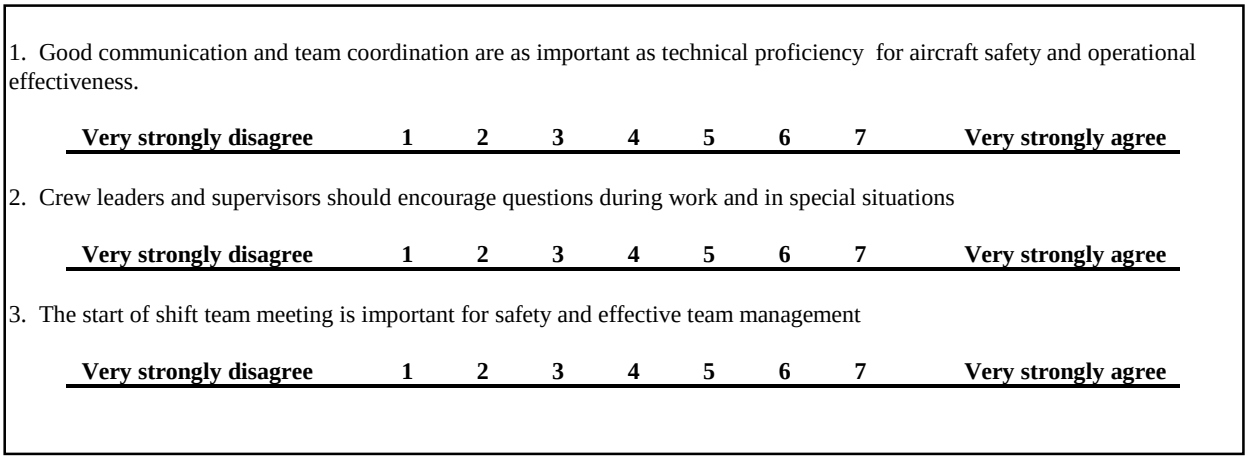

Figure 5. Sample questions from evaluator's/subject's questionnaire - communication

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