Evaluating Self-Analysis as a Strategy for Learning Crew Resource Management in Undergraduate Flight Training

GUY M. SMITH

College aviation programs are in a unique position to provide crew resource management (CRM) training to meet industry demands for pilots with a high degree of competence in interpersonal skills. CRM training is usually a student's first exposure to crew operations, requiring the college to modify airline training to create meaningful learning for inexperienced pilots. Research with airline pilots has found that line-oriented flight training (LOFT) was most effective for teaching CRM. LOFT is best when airline crews debrief themselves using self-analysis to evaluate their CRM performance. The study investigated whether undergraduate flight students could effectively learn CRM skills by using self-analysis of LOFT as a debriefing strategy, despite their inexperience with crew operations. Eight men and two women completed CRM and LOFT training. Self-analysis was randomly inserted into their training using an alternating treatments research design. Crew effectiveness was assessed by measurements of crew attitudes, observations by trained observers, crew reflections on their performance, and communications analysis. It was found that at least one self-analysis session was effective for each crew, and overall gains were noted for two of the five crews. Self-analysis was effective when crews had the prerequisite technical skills and was ineffective if technical skills were lacking or if the scenario was too complex. Results suggest that self-analysis should not be applied universally in undergraduate flight training, but it is a valuable supplementary strategy to focus attention on personalities, roles, team dynamics, or specific CRM skills.

Sophisticated machines demand master operators with finely tuned motor skills, the ability to execute complex procedures, and an extensive information base. Modern aircraft require that professional pilots stretch far beyond these technical skills into the milieu of cognitive, behavioral, social, and organizational psychology, where interpersonal skills and teamwork are equally important. Statistics indicating that 70 percent of worldwide accidents in the public air transport sector are caused by flight crew actions (*1*) affirm that team skills are vital. The ideal airline candidate is a technical expert and a master of teamwork. For most of this century, however, pilot selection and training were based on technical proficiency alone. Airlines recognized this deficiency, poured substantial investments into human factors research, and developed advanced training programs such as crew resource management (CRM).

It is argued that CRM is advanced training and is not appropriate for beginning students, who should concentrate on "stick and rudder" skills. Others contend that teamwork is an indispensable pilot skill and that it is a disservice to students to postpone crew training until they reach the airlines (*2*). European ab initio programs, in which nonpilots are taught from the beginning to be airline pilots, have successfully included CRM in initial flight training for years (*3*). College aviation programs are in a unique position to develop effective CRM training for initial flight students.

Department of Education, Montana State University, Bozeman, Mont. 59717. Current affiliation: Department of Aviation, Rocky Mountain College, 1511 Poly Drive, Billings, Mont. 59102.

LINE-ORIENTED FLIGHT TRAINING

The Federal Aviation Administration (*4*) developed three guidelines for an effective CRM program for airlines operating under Federal Aviation Regulations (FAR) Parts 121 and 135:

- The course content should emphasize CRM skills.
- Students should experience and practice these skills.
- Students should get feedback on their CRM performance.

To make these guidelines applicable to undergraduates, a content model, concerned with transmitting information and skills, was insufficient. An experiential or process model, concerned with providing resources to help learners acquire CRM skills, was required. Moreover, to evaluate the outcomes of this model, the primary effectiveness measure had to be performance.

There are many CRM instructional methods to choose from. Of the 16 listed by Sams (*5*), the most effective for airline pilots was line-oriented flight training (LOFT), an experiential learning method in which flight crews fly a complete scenario in a high-fidelity simulator in real time. Airlines achieved striking results with LOFT, but systematic research was necessary to ensure that LOFT is also effective in teaching CRM to undergraduate students.

Self-analysis is a discovery learning strategy based on the theory of objective self-awareness (*6*). It proposes that self-focusing stimuli often force objective appraisals of oneself that may lead to attitude and behavior changes. Self-analysis of LOFT, in which the debriefing is led by the crew themselves, has been a highly effective technique for improving CRM performance in airline pilots (*7*). For college crews, self-analysis could give powerful insights into CRM performance, offsetting some of their inexperience (*8*).

DEVELOPMENT OF AN EFFECTIVE COLLEGE CRM PROGRAM

For most undergraduates, LOFT is their first exposure to nonroutine, high-stress, high–work load, and emergency situations re-

quiring teamwork. To expand technical skills into higher-order CRM skills, students must be actively involved in each stage of the learning process (*9*). Active learning strategies gave direction to a college CRM program that progressed through three distinct phases: learning sessions where CRM skills were introduced, practice sessions where CRM skills were exercised, and feedback sessions where behaviors were reinforced or corrected.

Learning sessions were content sessions that used an active cooperative learning method called jigsaw (*10*). Students read assigned material and then share information with their crew member by discussing case studies, analyzing accident reports, and writing team response papers.

Practice sessions were LOFT simulator exercises that required students to actively use CRM skills in an operational environment. They were flown in real time without assistance and were videotaped from start to finish.

Feedback sessions were debriefing periods during which two distinct methods were used: conventional debriefing and self-analysis. Conventional debriefing was not an active learning strategy; feedback was immediate, quantifiable, and objective. Instructors provided most of the input (*11*). Self-analysis debriefing, as an active learning strategy, gave students responsibility for their own debriefing. Self-analysis debriefings were postponed for 2 days while videotapes, verbatim transcripts, and communications analysis were being prepared as objective material for their exploration (*9*).

RESEARCH DESCRIPTION AND METHODOLOGY

Objectives

The purpose of this study was to determine whether undergraduate flight students could effectively learn CRM by using self-analysis of LOFT as a debriefing strategy, despite their inexperience with crew operations. Performance was selected as the measure of effectiveness. The jigsaw learning sessions and LOFT practice sessions were common to all crews, but debriefing sessions (conventional or self-analysis) were distinctive so that differences in CRM performance could be measured.

Design

The research design was an alternating treatments design (*12*), a type of single-subject design. Subjects were alternately exposed to a nontreatment (conventional debriefing) and a treatment (self-analysis of LOFT training). Repeated measurements of attitudes, effectiveness, performance, and self-reporting were taken to determine whether differences in performance could be noted. The alternating treatments design was selected because the population was small (five crews). The performance of each crew was analyzed independently, and any comparisons between crews were speculative and noninferential. There was no attempt to generalize from this research to any other population.

Subjects

The subjects were 12 students enrolled in the CRM course in spring 1993. Before any CRM instruction, each student completed a questionnaire to document pilot experience, education, and exposure to CRM. They were instructed in the LOFT simulator individually and evaluated on their technical flying skills. Students of equal skills were assigned to permanent crews to balance the crew technical skill level. Of the 12 students, 9 were fully qualified to be research subjects, 2 were unqualified and excluded, and 1 (Ed) was marginally qualified and included because each crew requires two people. Eight men and two women were teamed as follows:

- One crew with above-average skills (Alex/Art),
- Two crews with average skills (Betty/Bob and Carl/Cathy),
- One crew with mixed skills (Dan/Dave), and
- One crew with below-average skills (Ed/Eric).

Each crew completed five sessions of CRM and LOFT training; two sessions of self-analysis debriefing were randomly inserted into their training.

LOFT Scenarios

The LOFTs were flown in a Frasca model 142 twin-engine flight simulator with scenarios based on FAR Parts 91 and 135 operations requiring commercial pilot skills. Instrument flight rules were required throughout. No scenario forced students to choose a solution that would violate regulations. Flights took place in the United States intermountain Northwest, an area that requires extreme vigilance because of mountainous terrain and intermittent radar coverage. Unfamiliar airports and routes were chosen. Flights were designed to last 45 min, including 15 min of normal work load followed by an occurrence triggering a high–work load phase.

LOFT 1 was designed as a crew training session because it was their first crew experience. The scenario required normal crew interactions for instrument flight; there were no critical occurrences. There were two similar legs allowing each student the opportunity to fly as captain. Two crews (Alex/Art and Carl/Cathy) received self-analysis debriefing.

LOFT 2 was a communications exercise concentrating on the CRM skill of advocacy. The scenario was a medical support flight that was requested to divert because of an urgent need for blood replacements. It required crew interaction and radio communication to choose a divert airport that was above weather minimums and could deliver the required blood. Self-analysis debriefing was used for Betty/Bob, Dan/Dave, and Ed/Eric.

LOFT 3 was a decision-making exercise focusing on the CRM skills of prioritizing and analyzing alternatives. The crew was on a long-distance flight that encountered arrival deadlines, departure delays, and unsuitable weather at the destination. It required consideration of operational commitments, weather complications, and fuel constraints. Self-analysis debriefing was used for Alex/Art and Carl/Cathy.

LOFT 4 was designed as a situational awareness exercise to emphasize the CRM skills of situation monitoring and cross-checking. While transporting high-priority medical supplies, minor mechanical difficulties progressively developed into a total loss of electrical power. The scenario required attentive monitoring of the aircraft's capabilities and awareness of external factors: weather, operational requirements, navigation capabilities, and alternatives. Communication with air traffic control and radar

services was lost about 30 min after takeoff. Self-analysis debriefing was used for Betty/Bob, Dan/Dave, and Ed/Eric.

LOFT 5 was a team management exercise highlighting the CRM skills of work load assessment and management. The crew was exposed to operations in a high-density (Class B airspace) environment where the weather was unsuitable for the destination but above minimums for several nearby alternatives. The crew lost communication with air traffic control, requiring crew interaction and leadership skills to select a course of action from a large number of alternatives. Because of the complex airspace, marginal weather, and faulty radios, LOFT 5 became known as the "LOFT from Hell."

Analytical Instruments

A repeated measures strategy was used to evaluate crew effectiveness via converging sources of data (*13*). Each measurement used five evaluation methods to assess different aspects of effectiveness. Reliability was maximized by collecting data from these five sources and establishing that they converged on a global measure of effectiveness (*13*).

The cockpit management attitudes questionnaire (CMAQ) is a 25-item Likert scaled instrument measuring attitudes that are an indirect indication of crew performance (*14*). It was completed by each crew (scored by consensus) after each LOFT as a measure of the effectiveness of the strategy (conventional or self-analysis). The CMAQ was factored into three subscales: communication and coordination, command responsibility, and recognition of stressor effects (*15*).

The LINE/LOS checklist (LLC) is an evaluation of a crew's performance of CRM skills by trained observers (*16*). It was scored immediately after each LOFT by two instructors who used extensive field notes and deliberations to reach consensus scores. The checklist consists of two global ratings and eight crew effectiveness markers that are indicators of crew performance (*17*).

Communications analysis is a measure of crew interaction and coordination that reflects trends in flight crew performance (*18,19*). Communications analysis started at the beginning of the high–work load phase and lasted for exactly 30 min. Using a procedure adapted from Foushee and Manos (*18*), cockpit communications were transcribed verbatim, and each statement or phrase was coded into 1 of 20 categories of communication. Two coders worked independently on all of the transcripts, and a point-by-point comparison established an interrater reliability of 81 percent. Four categories that have been related to performance were used as measures of crew effectiveness: total communications, commands by the captain, acknowledgments by the first officer, and observations by both crew members (*20*).

The CRM survey is a survey of crew reactions to their training experience that was completed by consensus after each LOFT. Responses were factored into six categories to obtain students' views on the value of LOFT as a training technique, the quality of the LOFT scenario, the work load imposed by the LOFT scenario, the ratings of the LOFT instructor, a self-evaluation of overall performance, and a self-report on use of CRM skills (*21*).

The lessons learned is another crew report of 10 lessons that they learned from each training phase. Students reflected on the entire experience, listed their CRM lessons learned, and specified the source of learning for each lesson.

RESEARCH FINDINGS

Data analysis in this single-subject design involved inspection and analysis of graphic presentations (*12*). To summarize the graphs, a variant of the nonparametric sign test was used to show magnitude and direction of a change (*22*). Tables of findings list only those factors that showed gains for self-analysis that were more than one standard deviation higher than the preceding conventional session.

Alex/Art

Table 1 gives factors exhibiting measurable gains in performance for Alex/Art after self-analysis sessions. The Alex/Art crew was above average in technical skills and well matched. There was, however, a significant difference in experience; Art was a low-time private pilot, whereas Alex was an active flight instructor. Alex struggled with role definition, thinking of himself as a flight instructor and recognizing that he was expected to perform as a

TABLE 1 Gains After Self-Analysis Sessions (Alex/Art)

	1ST SELF-ANALYSIS (LOFT #2)	2ND SELF-ANALYSIS (LOFT #4)
LINE/LOS CHECKLIST		
OVERALL TECHNICAL EFFECTIVENESS	+	++
OVERALL CREW EFFECTIVENESS	nc	++
CRM SURVEY		
SCENARIO QUALITY	+++	+
WORKLOAD IMPOSED	++	++
INSTRUCTOR RATING	++	--
COMMUNICATIONS ANALYSIS		
TOTAL COMMUNICATIONS	+++	+
COMMANDS (BY CAPT)	+	+++
ACKNOWLEDGEMENTS (BY FO)	+	++
OBSERVATIONS (CAPT & FO)	++	+

Standard deviations since the previous observation:
- - - = <-2, - - = -1<-2, - = 0<-1, nc = no change,
+ = 0>1, + + = 1>2, + + + = 2>3

crew member. The crew grappled with role definition in both self-analysis sessions, resulting in keener awareness of CRM issues. Their LLC showed that self-analysis increased both technical and CRM skills, consistent with their concern for "looking good." The CRM survey showed that self-analysis imposed greater work loads but resulted in higher-quality scenarios. Their rating of instructors decreased after the second self-analysis session, indicating that they preferred conventional debriefing. Communications analysis showed gains in all four categories in both sessions, the strongest evidence that self-analysis motivated this crew. Lessons learned focused on team building, though that CRM skill was not formally taught until LOFT 5. They recorded their principal learning sources as LOFT and self-analysis. It appears that self-analysis made an important contribution to their learning experience.

Betty/Bob

Table 2 gives factors exhibiting measurable gains in performance for Betty/Bob after self-analysis sessions. The Betty/Bob crew had difficulty disregarding the research and concentrating on learning. They were also reluctant to "suspend reality" and accept the realism of the simulator. More important, crew dynamics was a possible hindrance to their learning. Bob was confident, capable, and occasionally patronizing. Betty was equally capable but more acquiescent; her voice inflections exhibited some sensitivity to his manner. Evidently, these dynamics were more apparent to the instructors and were not a concern the crew discussed in self-analysis sessions. Their first self-analysis session was very successful, with every item on the LLC and three CRM survey items showing strong gains. Their progress was strongly supported by two communications analysis items. These gains contrasted sharply with a significant decline in the second self-analysis session. There was no link between these declines and self-analysis, who was captain, or responses on the CRM survey. However, lessons learned gave evidence that the crew was struggling with crew dynamics:

- "Do not assume that your partner knows what you mean."
- "Share decision making. Don't let captain override the crew."
- "The need for CRM skills was not practiced. We used a lot of nonverbal communication and that was a mistake."
- "First officer learned to wait for captain decisions or make verbal suggestions before taking action."

They showed gains in communications analysis, contrary to the other measures, suggesting that perhaps they were making improvements in crew dynamics. Betty/Bob concentrated their lessons learned on situational awareness and communication. They primarily learned from LOFT; only 10 percent of their learning was attributed to self-analysis. The data suggest that self-analysis had limited value for this crew in learning CRM skills.

Carl/Cathy

Table 3 gives factors exhibiting measurable gains in performance for Carl/Cathy after self-analysis sessions. The Carl/Cathy crew was matched in skills and compatible in personality, performing well as a male/female crew. Preoccupation with technical details such as crew coordination, radio communication, and checklists limited their ability to absorb CRM skills. After the first self-analysis session the LLC indicated negative results for their comprehension of crew concepts. Contrary to this outcome, the crew recorded an increase in usage of CRM skills in the CRM survey. Their perceived gains were mostly in technical areas, confirming that they were unable to recognize CRM skills at that point. Communications analysis showed a notable increase in total communications, usually an indication of increased performance. Foushee and Manos (*18*) warn that more communication among flight crew members does not necessarily translate into better performance. The crew worked hard but did not know what to do. Initially, self-analysis provided few answers; the crew needed an explicit role model, someone with considerable experience in crew operations to demonstrate effective crew performance.

Deliberately modifying procedures, the instructor closely monitored their second self-analysis session to circumvent digressions into technical discussions. It became a hybrid between self-

TABLE 2 Gains After Self-Analysis Sessions (Betty/Bob)

	1ST SELF-ANALYSIS (LOFT #3)	2ND SELF-ANALYSIS (LOFT #5)
LINE/LOS CHECKLIST		
COMMUNICATIONS/DECISION BEHAVIOR	+++	--
TEAM BUILDING AND MAINTENANCE	+++	--
WORKLOAD MGMT/SITUATION AWARENESS	+++	-
OVERALL TECHNICAL EFFECTIVENESS	++	--
OVERALL CREW EFFECTIVENESS	+++	-
CRM SURVEY		
SCENARIO QUALITY	++	--
SELF-EVAL OF PERFORMANCE	++	--
SELF-REPORT ON CRM SKILLS	+++	-
COMMUNICATIONS ANALYSIS		
TOTAL COMMUNICATIONS	-	+++
COMMANDS (BY CAPT)	+++	--
OBSERVATIONS (CAPT & FO)	+++	++

Standard deviations since the previous observation:
- - - = <-2, - - = -1<-2, - = 0<-1, nc = no change,
+ = 0>1, + + = 1>2, + + + = 2>3

analysis and conventional debriefing, herein referred to as guided self-analysis. Guided self-analysis manifested strong gains in the LLC and in communications analysis, indicating that it was an effective learning method. The crew reported lessons learned in situational awareness and in technical areas. They learned mostly from LOFT debriefings and self-analysis. Although self-analysis, as designed for this research, indicated marginal gains for this crew, guided self-analysis was more effective.

Dan/Dave

Table 4 gives factors exhibiting measurable gains in performance for Dan/Dave after self-analysis sessions. The Dan/Dave crew was mismatched in skills; Dan was above average and Dave was below average. They had steady gains in effectiveness for both self-analysis sessions, regardless of who was captain. However, they disliked self-analysis and sometimes requested conventional debriefing with the instructor. The CMAQ showed gains in recognizing stressors, and their LLC gave the most persuasive confirmation that self-analysis was effective. In the CRM survey they rated self-analysis high, despite their stated dislike of the method. Communications analysis supported the gains of the first self-analysis session. In the lessons learned, the crew documented the best variety of lessons: decision making, situational awareness, teamwork, and communications. Their learning sources were predominantly LOFT and self-analysis. Self-analysis was noticeably effective as a learning agent for this crew.

Ed/Eric

Table 5 gives factors exhibiting measurable gains in performance for Ed/Eric after self-analysis sessions. The Ed/Eric crew had a positive attitude and were exceptionally conscientious. Both had excellent academic records but below-average technical skills. In the first self-analysis session, the crew realized that their communication was poor; subsequently they focused exclusively on communication and registered partial gains in the CMAQ, the LLC, and the CRM survey. Communications analysis strongly corroborated their concentration on communication and indicated considerable progress in that area. Beginning in LOFT 4, the crew experienced scenario complexity that was beyond their technical ability. As difficulty increased, effectiveness measurements, particularly communications analysis, document a laborious and mostly futile journey from textbook knowledge (theory) to practical skills. LOFTs 4 and 5 were "lost communications" incidents, in which they did not use CRM skills because they were "in over their heads" with scenarios that were too difficult for their skill level. The lessons learned for Ed/Eric focused on communication and team building. They reported that most of their lessons were learned from LOFT; self-analysis accounted for only 14 percent of lessons learned. Self-analysis was effective in the first session but proved ineffectual when their technical skills were deficient.

SUMMARY OF LESSONS LEARNED

Table 6 is a compilation of lessons learned for all crews. Each crew focused lessons learned on a specific CRM skill, and four crews had a CRM skill they neglected:

Crew	*Focus*	*Area of Neglect*
Alex/Art	Team building	None
Betty/Bob	Situational awareness	Team building
Carl/Cathy	Situational awareness	Team building
Dan/Dave	Decision making	Communication
Ed/Eric	Communication	Decision making

Crews were asked to name the source of learning for each lesson learned. Without exception, LOFT proved to be a valuable learning source, an indication that these students learned CRM by doing it. Self-analysis was a valuable learning source for three crews, indicating that it also had value. The strongest support for self-analysis came from Dan/Dave, who frankly acknowledged that they did not like doing self-analysis but attributed 40 percent of their learning to it.

TABLE 3 Gains After Self-Analysis Sessions (Carl/Cathy)

	1ST SELF-ANALYSIS (LOFT #2)	2ND[a] SELF-ANALYSIS (LOFT #4)
LINE/LOS CHECKLIST		
COMMUNICATIONS/DECISION BEHAVIOR	--	+++
TEAM BUILDING AND MAINTENANCE	--	+++
WORKLOAD MGMT/SITUATION AWARENESS	--	+++
OVERALL TECHNICAL EFFECTIVENESS	--	+++
OVERALL CREW EFFECTIVENESS	--	++
CRM SURVEY		
SCENARIO QUALITY	++	++
WORKLOAD IMPOSED	++	+
SELF-REPORT ON CRM SKILLS	++	nc
COMMUNICATIONS ANALYSIS		
TOTAL COMMUNICATIONS	+++	-
COMMANDS (BY CAPT)	-	+++

Standard deviations since the previous observation:
- - - = <-2, - - = -1<-2, - = 0<-1, nc = no change,
+ = 0>1, + + = 1>2, + + + = 2>3

[a]Guided self-analysis session.

TABLE 4 Gains After Self-Analysis Sessions (Dan/Dave)

	1ST SELF-ANALYSIS (LOFT #3)	2ND SELF-ANALYSIS (LOFT #5)
CMAQ		
RECOGNITION OF STRESSOR EFFECTS	nc	++
LINE/LOS CHECKLIST		
COMMUNICATIONS/DECISION BEHAVIOR	+	++
TEAM BUILDING AND MAINTENANCE	++	++
WORKLOAD MGMT/SITUATION AWARENESS	++	++
OVERALL TECHNICAL EFFECTIVENESS	--	++
OVERALL CREW EFFECTIVENESS	+	+++
CRM SURVEY		
WORKLOAD IMPOSED	++	--
SELF-EVAL OF PERFORMANCE	++	++
SELF-REPORT ON CRM SKILLS	++	---
COMMUNICATIONS ANALYSIS		
ACKNOWLEDGEMENTS (BY FO)	++	-
OBSERVATIONS (CAPT & FO)	+++	+

Standard deviations since the previous observation:
- - - = <-2, - - = -1<-2, - = 0<-1, **nc** = no change,
+ = 0>1, + + = 1>2, + + + = 2>3

DISCUSSION OF RESULTS

For every crew, the CMAQ had only slight variability and provided essentially no evidence for effectiveness of self-analysis. Relationships between attitudes and performance have been validated for airline crews (*23*), but the instrument may be unsuitable for undergraduates because they lack crew experience on which to base attitudes. Also, the CMAQ was scored by a crew as a consensus measure of crew attitude, though it was designed as an individual instrument. A "crew attitude" may not even exist. It is also conceivable that the CMAQ showed small variations because it was completed so often (every 2 weeks) and crews remembered previous responses. For these reasons, the CMAQ did not render an acceptable measure of self-analysis effectiveness.

The LLC was probably the most objective measure of effectiveness because it required systematic data collection of CRM skills distinct from technical performance. Consensus grading compelled justification for every grade and reduced the possibility of grading by instinct, crew reputation, or preferred results. Of all the measurements taken, the LLC is the best summary of the study. It shows significant gains in 5 of the 10 self-analysis sessions.

The CRM survey was designed as a self-analysis instrument. One factor in the survey, self-report on CRM skills, is probably the most direct measure of self-analysis. Three of the five crews showed a step increase in this factor after the first application of self-analysis, but none reported gains in the second session. It appears that crews became more discerning and critical as they gained awareness of CRM skills. For self-analysis sessions, two other trends were evident in the survey: instructor ratings declined and work load imposed increased. Crews apparently preferred conventional debriefing with the instructor; the extra work was perceived as a negative feature of self-analysis.

Multiple measures of effectiveness were used because each data source has its strengths and weaknesses. A data source has merit if it consistently validates or disproves the results from other measures. In communications analysis, frequencies are an equivocal measure of effectiveness because communication must be interpreted within a task, environment, or interpersonal context (*24*). In this study, three of the four communications categories

TABLE 5 Gains After Self-Analysis Sessions (Ed/Eric)

	1ST SELF-ANALYSIS (LOFT #3)	2ND SELF-ANALYSIS (LOFT #5)
CMAQ		
COMMUNICATIONS AND COORDINATION	++	+
LINE/LOS CHECKLIST		
TEAM BUILDING AND MAINTENANCE	++	--
CRM SURVEY		
SCENARIO QUALITY	++	---
WORKLOAD IMPOSED	++	nc
COMMUNICATIONS ANALYSIS		
COMMANDS (BY CAPT)	++	---
ACKNOWLEDGEMENTS (BY FO)	+++	-
OBSERVATIONS (CAPT & FO)	+++	-

Standard deviations since the previous observation:
- - - = <-2, - - = -1<-2, - = 0<-1, **nc** = no change,
+ = 0>1, + + = 1>2, + + + = 2>3

confirmed results of other measures. However, "total communications" was not consistent as a measure of effectiveness. It appears that well-intentioned crews, in an effort to practice communications skills, "talked" more but "communicated" less.

The two women who participated in the study were as professional and competent as the men, indicating that women belong in aviation and should be encouraged to participate equally with men in all domains of the industry. Crews in this study found that the cockpit can be a confining and sometimes emotional environment and that male/female relationships can add CRM issues that must be considered. Further research is needed to understand perceptions of male dominance, male/female dynamics, and the seniority of captains regardless of age, sex, and often skill. These issues are compelling reasons why CRM should be included in initial flight training: to educate men and women to the paradigm that men and women are equal and that performance, not gender, is the decisive factor.

Because they involved "lost communication," LOFTs 4 and 5 were particularly difficult, especially for the less skilled. All crews experienced some difficulty with lost communication, and two deliberately chose to violate regulations in a lost communication situation. All students were cognizant of textbook answers, but LOFT required them to convert their knowledge into appropriate action without assistance or feedback. LOFT elicits higher-order thinking, just as do life's situations, providing another argument for introducing LOFT in initial flight training.

Reflection on the crews that struggled with role definition and crew dynamics reveals an important difference between airline CRM training and undergraduate training. Airline crews are expected to have resolved such issues beforehand, but these contentions are natural learning encounters for college students. The outcome for Alex/Art was positive because self-analysis made them aware of the role definition problem and they struggled with it, though it was not totally resolved. On the other hand, self-analysis did not expose the crew dynamics issue to Betty/Bob, so it was not addressed forthrightly and the outcome is uncertain. It proved insufficient for the researcher to document the problem; education should have overridden research, and the issue should have been addressed so the students could resolve it.

CONCLUSIONS

None of the crews rated self-analysis highly, suggesting that they preferred conventional debriefing to self-analysis. Evidence weighed against self-analysis as a stand-alone strategy for teaching CRM to undergraduate flight students. The results are characteristic of initial flight students, who are accustomed to more guidance and rely heavily on feedback from instructors to evaluate their performance. However, there are sufficient data supportive of self-analysis, especially for experienced crews, that self-analysis should not be rejected. Self-analysis seems to be more effective as a supplemental strategy to be used when certain conditions exist. Further research is needed to determine the circumstances (personalities, team dynamics, experience, etc.) that would make it successful. Self-analysis appears to gain effectiveness as students accumulate experiences with crew operations.

The LLC reported the observer's overall evaluation of both technical and CRM performance; the CRM survey reported each crew's self-evaluation of technical and CRM performance. Concerning technical performance, crews' assessment of gain through self-analysis matched the observer's appraisal in 70 percent of cases. Concerning performance of CRM skills, crews' evaluation of gain through self-analysis matched the observer's assessment in only 50 percent of cases. Despite their focus on CRM skills, these students were more adept in evaluating their changes in technical performance than in assessing variations in crew effectiveness.

TABLE 6 Summary of Lessons Learned for All Crews

	Lessons-Learned					
CREW	**Communication**	**Decision Making**	**Sit. Aware**	**Team Building**	**Tech**	
A/A	-	-	-	++		
B/B	+	-	++	--		
C/C	-	-	++	--	+	
D/D	--	++	-	-		
E/E	++	--	-	+		
	Where Learned					
CREW	**Debrief**	**Instructor**	**LOFT**	**Preflight**	**Rdgs**	**Self-analysis**
A/A	-	-	++	-	+	+
B/B	-	-	+++	-	-	-
C/C	+	- -	++	-	--	+
D/D	-	-	+++	-	-	+++
E/E	-	-	+++	-	-	-

Standard deviations from the mean:

- = 0<-1 -- = -1<-2 --- = -2<-3
+ = 0> 1 ++ = 1> 2 +++ = 2> 3

The objective of LOFT is to provide crew members with the opportunity to practice both technical and CRM skills in a realistic scenario. The scenarios for this research were created, field tested, and evaluated by experienced aviators on the basis of perceived skills of commercial pilots. "Realistic and reasonable" for designers may not be viable for the students. In retrospect, two unanticipated factors may have influenced the results: students needed more low–work load time in all scenarios, and LOFTs 4 and 5 were too difficult for most of the crews. With the exception of Dan/Dave, overall technical performance in LOFT 5 was deficient, making it difficult to determine whether outcomes were attributable to self-analysis or to the scenario itself. Future research should recognize that college students need acclimation to crew operations; scenarios should be uncomplicated and should include significant low–work load periods. Guidelines and scenarios developed for airline pilots may not be appropriate for undergraduate flight students.

Throughout this research the focus has been on CRM skills, leaving the impression that CRM skills are superior to or more desirable than technical skills. A high degree of technical proficiency is essential for safe and efficient flight operations (*4*). In this study, crews with lower technical ability had considerable difficulty learning CRM skills. In 8 of 10 self-analysis sessions, differences in technical skills reflected analogous variations in CRM skills. CRM skills were not taught in isolation, confirming the conventional wisdom that mature technical skills are essential for developing CRM skills. This finding confirms the value of LOFT and self-analysis of LOFT as training technologies that integrate technical and CRM training.

RECOMMENDATIONS

Because one crew centered on technical discussions, guided self-analysis, a combination of self-analysis and conventional debriefing, was used. It produced strong gains for them in the LLC, suggesting that a research design using guided self-analysis may be more effective than self-analysis alone for undergraduate flight students. Research would be complicated; differences between guided self-analysis and conventional debriefing are less distinct.

Participants in this study were sometimes frustrated because they did not always know "the right way" to do things. They had difficulty applying theory to practice in the LOFT, and self-analysis did not furnish a standard for comparison. This inadequacy suggests that a research design in which self-analysis is preceded by role modeling to illustrate effective crew performance would be more appropriate. Students could observe role models on videotapes or role plays, but the best training would be achieved by flying a LOFT scenario with a pilot experienced in crew operations.

For thorough training, students swapped roles between captain and first officer in each scenario. This is an inferior design for research because crew performance could vary significantly with the captain. Assigning the more experienced crew member to be captain for the entire study would be better for research and would strengthen training because the concept of seniority would be established. That option was not possible in this study because students required exposure to both roles in a single-semester course. In further research, CRM could be taught in two semesters with beginner students flying first officer and experienced ones flying captain. A potential benefit is that experienced students could provide a role model for novice students. Research should also determine whether a student with one semester of LOFT experience is an adequate role model.

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