

01 Oct 2007

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Recommended Citation

R. Luechtefeld et al., "Expert System for Team Facilitation Using Observational Learning," *Proceedings of the 2007 37th Annual Frontiers In Education Conference - Global Engineering: Knowledge Without Borders, Opportunities Without Passports*, Institute of Electrical and Electronics Engineers (IEEE), Oct 2007.

The definitive version is available at <https://doi.org/10.1109/FIE.2007.4418088>

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Expert System for Team Facilitation using Observational Learning

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Abstract - While ABET criteria require that engineering graduates be able to “function on multidisciplinary teams” and “communicate effectively”, the need for effective team skills goes far deeper. One solution is the use of a computationally intelligent “virtual facilitator” that contains a subset of the expert knowledge of a skilled facilitator. The “virtual facilitator” models behaviors of an expert facilitator to engineering student teams as they are working together. Albert Bandura’s theory of observational learning suggests that skills can be developed through observation of expert “others” engaged in practice. Preliminary research indicates that students can increase beneficial team behaviors (such as inquiry) through observation and imitation of an expert system.

This paper is an extension of a 2005 FIE Work-In-Progress presentation that documented an expert facilitator system. In this study the system is used as part of an hour-long team exercise for engineering students. This study looks at student interactions during the exercise. Measures include analysis of team conversations for instances of imitation of the expert system, as well as a comparison of differences in team performance. The potential for an easily disseminated method to help engineering students learn effective team skills is discussed.

INTRODUCTION

The development of communication skills is necessary preparation for effective engineering team work. Team with a high degree of openness and interdependence exhibit enhanced quality of decision making [1]. ABET requirements for accrediting Engineering Programs 2007 – 2008 state “Engineering programs must demonstrate that their students attain: an ability to function on multi-disciplinary teams.....and....an ability to communicate effectively.....” [2]. While many faculty and institutions work to make team skills a part of the technical repertoire of the students, the portability of this knowledge is limited as it is difficult to share between institutions.

History attests to the catastrophic consequences of team dysfunctions and neglect of group dynamics. For example the space shuttle Challenger and Columbia tragedies can be attributed to failures in team skills [3]-[5]. The Columbia Accident Investigation Board found that “the hole in the wing of the shuttle was produced not simply by debris, but by holes in organizational decision-making. Furthermore, the factors that produce the holes in organizational decision-making are not unique to today’s NASA or limited to the shuttle program, but are generic vulnerabilities that have contributed to other failures and tragedies across other complex industrial settings” [6].

Such conflicts and team dysfunctions are related to difficulties of team members sharing their perspectives and making tradeoffs [7], [8]. Since engineering teams are often multi-disciplinary, the complex set of problems that engineers face need to combine the expertise of different disciplines. Also, to make the project successful they need to collaborate with others in a team who may have different perspectives and technical objectives. The quality of decision-making in these contexts is enhanced by increasing openness and interdependence, and diminished when team members regulate or ignore certain information [1], [9].

While engineering institutions regularly give students projects involving technical knowledge, all too often students are put in project teams where they are expected to work together successfully without sufficient support in interpersonal and team skills. Mere placement in teams does not guarantee the learning of these skills [8]. This can be improved in engineering education through activities specifically designed to nurture team skills [8], [10].

One solution is the use of a computationally intelligent “virtual facilitator” that contains a subset of the expert knowledge of a skilled facilitator. The “virtual facilitator” models the behaviors of an expert facilitator to engineering student teams as they are working together.

Automated facilitation tools may provide a simplified model for conversational interventions, which students can imitate [8]. Albert Bandura’s theory of social (or observational) learning suggests that skills can be developed

through observation of expert “others” engaged in practice. Bandura’s theory has received a strong support in research on this area. This paper describes the Virtual Facilitator tool and presents findings from its use by several student groups [8].

Albert Bandura’s theory of Social Learning

Given that team skills produce highly beneficial results, the question arises ‘How does someone learn to improve communication skills?’ One possibility is that team skills could be learned in a fashion similar to other skills. The theoretical basis for this study is provided by Bandura’s theory of social learning.

Albert Bandura suggested that individuals learn many skills through a process of modeling, in which behaviors are observed and imitated within a social context [11]-[14].

There are four steps involved in this process:

1. Attention – The first step is paying attention to the actions of another person modeling a behavior [11]-[14].
2. Retention – The second step involves retaining or remembering what one paid attention to. Imagery and language have a significant part to play in this because an individual stores what he has seen the model doing in the form of mental images or verbal descriptions. When stored in this form, he can later recall the image or description, so that he can reproduce it in his own behavior [11]-[14].
3. Reproduction – The ability to reproduce what has been observed and retained results in a more effective learning process. Reproduction is significant because the ability to imitate a behavior improves with practice. People’s abilities improve even by just imagining themselves performing a behavior. [11]-[14]. Many athletes rehearse their performance in their own minds prior to the actual event.
4. Motivation – The final step for learning comes from seeing the model as useful based on its outcomes [3]. If outcomes are perceived as valuable a person will be more likely to pay attention to that behavior because it has personal relevance [6], [15].

Bandura’s theory thus predicts that “individuals in contact with models that produce useful outcomes will pay attention to their behaviors and are more likely to produce similar behavior” [11]-[14].

PROJECT OVERVIEW

The Virtual Facilitator – An Expert Dialogic System

Much learning occurs through the presence of real-life models but with the advancing technology as well as written and audiovisual means of communication, there can be increasing use of audiovisual and computational models that create imitable behavior [11]. Verbal instructions that describe the correct responses and their sequencing comprise

one of the widely prevalent means of providing symbolic models [11].

Abstract theoretical concepts of leadership, management, teamwork, facilitation and communication can be connected to real experience through these ‘symbolic models’ [16]. Model-based activities that enhance such experiences offer valuable opportunities for learning concepts like group facilitation.

(a) *Facilitation for effective team communication*

Group facilitation is a process “in which a person who is acceptable to all members of the group, substantively neutral, and has no decision – making authority intervenes to help a group improve the way it identifies and solves problems and makes decisions, in order to increase the group’s effectiveness” [16].

Researchers in team learning and group development have described “recipes for action” in interventions used for group facilitation [8], [17]. Recipes in this context refer to “relatively simple statements or questions that are triggered by particular words or phrases” [8].

While the literature on team learning and group development acknowledges the existence of “recipes for action” as a platform for mastering intervention skills, previous research on approaches to individual therapy have accounted for a “far richer set of these recipes” [8], [18]. For example, interventions used by experts in organizational facilitation can also be found in the behaviors used in therapy to help individuals surface information [8]. Research conducted with more than 100 virtual teams working in chat space found that teams exposed to these type of interventions performed significantly better than teams that were not exposed” [8], [19].

An increase in team performance has been associated with facilitation [20]. Facilitation encompasses several goals, for example, helping team members to manage conflict effectively and share knowledge and expertise. These goals are achieved by facilitators through an observable process of intervening with questions and comments into group dialogue [11]. Outcomes such as conflict resolution and increased efficacy are expected to be some outcomes of observational/social learning.

Expert facilitation promotes greater shared understanding by:

1. Assisting team members unearth and test negative evaluations of others in the team.
2. Helping team members to reach conclusions and make their emotional reactions explicit, on the basis of their reasoning and data they have.
3. Encouraging everyone in the team to collaborate on team decisions.

Analysis [22] of previous work in this area indicated that teams exposed to interventions exhibited significantly ($p < 0.05$) higher levels of “constructive controversy” [23], a set of behaviors associated with the ability to manage conflict effectively, which is widely associated with improved team

performance. Constructive controversy within a team involves the open-minded sharing of alternative perspectives in order to achieve a cooperative (win-win) solution that accrues benefit to the entire team.

(b) *Virtual Facilitator as Expert System*

The virtual facilitator is a responsive software system that works like a chat space over the internet. It has a dialogue box that lists the names of the team members participating. As with a typical chat tool, conversations appear in the dialogue box. However, it also has a space where system-generated interventions into the team’s conversation appear. The software includes the option of turning these interventions on or off as desired.

The software also has the ability to save the conversations between the team members and generate a transcript listing the detailed timings of the conversations and showing the interventions in a different font and color.

The virtual facilitator automatically “listen” to a team conversation (with the use of notebook computers equipped with microphones and wirelessly interconnected) and then generate a transcription of the conversation (using commercially available speech-recognition systems). Figure I illustrates the system [8].

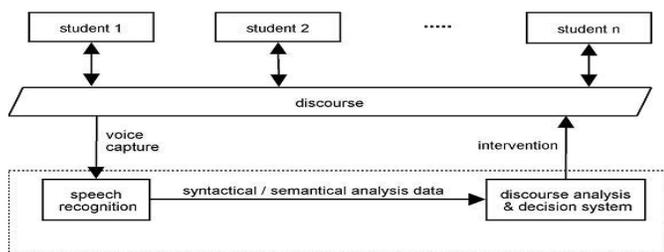


Figure I: Student Team Interaction using the expert dialogic system

When using the system, students participating in a team discussion wear a headset fitted with a microphone that is plugged into a notebook computer [8]. Commercially available speech recognition software converts each individual’s spoken words into text [8]. The Expert Dialogic System connects each individual notebook computer with the others wirelessly and knits together each individual’s text into

a transcription of the group conversation [8].

The virtual facilitator’s main function is to help the group increase its effectiveness by improving its communication skills [17]. It does this by intervening in the conversations that occur between team members.

Interventions are triggered by particular words or phrases in the team conversation. These responses (interventions) are based on rules built into the software. The rules currently in use are based on the work of Chris Argyris. [21], [24]-[26]. They are designed to foster the surfacing of information involved in the dialogues between team members [8].

The rules are stated in terms of IF-THEN relationships [8]. See Table I for the rules currently used.

It has been shown that teams exposed to these specific interventions exhibit greater degree of beneficial team behaviors, such as constructive controversy [23].

Through the process of observing the virtual facilitator generate inquiries into the team’s conversation, it is hypothesized that students can increase level of beneficial team behaviors, such as inquiry. Two specific hypotheses are tested.

1. Students exposed to questions posed by the virtual facilitator (the Treatment group) will ask more questions than those not exposed to it (the Control group).
2. Students exposed to questions posed by the virtual facilitator will exhibit higher performance on a team decision-making exercise than those not exposed to it.

EXERCISE DESCRIPTION

Teams in this research worked through one of two decision making exercises. The exercises involve team decision-making and information sharing as part of a mock engineering and managerial design scenarios.

Description of Simulation Games

A brief description of the simulation games is given below.

1. Solar Car Team – The goal of this game was to make choices of solar car components that would maximize the number of miles the car would be able to travel. Each team consisted of four members representing one department each. The Mechanical Department had to suggest the type of motor to be used from the list of

Situation	Indicators (IF)	Questions (THEN ASK)
Deletion - Clearly and Obviously	-ly ending or "it was clear to me"	What leads you to see it that way? Can you give specific examples?
Deletion - Comparisons	-er, -est, more/less, most/least, etc.	Better (faster, etc.) than what? How, specifically, do you see it this way?
Deletion - Can't, Impossible, and Unable	can't, impossible, unable, no one can	What prevents you from doing so? (Does anyone see things differently?)
Deletion - Advocacy without illustration	"should, must, expect, encourage"	What leads you to see it that way?
Distortion - Forcing or Making	"I had to, you made me, you bore me"	What experience had you had that leads you to believe X? What was done that makes you Y?

TABLE I: EXAMPLES OF IF-THEN RULES

choices, the Electrical Department suggested types of batteries, and the Frame Design department suggested the type of frame and solar cell. Finally, the Cost Management department was charged with ensuring that the car did not exceed the budget.

- Budget Balancing Team – Students participating in this game were given the task of balancing the budget of a fictional company to maximize profit. Each team had four roles, with one member playing each role. The team consisted of the Union Representative whose goal was to protect regular employee interests by limiting layoffs. The Director of Personnel on the other hand had to retain not only employees but also managers from different departments. The Director of Development and the Director of Finance had to retain employees, their own department’s managers and also had to make sure that they had funds for projects.

These two simulation games were conducted with students from four senior/graduate level courses at the University of Missouri – Rolla. These courses were chosen because the advisors of these courses agreed to allow access for an hour for the simulation games. Table II below shows the list of courses and other details.

Course Name	Number of Students	Type of Simulation Game
Project Management	8	Solar Car
Business Logistics & Systems Analysis	16	Budget Balancing
Organizational Psychology	4	Budget Balancing
Psychology of Leadership	4	Budget Balancing

TABLE II: COURSES INVOLVED IN THE RESEARCH

The games were conducted as a virtual team, which meant that members communicated over the internet in chat-space using the Virtual Facilitator.

Each team member was asked to balance personal goals (e.g., retaining as many employees as possible) with group goals (e.g., maximizing profitability). The exercises simulate those real-life scenarios in which personal goals must be weighed against group needs.

Team members were asked to use mathematical, communication, and critical thinking skills to solve problems in such a way that each member could meet a basic level of individual role interests while maximizing team performance. Different team members achieved higher or lower individual goals depending on their ability to communicate and influence others in the team. Teams were required to reach a consensus agreement.

Settings and Treatments

Immediately after entering the laboratory the students were assigned randomly to computer systems. These systems were arranged to have similar kind of departmental

representatives sitting together (e.g. – for the solar car team simulation game the mechanical department members from each team were juxtaposed). Each team member was given a profile sheet which illustrated his or her own specific roles in the team. Also a common sheet which described the team’s goals and the other departments on the team was given to each student.

The participants of the Solar Car and the Budget Balancing games were given forty and thirty minutes respectively to make the first decision and later ten minutes more for improving and making the second decision. At the end of each decision a particular team member was asked to bring the team’s decision sheet and their results were calculated on the spreadsheets that were prepared for each game. After the game the conversations were saved and compared.

Students were divided into two groups -

- The first group (the “treatment group”) received facilitation by the Virtual Facilitator (expert system) throughout the exercise.
- The second group (the “control group”) was not exposed to facilitation by the expert system.

RESULTS

The conversations between the team members were saved and were later evaluated for results of the three hypotheses.

- Number of inquiries during the conversation of each team (see Table III) - A paired comparison T-Test was performed to evaluate whether there was a significant difference in the means of the average number of

Type of Simulation Game	Type of Group – Team #	No. of questions asked	Difference (treatment – control)
Solar Car (Project Management)	Treatment – Team 1	83	10
	Control – Team 2	73	
Business Budgeting (Business Logistics & System Analysis)	Treatment – Team 1	37	11
	Control – Team 2	26	
	Treatment – Team 1	31	2
	Control – Team 2	29	
Business Budgeting (Psychology)	Treatment – Team 1	26	5
	Control – Team 2	21	

TABLE III: RESULTS - NUMBER OF QUESTIONS ASKED

questions asked by the treatment and the control groups. The test was based on the assumption that the two groups have a normally distributed population.

- Quantitative performance of the teams based on the decisions made by each (see Table IV) – A comparison on the basis of the team performance was made. Team performance was measured by evaluating which team reached a greater number of miles/day (Solar Car simulation game) and which team made more profit (Budget Balancing simulation game), without violating the rules and by reaching a consensus.

Type of Simulation Game	Type of Group – Team #	Decision Reached
Solar Car (Project Management)	Treatment – Team 1	346.9 miles/day
	Control – Team 2	352.4 miles/day
Business Budgeting (Business Logistics & System Analysis)	Treatment – Team 1	Loss - \$11,950
	Control – Team 2	Loss - \$17,000
	Treatment – Team 1	Loss - \$11,200
	Control – Team 2	Profit - \$5,000
Business Budgeting (Psychology)	Treatment – Team 1	Loss - \$10,000
	Control – Team 2	No Consensus Reached

TABLE IV: RESULTS – QUANTITATIVE PERFORMANCE

- Conversations were coded based on the degree of Constructive Controversy behaviors [23]. If a positive connotation behavior was reflected it was coded “+1” and a negative connotation behavior received a “-1”. Table V shows a brief description of the behavior. Table VI shows the level of constructive controversy for each team.

Positive Connotation	Negative Connotation
Contributes Ideas & Opinions	Emphasizes win-lose competition
Emphasizes mutual goals	Criticizes and disagrees with others
Asks others for proof, facts & rationale	Criticizes others as persons.

TABLE V: TYPES OF BEHAVIORS

The results of the hypotheses are:

- Hypothesis 1 is supported, with $p = 0.02286 (\leq 0.05)$. There is strong evidence that students exposed to questions posed by the virtual facilitator asked more questions than those not exposed to it.
- Hypothesis 2 was not supported. There was no significant result on whether students exposed to questions posed by

Type of Simulation Game	Type of Group – Team #	Constructive Controversy level	Difference (treatment – control)
Solar Car (Project Management)	Treatment – Team 1	69	60
	Control – Team 2	9	
Business Budgeting (Business Logistics & System Analysis)	Treatment – Team 1	64	25
	Control – Team 2	39	
	Treatment – Team 1	42	-20
	Control – Team 2	62	
Business Budgeting (Psychology)	Treatment – Team 1	34	2
	Control – Team 2	32	

TABLE VI: RESULTS – CONSTRUCTIVE CONTROVERSY LEVEL

the virtual facilitator exhibited higher performance on a team decision-making exercise than those not exposed to it.

- Hypothesis 3 is not supported, with $p = 0.19971 (\geq 0.05)$. There is not strong evidence to indicate that students exposed to questions posed by the virtual facilitator showed a higher level of constructive controversy.

DISCUSSION

Earlier work [19] showed that student team performance could be significantly improved ($p < 0.05$) by applying a set of basic interventions, which have now been embedded in the proof-of-concept virtual facilitator. This work investigated the effect of manually typing the interventions triggered by these rules into a chat room used by student teams as they worked on a team problem-solving exercise in cyberspace. The results indicated that interjecting these interventions into team conversations significantly improved team performance by around a half-sigma.

The previous results were obtained with a much larger sample size. Because the deviation of performance and constructive controversy results was quite large, it is understandable that the results of this research would not show statistically significant effects.

CONCLUSIONS

As an investigation of Bandura’s Observational Learning theory, this study tested the effect of inquiry on the team members. Results supported one of our hypotheses. These results have two implications.

The expert dialogic system increased beneficial team behaviors. The Virtual Facilitator does appear to modify behavior by increasing the frequency of inquiry. While not conclusive, this indicates the possibility of observational learning.

This implies that learning inquiry is like many other human behaviors, and can occur through observational learning.

These results suggest that additional research is necessary to further study the effects of an expert dialogic system on team behavior and performance. Some avenues to explore include –

1. Using the virtual facilitator during face to face “spoken” team meetings by converting the conversations between the team members into written scripts for evaluation.
2. Further developing intervention rules by adding more complex rules or by adding rules from other experts.
3. Incorporating emotional components of communication between team members. The system has the capability to incorporate recognition of words and phrases with emotional attributes and to inquire accordingly into the discussion.

ACKNOWLEDGMENT

We gratefully acknowledge support of this research through NSF Award No. EEC - 0644917.

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