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Training for Self-Managed Student Teams*

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A self-managed team is one that is empowered to determine structure, processes, assessments and corrections as it performs assigned tasks. The autonomy of these teams is needed in flat organizational structures or environments with limited hierarchy. Little research has focused on the antecedents of self-management in teams, especially in engineering and engineering education. This work links self-managed, autonomous team behavior and double-loop learning as described by Argyris in conjunction with Hackman's model of effective teamwork. Traditional methods of team training are contrasted with a double-loop training approach. A differentiated training program was used among freshman engineering design teams in a required, introductory course to determine whether a particular type of team training increased students' ability to be self-managing. Self-management characteristics were observed in this engineering environment. The suitability of a double-loop training approach within undergraduate engineering education is discussed.

Keywords: Engineering education, self-managing work teams, double-loop learning, mutual learning model.

INTRODUCTION

ACCORDING TO JEFFREY PFEFFER *in The Human Equation,* 'Organizing people into self-managed teams is a critical component of virtually all high performance management systems' [1]. A self-managed team is one that is empowered to determine structure, processes, assessments and corrections as it performs assigned tasks [2]. Such a team is highly autonomous. The guidance functions that are provided by management in more hierarchical organizations are performed by the team itself. Therefore, not only do self-managing teams have to plan and perform tasks, but they are also required to autonomously promote reflection, learning and change. While there have been calls for engineering students to engage in peer evaluation to detect failures in performance [e.g. 3], simply noticing and correcting errors is not adequate for self-managing teams to function effectively. Rather, they must engage in double-loop learning, a process that occurs when teams reflect on and alter the values that are directing their behavior [4, 5].

Double-loop learning results from behavior based on Mutual Learning values (also known as Model II values) [4, 5]. The governing values of these behaviors are valid information, the promotion of informed choice by participants and vigilant monitoring of the effectiveness of implemented actions.

Self-managed engineering teams are implemented as organizational structures adapt to economic and cultural shifts. These are particularly important as engineers are increasingly called upon to work in global, virtual teams [6]. Consequently, engineering students need new skills to be effective members of these self-managing teams. There has been limited recognition of the similarities between in-class student project teams and workplace self-managing teams in the engineering education literature. More importantly, most literature on self-managing teams provides little insight for how engineering educators may enable students to become effective members of these teams. The questions this paper investigates are, 'How can educators train students to promote effective self-managing teams?' and, in particular, 'What will promote double-loop learning among students teams?' More specifically, it investigates whether specific types of team training activities may increase the degree of self-management in engineering undergraduates.

This work describes the increasing importance of self-managed teams and the characteristics of effective engineering teams using Hackman's model of effective teams. The role of double-loop learning as defined by Argyris is linked to self-managed team behaviors. Traditional approaches of team training are contrasted with an approach based on double-loop learning and Argyris' mutual learning values. Differentiated training is investigated for freshman undergraduates in a required team-based course on engineering design. Eleven teams received training based on Mutual Learning values and eleven teams received training based on traditional approaches to team training. Self-reported surveys addressing student attitudes related to self-management were used as an assessment and issues for further research are identified. Recommendations for applying double-loop team-training approaches in engineering education are given, including approaches to evaluation and measures of performance.

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Table 1. Characteristics of teams

Characteristics of Self-Managing Teams in the Workplace	Characteristics of Student Project Teams in Universities
Initiated by organizational hierarchy	Teams organized by course instructor
Responsible for completing an entire task	Independent teams responsible for completing a specified project
Responsible for deciding how to complete the task	Responsible for choosing roles, dividing responsibilities, coordinating overlapping work, etc.

ORGANIZATIONAL AND EDUCATIONAL SELF-MANAGED TEAMS

The increasing reliance on self-managed teams represents a shift in management philosophy. The hierarchical structures of past decades are transitioning to participative management trends of the current era. This new environment represents the future work context of today's engineering students. Part of the shift in the United States is out of economic necessity resulting from recent global competition [7]. Another component of the transition stems from the cultural shift from modernism to post-modernism. A 'post-modern organization may be defined as that comprising a networked set of a diverse, self-managed, self-controlled teams . . . these teams are organized in flat design, employees are highly empowered and involved in the job, information is fluid and continuous improvement is emphasized throughout' [8]. These changes are reflected in the empirical evidence as well. Lawler and Associates found that 68 per cent of Fortune 1000 companies use self-managed teams in 1993, up from 28 per cent in 1987 [9]. Students in today's classroom will be members of tomorrow's self-managing teams.

But perhaps students are already members of today's self-managing teams. A review of the literature reveals a focus on industry-related self-managed teams rather than on self-management by students. This suggests educators are missing a crucial connection. Students are often grouped into project teams of 3–6 students, instructed to organize and self-determine roles, and given a task with a definite due date. When this occurs, students are actually being placed in self-managed teams. Table 1 illustrates the similarities between self-managing teams and student project teams.

HACKMAN'S MODEL OF EFFECTIVE TEAMS

The circumstances students encounter in their project teams are similar to those they will face after graduation, which provides educators with an excellent opportunity to provide the often requested 'real-life' experience. While problems may be different in an academic setting, the processes students employ to resolve issues will be similar to those they use in the workplace. The research question this paper investigates is, 'How can educators train students to promote effective self-managing teams?'

'A manager who wants a team task done well cannot simply call some people together, toss them a task, and hope for the best' [2]. The same could be said for educators. Unfortunately, this is the approach many instructors adapt in an effort to promote teamwork. Instructors often give team projects in an effort to help students learn effective teamwork skills, but this practice alone does not teach team dynamics [10]. Hackman [11] assesses the effectiveness of self-managing teams by:

1) the degree to which the team's productive output meets the requirements of the customer;
2) the degree to which the process of carrying out the work enhances the capability of the team to work interdependently in the future;
3) the degree to which the team experience contributes to the growth and personal well-being of the team members.

Accomplishing these three components requires significant support from the organization that initiates the self-managing team. Hackman's four stage model [2] raises issues to consider when creating and nurturing teams.

Stage 1: Prework

1. What is the task?
2. What are the critical task demands?
3. Will the team be manager-led, self-managing, or self-designing?
4. Overall, how advantageous is it to assign the work to a team? How feasible is it?

Stage 2: Creating Performance Conditions

5. How should the team be composed and the task structured?
6. What contextual supports and resources must be provided?

Stage 3: Forming and Building the Team

7. How can a team be helped to get off to a good start?

Stage 4: Providing On-Going Assistance

8. How can opportunities be provided for the team to renegotiate its design and context?
9. What process assistance can be provided to promote positive team synergy?
10. How can the team be helped to learn from its experiences?

In the context of self-managing student teams, questions 1–4 are determined by the instructor before the team is created. Questions 5–10 involve an interaction between the team and the instructor to promote team effectiveness. These last six questions also require the self-managing team to act, reflect, learn and change; an unfamiliar process for most student teams.

STUDENT TEAMS AND AUTONOMY

In research on manufacturing facilities, Banker [12] delineates types of teams based on team autonomy, a measure of the independence or self-sufficiency of a team, as shown below in Figure 1.

Compared to other types of teams, self-managing teams are relatively high on the scale of team autonomy and can be identified by two important criteria. First, self-managing teams are collectively responsible for completing a task or delivering a product. Typically, the team is created higher in the organizational structure in response to an internal or external need perceived by management. Second, self-managing teams are given the responsibility to decide how to accomplish the required assignment [13]. This characteristic is manifested as members self-regulate the team's interdependent tasks, such as planning, performing and assessing work [7]. Hackman [2] summarizes the actions of self-managed teams as monitoring and managing performance processes and executing the task. In contrast, Traditional Work groups have very little to no management responsibility or decision-making ability. At the highest end of the spectrum, Self-Designing Teams have all of the characteristics of self-managing teams but also determine which tasks must be accomplished and who belongs to the team [12].

DOUBLE-LOOP LEARNING FOR EFFECTIVE SELF-MANAGEMENT

The responsibilities of self-managing teams suggest that members engage in a process called double-loop learning. Single-loop learning occurs when individuals recognize an error and take corrective action. Double-loop learning describes the process of rethinking the assumptions or beliefs that guide behavior and action. Consider the following example:

> A person engages in single-loop learning, for example, when he learns new techniques for suppressing conflict. He engages in double-loop learning when he learns to be concerned with the surfacing and resolution of conflict rather than with its suppression. [4]

Double-loop learning allows teams to examine and alter the beliefs and assumptions that guide action. In teams with low autonomy, managers or supervisors provide this guidance whereas autonomous teams must guide themselves without oversight. Single-loop learning cannot provide the guidance self-managing teams require because it does not consider the governing values that determine action. If the self-managed team must determine the values it will use to lead itself but its learning loop does not include this component, 'attempts to solve technical or interpersonal issues will be ineffective' [5]. Figure 2 illustrates where corrective reflection and learning occur for both single- and double-loop learning [14].

Argyris states that double-loop learning 'should decrease dysfunctional group dynamics because the competitive win/lose, low-trust, low-risk-taking processes are replaced by cooperative,

Traditional Work Groups	Quality Circles	High Performance Work Teams	Semi-Autonomous Work Groups	Self-Managing Teams	Self-Designing Teams
Low Team Autonomy	←			→	High Team Autonomy

Fig. 1. Team autonomy continuum [12].

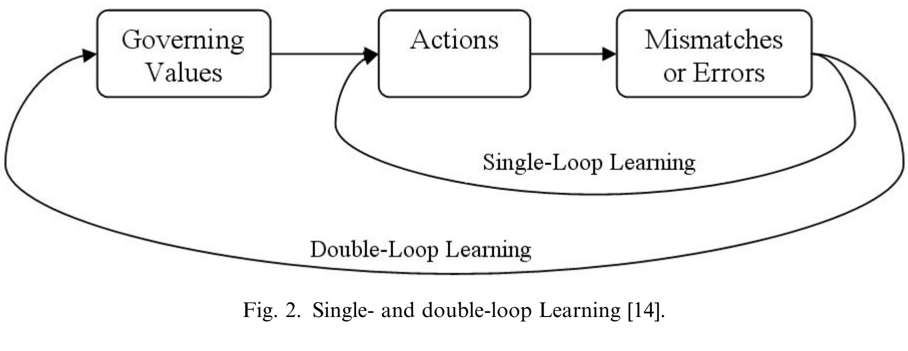

Fig. 2. Single- and double-loop Learning [14].

Table 2. Unilateral action model governing values

1. Attempt to be in unilateral control over others
2. Strive to win and minimize losing
3. Suppress negative feelings
4. Act in ways that minimize the possibility of being held responsible for making others defensive

Table 3. Mutual learning model governing values

1. Produce valid information
2. Promote informed choice
3. Vigilantly monitor the effectiveness of implemented actions

inquiry oriented, high-trust and high-risk taking dynamics' [14]. Helping self-managed teams engage in double-loop learning requires that individuals reflect on the values and strategies that guide their behavior.

Argyris and Schön state that people have theories that guide their deliberate behavior called Theories of Action [4]. They differentiate between a person's 'espoused theory' (what they say they do) and a person's 'theory-in-use' (what they actually do). Argyris and Schön defined two models of theories-in-use, each with their own governing values that shape behavior. The Unilateral Action Model (also called Model I) has the governing values shown in Table 2. Across gender, ethnic and educational lines, nearly every person Argyris has studied held the Unilateral Action theory-in-use [4, pg. xxii]. Of the thousands of people involved in his research, nearly every one acted according to a model that prevents effective decision-making and double-loop learning. To address these problems, Argyris recommends an alternative, the Mutual Learning Model (also called Model II). The Mutual Learning Model is a theory-in-use that produces behavior in accordance with the governing values illustrated in Table 3.

Individuals operating under Unilateral Action values create action that only allows single-loop learning [4]. Adopting the Mutual Learning values allows teams to engage in both single- and double-loop learning. Teams guided by Mutual Learning values could promote and benefit from double-loop learning in several specific situations.

Planning

Facing a strict deadline, a team member estimates a critical task will take five days to complete. At the end of the fifth day, the task is only 40 per cent accomplished and the member has no explanation for the delay. Teams using single-loop learning would recognize this error and ask, 'Do we need to assign more people or resources to future tasks?' or 'How can we produce better time estimates?' Double-loop learning would ask, 'What led the planner to underestimate the duration?' or 'What prevented the team from asking for additional resources when the task first fell behind?' to prevent similar situations from reoccurring.

Execution

When determining who will be responsible for completing a task, team members may act unilaterally to accomplish hidden agendas. Often, an individual volunteers to complete work as a method of controlling the outcome. If a team is only capable of engaging in single-loop learning, this domination will remain latent so long as the individual performs adequately. However, if team skills are able to create double-loop learning, the team may inquire, 'What causes you to undertake an inequitable amount of work?' Doing so may uncover a problem with the perceived abilities of the team or the goals of the person claiming the work. Single-loop learning conceals these issues from team awareness.

Team assessment

A difficult challenge for any team is providing honest, constructive feedback. At the end of a project, several members suggest that the team has worked well together and that 'no one wants an uncomfortable atmosphere'. Single-loop learning examines 'How can I minimize hostility?' or even 'How can I vent my frustration without negative repercussions?' Exemplars of double-loop learning might include 'What prevented the team from providing feedback during the project?' and 'How can we promote valid information about our performance?'

In addition to these specific areas, all of the questions contained in Hackman's fourth stage, 'Providing On-Going Assistance', indicate areas in need of double-loop learning. Question 10 ('How can the team be helped to learn from its experiences?') is the most noticeable appeal for double-loop learning because it asks how the team will learn from its experience. It is apparent that single-loop learning is beneficial for solving the presenting problem, but insufficient for answering why the problem occurred in the first place [14]. Given this, self-managing teams in all organizational and educational contexts would be greatly assisted by acquiring skills that encourage double-loop learning.

DIFFERENTIATED TRAINING PROGRAM

The original research question, 'How can educators train students to promote effective self-managing teams?' can be answered, 'By helping students engage in double-loop learning'. Accordingly, the next question in the research became, 'What will promote double-loop learning?' This issue is at the core of Hackman's sixth question, 'What contextual supports and resources must be provided?'

There is little disagreement that team training is a positive addition to engineering coursework, but there have been few comparisons between different approaches to supplying that education. In general, research has focused on assigning members to teams based on particular characteristics [15] or on evaluating the effectiveness of a particular team skill education program [e.g., 16, 17]. For this study, the researchers implemented a differentiated training program to determine whether one type of instruction was more useful for helping students practice double-loop learning. This is an extension of previous work that investigated a small sample of student teams [18].

Two forms of training were delivered to two groups of students simultaneously. The traditional training was delivered in six modules that covered topics typically suggested as being essential for team functioning [19]. Information in the six modules was consistent with the instruction given in a typical organizational behavior textbook:

- Practising effective listening.
- Communicating across cultures.
- Understanding the differences between facts and inferences.
- Building trust.
- Resolving conflict.
- The problem-solving process.

In addition to these six modules, one additional training exercise was conducted to help students build trust within their teams. Homework was assigned each week to help students apply the instruction to their specific team situations. The content and approach of the traditional training was consistent with typical team education.

The second form of training utilized an action science approach to improving team skills based on the mutual learning values. Action science aims to help engineering teams critically reflect and inquire into the social and technical aspects of their team [20]. A seven-module version of Rossmoore's [21] approach to developing these skills based on mutual learning values was given:

- The ladder of inference.
- Directly observable data.
- Heuristics for inquiry.
- Advocate, illustrate, inquire.
- Effective inquiry.
- Self-censorship and circular causality.
- Confrontability.

The mutual learning training also included homework assignments intended to help students implement the training ideas in their own team.

One of the greatest distinctions between the traditional and mutual learning training is that the traditional training emphasizes the description of how things are while the action science training emphasizes understanding how things may change. For example, while the Traditional training focuses on how to evaluate team members at the end of the project, the mutual learning training encourages teams to understand what would prevent evaluation from occurring throughout the project and how that might be changed. Another important difference is that mutual learning training places a high value on the specifics of interaction whereas traditional training focuses on abstractions. For example, traditional training emphasizes giving feedback to improve performance. The mutual learning training is concerned with what specifically was said during the feedback process and the thoughts and words the recipient had in response [18]. Action science training has been shown to improve a variety of team effectiveness measures, including constructive controversy, in previous studies [22, 23].

EXPERIMENTAL ENVIRONMENT

All freshmen planning to major in engineering at the Missouri University of Science & Technology are required to take an introductory design course, Engineering Design with Computer Applications [24]. There are two primary components in the class, a design project and engineering software curriculum. Sixty per cent of a student's overall grade is related to team performance on the design project.

In the fall 2005, a study was conducted with 303 participants of the IDE 20 classes. Differentiated team training was given to students in two sections taught by the same instructor. Between weeks 4–12 of the semester, seven fifteen-minute training sessions were delivered by graduate students to the appropriate section. Training based on mutual learning values was given to one section of the course, totalling 44 students. Training based on Traditional team theory was given to 44 students in the second section. A control group was also surveyed from five different instructors who taught multiple sections. Demographic data indicates 17 per cent of survey respondents were female and 94 per cent were between the ages 18–20.

The design challenge for the student teams was to develop a prototype capable of retrieving ball bearings from the bottom of a simulated riverbed. The ball bearings varied in size and magnetic properties. After set-up, students were given two minutes to retrieve as many ball bearings as possible from a tank approximately 4 ft long, 2 ft wide and 2 ft deep. Points were allocated to teams based on the number and types of bearings retrieved. Throughout the course of the semester, students were also responsible for developing preliminary designs, submitting written reports and assessing the contribution of other members.

SELF-MANAGEMENT ASSESSMENT

To assess whether or not the differentiated training program promoted self-managing teams, the researchers returned to Hackman's definition of team effectiveness.

Table 4. Statistical summary

Treatment Group	Measure	Mutual Learning	Traditional	Control	Median	Test Statistic (1-Tailed Sig)
Job Autonomy	# > Median	11	6	65	3.50	0.157
	# = Median	11	14	72		
	Mean	3.58	3.48	3.49		
Role-Breadth Self-Efficacy	# > Median	7	10	45	4.00	0.257
	# < = Median	13	12	92		
	Mean	4.08	3.90	3.84		
Flexible Role Orientation	# > Median	6	12	68	3.75	0.105
	# < = Median	14	10	69		
	Mean	3.82	3.76	3.83		

The second criteria contains the primary hypothesis of this work, that students given training based on Mutual Learning values will exhibit higher levels of self-management than students receiving traditional training and students receiving no training. Self-management was assessed using adaptations of Parker's [25] job autonomy, role-breadth self-efficacy and flexible role orientation measures. Students responded to the survey questions shown below using a five-point Likert scale:

Job Autonomy (response options: 1 = 'not at all' to 5 = 'a great deal').

- To what extent do you help to decide how much work your team will do?
- To what extent do you help to divide work among team members?
- To what extent do you get involved in team improvement?
- To what extent do you help to monitor your team's overall performance?
- To what extent do you get involved in the discipline of other team members?
- To what extent do you manage the budget or schedule of your team?

Role-Breadth Self-Efficacy (response options: 1 = 'not at all confident' to 5 = 'very confident').

- How confident would you feel helping to set targets for the team?
- How confident would you feel analyzing a long-term problem to find a solution?
- How confident would you feel representing your team in meetings with faculty?

Flexible Role Orientation (response options: 1 = 'of no concern to me' to 5 = 'most certainly of concern to me').

- If some members of your team were not pulling their weight, would this be a personal concern or 'someone else's' concern?
- If some members of your team were not coordinating their efforts, would this be a personal concern or 'someone else's' concern?
- If the way things were done in your team meant unnecessary work, would this be a personal concern or 'someone else's' concern?
- If the level of absence in your team was increasing, would this be a personal concern or 'someone else's' concern?

The job autonomy measure is the central focus of this study because it asks questions that are based on the actions students have taken in their teams. In contrast, the other two measures inquire into self-managing behaviors in the future. Surveys measuring reasons for learning, learning climate, goal interdependence, constructive controversy, tolerance for ambiguity, and locus of control were administered to students but did not show significant differences between the test groups [26–29].

A non-parametric median test was used to analyze the data. This is an appropriate test because the type of training is a nominal variable, not a scaled variable. Since it was anticipated that different types of team training would produce varying degrees of self-management between groups, a median test was chosen over the Kruskall-Wallis test because the survey responses were scaled, not nominal. One-tailed significance values are represented as the test statistic below. Table 4 summarizes the means and significance values of the three self-management measures:

Originally, the researchers planned to measure the first criteria based on the number of bearings the prototypes could retrieve. It was decided that this measure should not be used for two reasons. First, instructors had different policies that influenced the difficulty of retrieving the bearings. Second, the instructors suggested that this was not a fair measure of team performance. The final aspect of Hackman's criteria was not measured in this research.

DISCUSSION OF RESULTS

Although not statistically significant, student responses indicate higher degrees of self-management among the teams that received mutual learning training. None of the measures provided statistically significant evidence at the $p < 0.05$ to indicate that the group differences shown in Figure

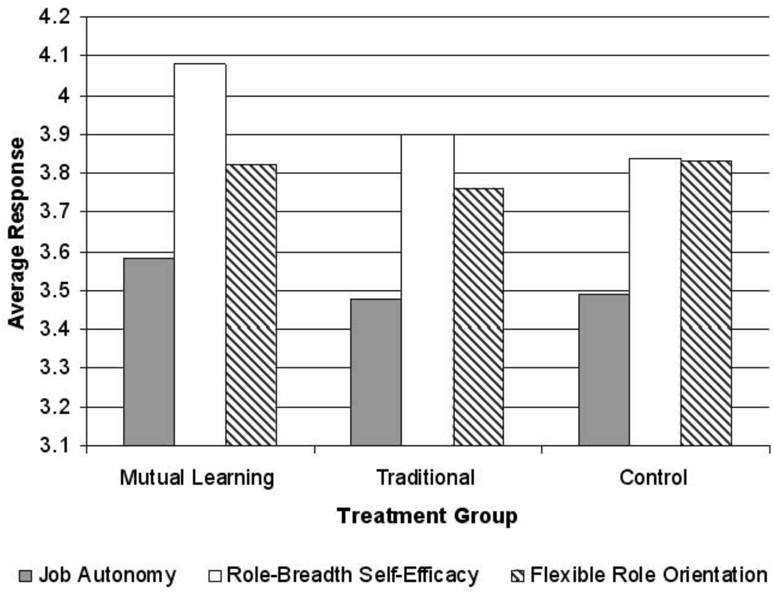

Fig 3. Group means from self-management survey.

3 were due to the differentiated training program. For both Job Autonomy and Role-Breadth Self-Efficacy, the Mutual Learning treatment indicated better results than the Traditional training or the Control group. For the Flexible Role Orientation measure, the Traditional group responded lower than both the Mutual Learning and Control groups.

The differences between groups for all three measures vary by less than six per cent. Extreme deviations in levels of self-management would be suspect since the team training was delivered in less than two contact hours total. It is interesting that despite such minimal contact, differences in means exist between the Mutual Learning group and Placebo/Control groups.

RESEARCH CONCERNS

There is concern among the researchers about the ability of freshman who have rarely, if ever, been in a team setting to engage in double-loop learning within the first months of college. Consider the comment sent by one student:

> And, no, I do not want to speak with you or email you about why I think these exercises are pointless. I really like you as a person, but I think the homework you give our class is way too strenuous and is just 'busy work'. . . . The activities are strenuous and annoying . . . At a college level, I think the material you instruct us with is just something to use time. This might be effective at a middle school level . . . but not for college . . . I just summed up what the entire class thinks about your exercises.

That same semester, similar training was being conducted with graduate and senior-level students. In general, the authors' believe these students had a different response to the training program, as exemplified in the following comment:

> I feel the information that you have been presenting will be useful in creating good working relationships. I was wondering if you could provide me with the references you have been using to base your modules on. I would like to read up and due some further study on some of these techniques in my personal time.

Several theories exist for the perceived difference. One is that the younger students are less behaviorally developed and less capable of reflection. Another hypothesis is that first-semester freshman have not yet had a 'bad' team experience which would cause them to want to improve team functioning. Related research with older students has indicated improvements in team functioning that were not observed with these students [23].

Team training is also influenced by the quality of team design. Effective team coaching has a greater impact among teams that were well designed than among teams which are poorly designed [30]. These findings suggest the effectiveness of any training program is related to a factor outside of the control of this study.

LIMITATIONS AND FUTURE RESEARCH

The study is limited by several factors the researchers will address in future iterations of this work. All of the data in this paper are based on first-semester freshman at an engineering university. Similar research should be performed across a variety of ages and disciplines. In addition, the number of respondents to the surveys used for this paper was approximately half of the students who had responded to a different survey earlier in the semester. A larger sample size may have given increased reliability to our findings.

In the future, the researchers desire to evaluate self-managing team effectiveness using the Team Diagnostic Survey [31]. This tool was published after this research ended, but the researchers plan to use it in the future to provide a robust assessment of team functioning. The authors also plan to measure double-loop learning through qualitative assessment. For instance, students might be asked, 'Describe a problem your team is facing and how you are working to solve it'. Responses will be coded based on single- and double-loop learning behaviors and compared between treatment groups.

Argyris writes that 'few subjects are interested in genuinely new options [double-loop learning], especially if learning them may be difficult and if having learned them there is little support from . . . peers, and superiors, as well as from organizational policies and practices to use the new skills' [32]. Perhaps the greatest difficulty with the Mutual Learning training is assessing the degree students are actually using it in team interactions. Even if students claim to 'value' and 'appreciate', or even 'benefit' and 'use', the Mutual Learning training, this assertion is an example of an espoused theory, not an observation of a theory-in-use.

The researchers are interested in the relationship between personality assessment and self-management. Continuing research will utilize the 'big five' personality markers and the subjects' age to determine the degree to which these characteristics affect self-management.

The development of self-management skills is of vital importance to the goal of improving the ability of engineering graduates to function effectively in the complex and dynamic organizations of the future. The capacity to engage in double-loop learning could be a key skill that can be taught as part of a competency-based model of education [33] to develop these abilities among engineering students.

CONCLUSIONS AND RECOMMENDATIONS

The research in this paper was initiated to explore the link between self-managed teams and Argyris' concept of double-loop learning. This connection provides a framework for training students to function in self-managed teams. In addition, this paper helps educators recognize student project teams as an opportunity to provide students with experiences they will encounter upon graduation.

Self-managing teams must function autonomously, internally providing the guidance and oversight once reserved for outside supervisors. As such, these teams must look inward to identify and eliminate ongoing problems. Argyris says, 'Most people define learning too narrowly, as mere "problem-solving", so they focus on identifying and correcting errors in the external environment. Solving problems is important. But if learning is to persist, managers and employees must also look inward. They need to reflect critically on their own behavior, identify the ways they often inadvertently contribute to the organization's problems, and then change how they act' [34]. The mutual learning training approach identified in this paper is grounded in creating this type of double-loop learning.

The experimental results reveal trends indicating that teams receiving training based on mutual learning values are more self-managing than teams that receive traditional or no training. While the initial results are interesting, they are not strong enough to confidently say the mutual learning training is the reason one section of students exhibited higher degrees of self-management. Improvements in future research include increasing the sample size, measuring the quality of team design and assessing multiple aspects of team performance. With these changes, the existence of links between training, double-loop learning and self-management should be more clear.

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