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The Impact of Structured Writing and Developing Awareness of Learning Preferences on the Performance and Attitudes of Engineering Teams

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ABSTRACT

This paper discusses efforts to develop metacognition in teams of engineering students by: first, exploring personal learning patterns, and second, ongoing biweekly journaling exercises. Thirty-three junior and senior engineering students (30 chemical engineer, one each from mechanical, civil and electrical) working on semester-long projects in the Rowan Engineering Clinics were broken into four groups. Members of the first determined their learning patterns by taking the Learning Connections Inventory (LCI) then met with faculty advisors to discuss their patterns and those of their teammates. The second group performed structured writing assignments focusing on team dynamics and logistical barriers to success. The third received both LCI instruction and the writing assignments, while the fourth received neither. Students who received instruction on their own learning patterns as well as those of their teammates performed better on semester-long team projects and reported a significant improvement in their attitude towards teaming skills. Structured writing assignments focusing on team dynamics also seemed to benefit performance, but were less popular with the students.

Keywords: learning connections inventory (LCI), teaming, team dynamics, metacognition, writing

INTRODUCTION

The term “metacognition” describes a learning process in which the learner is conscious of how he/she learns [1]. A metacognitive learner is one who understands how he/she learns and consciously uses this knowledge to facilitate learning [2,3]. The value of instilling metacognition in students has long been recognized; a 1984 Study Group on the Conditions of Excellence in American Higher Education, for example, stated:

> There is now a good deal of research evidence to suggest that the more time and effort students invest in the learning process and the more intensely they engage in their own education, the greater will be their satisfaction with their educational experiences, their persistence in college, and the more likely they are to continue their learning [4].

This paper explores methods of instilling metacognition in engineering students in a team-based, project setting. It builds upon a pilot study published in *Chemical Engineering Education* in 2004 [5].

Let Me Learn®

The Let Me Learn (LML) process is a comprehensive strategy for building metacognitive practice in students. It was developed by Dr. Christine Johnston and is described in detail in her 1998 book [6]. The process begins by having students take the Learning Connections Inventory (LCI), a self-report instrument that characterizes a student's combination of learning preferences with respect to four distinct (discrete) learning patterns. Studies validating the LCI as an instrument are summarized on the LML web site at http://www.letmelearn.org [7]. The four patterns are: sequence, precision, technical reasoning, and confluence.

- *Sequence* refers to organization, structure, and step-by-step directions. Individuals who use this pattern tend to be well organized and meet deadlines reliably, but may be intimidated by open-ended projects.
- *Precision* refers to needing detail, specifics, and information. Individuals who use this pattern tend to take extensive notes, speak and write with high levels of detail, and choose their words carefully even in informal settings.
- *Technical Reasoning* refers to problem-solving by understanding function and active work rather than through the use of words. Individuals who use this pattern typically like to work in a lab or shop, often dislike abstract material and demand a practical application for everything. They value accomplishment and hands-on learning but don't necessarily value demonstrating their knowledge to others.
- *Confluence* refers to rapid generation of ideas and risk taking. Individuals who use this pattern tend to find detailed instructions confining, preferring to do things their own way. They are generally vocal participants in all activities and do not fear failure.

All learners are capable of using any or all of these patterns, but individuals have preferences which the LCI quantifies as a number in the range 7–35. Each individual pattern is measured along a continuum of "use first (25–35)," "use as needed (18–24)," or "avoid (7–17)." Once an individual understands the four patterns and his or her own preferences for using or avoiding them, he or she can:

- Identify tasks that require use of, or avoidance of, particular patterns.
- Intensify the use of patterns that he or she prefers to avoid but needs for particular tasks.
- Tether the use of preferred but task-inappropriate patterns.
- Understand, appreciate, and value peers who have different learning patterns.
- Formulate effective strategies for group tasks, based on individual learning patterns.

LML has been implemented by hundreds of teachers with thousands of K-12 students, demonstrating that children as young as six years old can learn to do these things; and that the process improves learning, students' attitudes toward school and working relationships with peers and teachers [6].

Role of LML in the Engineering Curriculum

To date, the authors are aware of no applications of LML in engineering education outside Rowan University. Numerous authors have used instruments such as the Myers-Briggs Type Indicator [8] or the Felder-Silverman Model [9,10] to characterize student learning styles and have applied the concept of learning styles to various aspects of engineering education. An excellent summary of this work is given by Felder and Brent [11]. These studies demonstrate [9,10,12,13] that the traditional lecture mode of instruction is much better for students with certain personalities and learning styles (e.g., sequential, intuitor). The focus in these studies tends to be on the instructor: The studies present teaching methods that engage all learning styles and show that students benefit from such methods [14]. The LML process is complementary to the previous work in that it is student-centered: the focus is on empowering students to *consciously and effectively control* their learning patterns. The differences between LML and learning style models are discussed extensively in Dr. Johnston's book [6].

This study examined the effect of implementing LML in a project-based engineering course. Engineering students tend to lead with the technical pattern (Table 1 summarizes the patterns of the Rowan class of 2006, and all cohorts that were tested have been similar) and this study was intended to address specific challenges associated with technical learners. While technical reasoning serves engineering students well in many respects, two common attributes [6,7] of technical learners are:

- They often prefer to work alone.
- They often have an aversion to writing.

These tendencies of technical learners have significant implications for the engineering curriculum. There is extensive literature [15–18] demonstrating the importance and benefits of teaming in the engineering curriculum, and also demonstrating that interpersonal and teaming skills are

	Sequence	Precision	Technical Reasoning	Confluence
Mean Score	25.9	20.9	29.8	22.0
% Students in "Use First" range (25–35)	62.5	22.5	91.3	26.3
% Students in "Avoid" range (7–17)	2.5	21.3	0	11.3

Table 1: Summary of learning patterns for 80 students in the Rowan Engineering class of 2006.

highly valued by practicing engineers and by employers [18,19]. Since 2000, ABET has specifically required an emphasis on communication skills and teaming skills in all engineering programs [20]. As a result, many engineering programs now incorporate writing-to-learn in their curricula [21–25]. But these vital skills are unappreciated by many engineering students, whose preferred learning patterns as measured by the LCI make them likely to resist activities that involve writing and teaming.

This study was a design experiment examining the effect of implementing LML in a project-based course, both with and without targeted writing exercises. The next section describes the course in which the experiment was conducted.

Junior/Senior Engineering Clinic

The project was carried out through the Junior/Senior Engineering Clinic. The Rowan Clinic program has been described in detail previously [26,27]. Briefly, Junior/Senior Engineering Clinic is a course in which teams of engineering students conduct semester-long and sometimes multi-year projects, many of which are sponsored by local industry. While the Sophomore Engineering Clinic provides an introduction to open-ended design problems, the Junior/Senior Engineering Clinic presents students with real research, design, and product development challenges; including accountability to real, external sponsors. The Junior/Senior Clinic thus provides an exciting and meaningful learning experience, but one fraught with challenges that students are typically encountering for the first time.

The LCI provides a context for understanding some of the barriers to effective learning and effective teaming. For example, the highly sequential learner's preference for order, planning, and consistency is in sharp contrast with the highly confluent learner's desire to try new ideas and willingness to take risks. The skill sets are complementary if used effectively. However, the potential for conflict is clearly present and is likely heightened by the intense, unfamiliar and often unpredictable environment of Junior/Senior Clinic. Another notable barrier to team success is the technical learner's aversion to writing. For example, a technical learner is likely adept at conducting hands-on experiments and is likely to learn a great deal from them. However, he/she is not necessarily adept at, and unlikely to place great value on, the activity of communicating what was learned to others. Yet in a Junior/Senior Clinic project, the final report is generally the primary vehicle by which the sponsors receive value from the project.

In the fall of 2003, a small sample of clinic teams within the chemical engineering department was given some basic LCI training and exposed to a series of structured writing assignments, in an attempt to instill metacognitive behaviors that would help teams overcome the obstacles described previously. This preliminary study, published in *Chemical Engineering Education* in 2004 [5], was encouraging, but the results were qualitative and anecdotal. Here we describe a more formalized design experiment intended to measure directly the impact of LML, with and without structured writing assignments, on the students' performance on team projects, as well as their attitude towards teaming.

EXPERIMENTAL

During the fall semester of 2004, 11 engineering teams in the Junior/Senior Engineering Clinics were broken into four categories, with two or three teams in each category.

- Category I teams received instruction in the use of the LCI, and met with a facilitator and their teammates to examine their LCI profiles. In this meeting, potential areas for future conflict were discussed, and the teams developed strategies to avoid these conflicts.
- Category II teams received no LCI instruction but participated in a series of structured writing assignments designed to encourage continuous, active reflection on the project and barriers to its completion. These assignments included developing and ratifying a team charter, and submitting biweekly reports on barriers to success and team dynamics.
- Category III teams both received the LCI training and participated in the structured writing assignments.
- Category IV teams served as a comparison group and participated in none of the activities.

The assignment of students to teams was completed before any LCI data was collected, and teams were assigned to meet the needs of the industrial clients sponsoring the projects, not to optimize this study. Drs. James Newell and Kevin Dahm placed their own clinic teams into category III and other teams were assigned into categories in accordance with the preferences of their faculty supervisors. Since this resulted in two to three teams in each category no further adjustments were made. In total, there were 33 Junior and Senior students on the teams, all but three of whom were

Team	Sequence	Precision	Technical	Confluence
1	**33**	**25**	24	20
	27	21	**25**	21
	20	23	**28**	**27**
2	**28**	22	17	19
	20	22	23	24
	22	17	**32**	22
3	**31**	**27**	21	23
	27	24	**25**	17
	26	21	**34**	22

Table 2: Summary of Learning Patterns for Category III teams. Use-first patterns are boldfaced.

chemical engineering students. There was one student from another engineering discipline in each of categories I, II and III.

The students in categories I and III met with Dr. Kevin Dahm and Dr. James Newell during the first week of clinic to discuss their LCI scores and those of their team members. These discussions included the attributes of each learning pattern, possible sources of conflict that were predictable from the team's specific patterns, consideration of how different people process information and approach problems, and ways to bridge differences in learning patterns. Two examples are provided:

1) A team (Team 1 in Table 2) had two members with a strong preference for sequence but one member who led with technical and confluence, while placing in the low use-as-needed range for sequence. Without intervention the high-sequence team members might well have viewed the other member as lazy, while the sequence-avoidance learner would likely view his teammates as uptight. The rationale for this study is that students recognize the potential for this conflict in advance, understand its cause and are equipped with a non-confrontational vocabulary with which to discuss the issue; e.g., "more sequential than me" and "less sequential than me," rather than "lazy" and "anal-retentive."

2) Some teams consisted largely or entirely of learners who used the technical pattern first. These students were counseled on the merits of the technical learning pattern as well as the potential pitfalls of exclusive reliance on this pattern. Technical learners when left to their own devices are generally inclined toward a purely hands-on, empirical approach that is not optimal for most projects. Team 1 in Table 3, for example, was composed of two very similar learners who strongly lead with technical reasoning, though neither avoided any pattern. The discussion, consequently, focused on the important role of background research and a literature review in the project, and

Team	Sequence	Precision	Technical	Confluence
1	22	24	**33**	**26**
	21	24	**29**	**25**
2	**30**	**25**	24	23
	29	22	**25**	24
	28	**26**	**28**	17
3	23	17	**25**	19
	31	24	24	20
	26	19	23	23

Table 3: Summary of Learning Patterns for Category I teams. Use-first patterns are boldfaced.

the importance of distinguishing between level of enthusiasm for a task vs. the importance of that task. Teams like this one, composed entirely of use-first technical learners, were advised to appoint one member to begin working on a literature review right away, even if this meant working outside his/her preferred pattern.

Many different levels of implementation of LML are possible within a course. In this case, there was no further use or even mention of the LCI (unless the students brought it up) beyond this single introductory meeting, or any explicit requirement that the students apply what they had learned to their projects. Eight of the eleven teams were supervised not by the authors of this paper, but by other chemical engineering faculty who were not knowledgeable about the LCI or LML. The assessment section will demonstrate that this modest time commitment had a measurable impact on team performance and student attitudes toward teaming.

The other strategy employed to inspire metacognition in teams was the use of targeted writing exercises. Faculty members supervising teams from Categories II and III required each individual on each team to answer the following questions, in writing, every two weeks:

1. What issues are you having with the technical aspects of the project?
2. What logistical issues (ordering problems, scheduling, software issues, etc.) are you facing?
3. What issues in team dynamics have arisen since our last meeting and how are you dealing with them?
4. What do you think the highest priority task is during the next two weeks?
5. What is the largest barrier to accomplishing that task?

These questions resemble journaling activities reported previously at Clemson University [28] and the University of Texas at Austin [29]. Here the intent was both to engage the students in

Bi-Weekly Submission Log

1. What issues are you having with the technical aspects of the project?
   *Galaxy slowed down work on Thursday November 7, 2002.

2. What logistical issues are you facing?
   *No issues.

3. What issues in team dynamics have arisen and how are they being dealt with?
   *No issues.

4. What do you think the highest priority tasks are during the next two weeks?
   *Validate Anisole thermo.
   *Complete Anisole Hysys model.
   *Saturated water to anisole process.
   *Incorporate catalyst degradation into spreadsheets (4 processes).
   *Finish modeling separation trains for each process and tie in recycle loops.

5. What, if any, are the largest barriers to accomplishing these tasks?
   *Not being able to get to the galaxy drive on Thursday slowed down advancement of work.

Figure 1: Actual bi-weekly memo submitted by a member of a category III team.

active reflection on the project, and to compare the students' perceptions on priorities, barriers, etc. These bi-weekly status reports were not graded (apart from ensuring that they were submitted), but often served as the starting point for discussion at subsequent team meetings with faculty project supervisors. Figure 1 shows a typical response; a very brief memo presenting responses in list form and not necessarily using complete sentences. A few students submitted detailed memos in more of a report style, such as the one shown in Figure 2.

Also during the first week of the semester, each team in Categories II and III was asked to develop and sign a team charter that addressed expectations for the team and the project. Charters could be as extensive as the team chose, but at minimum had to address the role of each individual, the responsibility of each individual to the team, and a process for addressing and resolving conflicts. Teams in Categories I and IV submitted written memos if required by their individual faculty supervisors to do so, but did not complete a team charter, and did not have a specific format or schedule for the memos.

Students in all four categories were told verbally and through the course syllabus (as is done every semester) that every clinic project is unique, that specific assignments, tasks and expectations would vary from one project to another and that these would be established by the faculty supervisor. Students were not, however, specifically informed that this design experiment was occurring. This specification served its purpose in that none of the students in any of the cohorts expressed a perception of unfairness, or of being required to do "extra" work, either anecdotally or in any of the assessment instruments used.

What issues are you having with the technical aspects of the project?:
The biggest issue at the current time deals with completing the student – to - student interactions that include offering orders to students and accepting and declining those offers. The first attempt on this dealt with placing orders to sell goods to a particular student in the database. The algorithm designed to solve this problem initially, however, was unsuccessful, and a new algorithm is being adopted. Provided that the new algorithm is both functional and desirable enough for the users, it will most likely be adaptable to complete all the various functions for student – to – student interactions.

What logistical issues (ordering problems, scheduling, software issues, etc.) are you facing: The only logistical problem faced was in gaining all the members of the group access to the Ravi folder on Andromeda. However, this has been done, although Steve Noonan needs the password for the temp account so that he can access the drive as well.

What issues in team dynamics have arisen since our last meeting and how are you dealing with them?: There have been no real issues in team dynamics at this time. The project has been divided into fully functional subgroups well enough at this time that each of the three members in the team can work independently of the others. Steve is working on completing the template for the pages, Chris has now moved on to examine the auction problems, and I will continue to work on the Student – To – Student segment until it is completed.

What do you think the highest priority task is during the next two weeks?: There are two major priorities for the next two weeks. The first will be to ensure that the student interaction algorithm is successful and to implement it properly to ensure all possible student transactions are taken care of. The second will be to complete the templates for the pages so that in the future the template will be completed, and page layout will become extremely simple, and not take time away from the ASP coding.

What is the largest barrier to accomplishing that task?: There are no foreseen barriers at this time, due to the fact that before beginning to implement the new student interaction algorithm, several ideas were constructed before a set one was chosen. In the event that this algorithm is unsuccessful, one of the other ideas can be taken into account and examined further as a possible solution.

Figure 2: Actual bi-weekly memo submitted by a member of a category III team.

RESULTS AND DISCUSSION

To evaluate the effectiveness of these strategies, student attitude and performance were both measured. To objectively measure performance, a set of rubrics that have been published previously in *Chemical Engineering Education* [30] were applied to the final Junior/Senior Clinic reports produced by each team. Although these rubrics focus on demonstrating specific learning objectives (such as "meaningful error analysis," "formulating appropriate conclusions," etc.), they are presented in terms of grades to make them more meaningful to students. A sample rubric is shown below:

Area: Technical Awareness

The A-team:

- Clearly demonstrates an awareness of the works of others and establishes a context for its project

- Identifies and understands works from multiple literature sources.

The B-team:

- Shows some understanding of the work in the field, but has limited depth and breadth.
- Demonstrates understanding that is limited to faculty-provided materials.

The C or lower–team:

- Fails to demonstrate an awareness of the works of others and the significance of its project.

The average performance of the teams in each of the four categories was quantified as a GPA, as follows: An A-level performance for a specific objective was assigned a score of 4, a B-level performance a score of 3, etc. Table 4 below summarizes the average results for the teams in each category, with respect to each objective. The "Overall Evaluation" is the average score for teams with respect to all objectives, weighted equally. Each report was read by two engineering faculty members, with no faculty member evaluating his/her own team's report. Agreement between readers was usually perfect and always within one point, and the results in Table 4 reflect an average of the ratings.

The sample sizes were very small and the authors do not regard the results as statistically significant, but the results do indicate that teams that received LCI training only (Category I) and teams that received both LCI training and structured writing assignments (Category III) performed better than those that received only structured writing assignments (Category II) and those that received no teaming training (Category IV) in all of the rubric areas, and the overall evaluation was approximately one full point better on the four point scale. Note that the Category I and III teams out-performed Category II teams in this course despite the fact that the Category II students had higher overall GPAs on average. Generally, little difference was found between teams

Rubric Topic	Category I LCI-Training Only	Category II Structured Writing Only	Category III Both LCI and Writing	Category IV Neither LCI nor Writing
Number of Teams	3	2	3	3
Overall Evaluation	3.9	2.8	3.8	2.6
Technical Awareness	4.0	3.0	3.3	2.6
Proposed Future Work	3.7	2.8	4.0	2.0
Meaningful Error Analysis	3.7	2.5	3.5	3.0
Appropriate Conclusions	4.0	3.0	3.8	2.3
Average Student GPA	3.16	3.44	3.21	3.07

Table 4. Average performance of teams in Categories I-IV with respect to desired learning outcomes (4 = best, 1 = worst).

receiving LCI training only (Category I) and teams receiving both LCI training and structured writing (Category III), though the Category I teams did much better on one particular outcome, "Technical Awareness."

There are at least two possible explanations for the improvement observed in teams receiving the LCI training. One is that the LCI training helped the students overcome potential obstacles to working effectively as a team, and therefore these students did a better job on the project. Another possibility is that the LCI training helped students overcome their natural aversion to writing, and therefore helped them to write better reports about their projects. The data include no way to isolate such effects, but anecdotally the authors believe both occurred to some degree.

To examine how the project affected team attitudes, all students on participating teams were given a survey at the beginning and end of the semester. The results of this survey are summarized in Table 5.

Analyzing the responses in Table 5 shows that the results of the pre-semester survey were very similar across the four categories, which is logical, as the assignment of teams to categories was in effect random. The results show that student attitudes toward teams changed markedly during

Question (5 = Strongly Agree; 1 = Strongly Disagree)	Time	Category I LCI-Training Only	Category II Structured Writing Only	Category III Both LCI and Writing	Category IV Neither LCI nor Writing
Number of students		8	6	10	9
I would like more training in dealing with team dynamics	Pre	2.25	2.33	***2.60***	2.25
	Post	3.25	3.00	***4.10***	2.50
I have received training in working effectively in teams	Pre	***1.25***	1.66	***1.60***	1.66
	Post	***3.75***	2.33	***4.00***	1.33
Learning to work effectively in teams is important	Pre	3.50	3.33	***3.40***	3.00
	Post	4.25	3.66	***4.40***	3.33
I prefer working with a team to working alone	Pre	***1.75***	2.00	1.80	2.33
	Post	***3.00***	2.66	2.60	2.33
Personality conflicts are a major problem with teams	Pre	4.00	3.66	3.60	3.66
	Post	3.50	3.66	3.00	3.33
Working on teams has helped me learn things about myself	Pre	***2.25***	2.66	***2.00***	2.33
	Post	***3.50***	3.00	***3.60***	2.00
I felt more comfortable working in teams this semester	Post Only	4.75	4.00	4.75	3.33

Table 5. Comparison of survey results given to students before (Pre) and after (Post) project. **Boldface italics indicate that the difference between pre- and post-project response is statistically significant ($p < 0.05$) for that cohort on that question.**

the semester for the students who received LCI training, but did not significantly change for those who did not. The single most compelling result is the responses to the statement "I have received training in working effectively in teams." All groups on average firmly disagreed (mean response below 2) with this statement on the pre-survey. On the post-survey, students in Categories I and III agreed (mean response 3.75 or better) with this statement. Students in Categories I and III on the post-survey also indicated an increased desire for more such training, placed an increased importance on these skills, and attributed working in teams with increased self-awareness. The results of the pre-survey reflect a clear preference for working alone to working in teams, a result which is consistent with the generalizations regarding technical learners that were noted in the section "*Role of LML in Engineering Curriculum*." The students in Categories I and III, on the post-survey, still did not prefer to work in teams but gave more neutral responses (3.0 and 2.6). On all of these matters, students in Categories II and IV showed no significant change between the pre- and post-surveys.

Despite the small sample size, the results were in some cases statistically significant. A series of paired sample t-tests applied to the responses showed that for the students in Categories I and III, the differences in responses to the pre- and post-semester surveys were statistically significant ($p < 0.05$) for some questions, including "Working on teams has helped me learn things about myself," and "I have received training in working effectively in teams," for both cohorts. Category I and III students also responded more positively to the question "I felt more comfortable working in teams this semester" than did their classmates in Categories II and IV.

The students in Category II, who received structured writing assignments but no LCI training, demonstrated some improvement in their attitudes toward teaming in the post-semester survey, though this improvement was less dramatic than that of the category I and III teams, and not statistically significant. Category IV teams that received neither LCI instruction nor structured writing exercises showed no changes in their opinions during the semester.

At the end of the semester, each person was also asked the following series of questions:

1. What progress are you making in your learning as a result of being on this team?
2. How is the team helping you overcome problems with the project?
3. How is the team contributing toward your progress on this project?
4. What personal qualities are you developing as a result of being on this team?
5. How is the team impeding your progress on this project?
6. What problems are you having as a result of being on this team?
7. In what ways are you finding it difficult to work on this project?
8. What have you found helps you follow through despite difficulties you are encountering?
9. In what ways are you contributing to or promoting effective teamwork?

Most of the responses to this survey were cursory. The most notable outcome was that although students reported few problems when answering these questions, they did show evidence of having developed the vocabulary to address issues in teaming. Responses to questions 8 and 9 included, "Even though I am not very sequential, I worked hard to meet deadlines and meet the expectations of the more sequential members of my group," and "Our group functioned well. Student X was high in precision and I was not, but student Y fell in between and helped keep us moving when it was time to write." Many students reported feeling more confident about working in teams.

Student teams in Categories II and III were also surveyed to determine their opinions of the targeted writing exercises (team charter, bi-weekly memos) used to improve their teaming skills. Nearly 75% of the students indicated that writing the team charters was a useful experience, though over 90% also said that they never referred to them again during the year. The most straightforward interpretation of these facts is that once all of the members agreed to a set of rules, they largely followed them. Most of the team charters focused on logistics: how frequently teams would meet, processes for notification if a meeting would be missed, and a process for resolving conflict (in which "go to the professor" would generally be regarded as a last resort.) Few really examined the responsibilities of the team to the individual or the individual to the team beyond saying all members must show up and do their assigned tasks.

In the year-end survey, the students expressed unanimously negative opinions of the bi-weekly memos, indicating they were a waste of time and not helpful. This was a somewhat surprising result in that during the semester, the authors had received anecdotal feedback indicating that the memos were valuable. An examination of the content of the students' writing suggests that, contrary to their views, the writing serves the important function of prompting students to externalize and articulate perceptions of and reactions to teaming issues, thereby providing explicit identification of pattern-based barriers and making it possible to reflect on and address those barriers. Indeed, faculty members indicated that the memos were a useful tool in identifying problems before they got out of hand. Further, the supervisors of all but one team from Categories I, II and III reported that their projects had been more successful this year than last, and both faculty and students indicated that there were no significant team dynamics problems in any of the teams in Categories I, II or III.

The LCI itself offers an explanation for the disparity between student opinion of the bi-weekly memos and the apparent value of the memos. The technical learner's aversion to writing was noted in the introduction. Affinity for writing is usually associated with the precise learning pattern, because of the preference for a high level of accuracy and detail, for which writing is well suited. The engineering student population at Rowan consistently has a mean score in the high "use first" range for technical learning and the low "use as needed" range for precision. From this combination, we would expect the majority of students to have a negative affective perception of writing, even if they had a rational or practical appreciation of its importance. Unfortunately, the category III teams disliked the bi-weekly memos just as uniformly as the category II teams did. This means that students who were aware of their own preferences for using the technical pattern and/or avoiding precision, and thus had an explanation for their instinctive aversion to writing, did not view the bi-weekly writing activity any differently from their classmates with no LCI training. Future studies will investigate whether the bi-weekly memos are necessary to articulate, reflect on, and address teaming issues and if so, by what mechanisms they do so. This understanding would provide a stronger rationale for the memo-writing, and potentially enable us to persuade more students to "buy into" it.

SUMMARY AND CONCLUSIONS

In an attempt to teach students to take a metacognitive approach to team projects, two activities were integrated into a Junior/Senior project-based course: use of the LCI to teach students about their own learning patterns, and targeted writing exercises intended to promote focused reflection throughout the semester. A design experiment was employed to assess the impact of these two activities used individually or together. The results indicated that teams receiving the LCI training performed better than teams that did not, though sample sizes were insufficient to draw statistically significant conclusions concerning how the LCI and writing exercises affected team performance. A survey given at both the beginning and the end of the semester demonstrates that the use of the LCI had a clear positive impact on the attitudes of students toward teaming, and these results were statistically significant. The LCI training, however, had no measurable effect on student attitudes toward the writing exercises. The impact of the targeted writing exercises on team performance is unclear: The bi-weekly memos were not popular with students, and while there were some indications that the exercises had value for the team projects, the results were not statistically significant.

This paper describes an experiment which the Rowan Chemical Engineering department graciously agreed to support on a one-time basis. Project managers have complete autonomy in project administration beyond a set of broad minimum guidelines (e.g., projects must include oral and written deliverables). Consequently, no uniform practice regarding use of the LCI in this course has been implemented as a result of the study described here. However, use of the LCI and Let Me Learn at Rowan has grown considerably since this study. Rowan University now administers the LCI to all incoming students and includes seminars on the Let Me Learn process in freshman orientation activities. Within the College of Engineering, Let Me Learn has now also been implemented in the Freshman and Sophomore Clinics. [31,32]

The model described here is readily adaptable to other schools and other team settings because the Let Me Learn activity consisted of a single day session with no further intervention. While the people leading the one-day activity were fluent with the LCI and the four learning patterns it measures, the supervisors of the individual projects needed no previous experience with LML, and in most cases had none.

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