Impact of Structured Writing and Awareness of Cognition on Effective Teaming

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Abstract
Metacognition is the awareness and understanding by a student of his or her own learning own skills, performance, preferences, and barriers. This paper describes a pilot scale effort to develop metacognition in engineering teams at Rowan University, through structured writing, and the use of the Learning Combination Inventory (LCI). The theoretical basis for the LCI is the Interactive Learning Model, which proposes that learning processes occur through four distinct learning patterns: sequential, precise, technical, and confluent. The LCI was used to profile the learning style of each student in the Rowan Chemical Engineering department.

During the Fall Semester of 2004, engineering teams in the Junior/Senior Engineering Clinics were broken into four categories. Category I teams received instruction in 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 enhance their awareness of teaming. These assignments included developing and ratifying a team charter and submitting biweekly reports on barriers to success and team dynamics. Category III teams received both the LCI training and participated in the structured writing assignments, while Category IV teams served as a control and participated in none of the activities.

At the beginning of the semester, each person was surveyed to determine their perception of their teaming skills, their opinion of teams, and their level of interest in learning about teaming. The participants were surveyed again at the end of the semester and were also asked to evaluate the usefulness of the strategies. Preliminary data analysis indicates that the teams did not feel that they benefited from the structured writing activities, though several individuals mentioned that they would have been helpful if their team was experiencing problems. Almost everyone that participated in the LCI said that they learned quite a bit and several found it useful in dealing with their teammates. Category III teams showed improvement in their perception of teaming and were less likely to report negative teaming experiences than members from the other categories. Final semester reports were also gathered and evaluated using rubrics to gauge impact on the

actual projects, but because most projects last one year, ultimate conclusions must wait until the early May submission of the final reports.

Background and Pedagogical Theory

Behavioral scientists classify thought processes into cognitive and affective domains [1]. The cognitive domain includes higher order thought processes such as logic and reasoning and is the primary (and in many cases, the only) target of engineering curricula. The affective domain includes attitudes, values, and self-concept. These attributes typically cannot be measured directly through exams and other classroom instruments, yet they are essential components of the overall developmental process.

ABET itself recognizes the importance of the affective domain by including criteria in their assessment of engineering programs such as "engages in lifelong learning," "understands the impact that engineering has on society," and "communicates effectively" [2]. Besterfield-Sacre *et al*. observed that students' attitudes about engineering and their abilities change throughout their education and influence motivation, self-confidence, perception of engineering, performance, and retention [3]. The same group also found that attitudes toward engineering directly related to retention during the freshman year [4]. Seymour and Hewitt [5] examined students who left engineering programs and found that according to measures *external* to the engineering curriculum (high school GPA, SAT scores, IQ, etc.) they were not academically different from their peers who continued in the program. Retention did, however, correlate closely with student attitude. For many students, college challenges their level of motivation and the academic aptitude for the first time, but too often provides them with little or no help in identifying and overcoming the barriers to their learning.

The Study Group on the Conditions of Excellence in American Higher Education 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" [6]. Thus, it is reasonable to conclude that an effective student must be both self-aware and self-directed, yet these issues are often ignored completely by engineering faculty.

Student awareness and understanding of their learning skills, performance, preferences, and barriers is referred to as metacognition. Although different research groups emphasize different aspects of metacognition [7], it clearly refers to two distinct, but related issues [8]:

- Awareness and knowledge of self as learner
- Conscious self-control and self-regulation of cognition

In essence, a metacognitive learner must understand his or her strengths and weaknesses in learning and control how he or she will approach a problem. Engineering professors tend to perceive barriers to student learning as lack of intelligence or motivation from students, when in reality, the student may lack awareness of the causes of the barriers he or she is facing.

Barriers to student learning also arise in connection with what has become a basic component of engineering education: working in teams. Experts agree on the importance of involving undergraduates in teamwork [9-11]. Seat and Lord [12] observed that while industry seldom complains about the technical skills of engineering graduates, industrial employers and educators are often concerned with performance skills (i.e., interpersonal, communication, and teaming). Lewis *et al.* [13] correctly observed that if students are to develop effective teaming skills, then teaming must be an explicit focus of the project. A metacognitive approach would encourage students to become conscious of their team skills. Thus, metacognition may be valuable for improving an individual's relationship not only to their own learning processes, but also to the learning processes of others and to the collaborative learning process in general.

Weinstein and Meyer [14] described the importance of students' understanding their own learning preferences, abilities, and cognitive styles, and discussed how "learning how to learn" helps students develop knowledge of strategies required to achieve specific tasks. To provide this metacognitive awareness to our students, we used the Learning Combination Inventory (LCI), a survey instrument developed by Johnston and Dainton to profile an individual's learning patterns [15]. The theoretical basis for the LCI is the Interactive Learning Model, which posits that learning processes occur through four distinct learning patterns: sequential, precise, technical, and confluent. The patterns are used by all learners to varying degrees; a given individual's LCI profile is determined by the strengths of their preferences and avoidances, scored as "avoid," "use as needed," and "use first." Some learners lead with one or two patterns, some avoid certain patterns, some are able to use a number of patterns on an as-needed basis, and still others exhibit strong preferences for a number of patterns. Each pattern is distinguished by a number of features. A few hallmarks are listed below:

- **Sequential** learners prefer order and consistency. They want step-by-step instructions, and time to plan, organize, and complete tasks.
- **Precise** learners thrive on detailed and accurate information. They take copious notes and seek specific answers.
- **Technical** learners like to work alone on hands-on projects. They enjoy figuring out how something works and insist on practical objectives for assignments.
- **Confluent** learners have a strong desire for creativity and innovation. They are not afraid of risks or failure and prefer unique, unconventional approaches.

Depending on the interaction of an individual's patterns, strong preferences associated with one pattern may coincide with strong avoidances of another pattern. For example, the sequential learner's preference for order and consistency may be evidenced as a desire for predictability, and, therefore, as a corresponding avoidance of the risk and openness to chaos that is a characteristic of the confluent learner. In each case, knowledge of this profile provides extremely useful insights into the conditions that promote learning. The LCI is based on three assumptions about these conditions:

1) Learners learn most efficiently and successfully when allowed to use their stable-over-time patterns of cognition (intelligence, aptitude, experiences, levels of

abstraction), conation (pace, autonomy, natural skills), and affectation (sense of self, values, and range of feelings) to engage in a learning task;

2) Learners learn best when given the opportunity to know their learning process, allowed to negotiate their learning environment, and provided the tools to strategize to meet the rigors of standardized and alternative methods of assessment and performance;

3) Learners receive the most effective instruction when their teachers have an appreciation for their diverse learning characteristics [15].

Other attempts to gain a better understanding of engineering students as learners have employed the concept of learning styles, using instruments such as the Myers-Briggs inventory [16, 17]. The developers of the LCI explain the difference between their approach and that of learning styles in this way:

> Unlike learning styles, [the Interactive Learning Model] is an advanced learning system that provides an inward look at a learner's internalized metalearning behaviors, an outward analysis of a learner's actions, and a vocabulary for communicating the specific learning processes that yield externalized performance. Other measures of personality, multiple intelligences, or learning styles provide information about the learner and then leave the learner informed but unequipped to use the information. . . . [The LCI] not only provides the learner with the means to articulate who s/he is as a learner, but then provides the strategies (metawareness) for the learner to use these learning tactics with intention [18].

The LCI survey is composed of 28 Likert scale items—descriptive statements followed by a five-point set of responses—and three questions requesting written responses. The 28 questions are scored according to the patterns they illustrate, and from these scores the LCI profile is generated. The three written responses are used to validate the preferences and avoidances exhibited by the scores. Over the past 9 years, teachers and administrators in 11 national and international sites, along with faculty at Rowan University, have tested the reliability and validity of the LCI [18]. Studies conducted to verify the reliability and validity of the LCI are described in the *LCI Users Manual* [15]. Professor Newell participated in a three-hour workshop on learning preferences and consulted regularly with personnel for Let Me Learn. Professor Harvey has subsequently begun a 10-week intensive course involving 28 hours of instruction on all aspects of the LCI.

The LCI has been used in the engineering program at Rowan University to enhance the performance of student teams [19]. In Sophomore Clinic I, a multidisciplinary sophomore design and composition course that is taught collaboratively by faculty from engineering and composition and rhetoric, faculty used the results of the LCI to form teams with balanced components of each learning pattern, based on research suggesting that successful learning in team environments occurs if team members have complementary learning patterns.

Our hypothesis was that this particular combination of avoidances and preferences leads to barriers that specifically impact performance of student teams in the upper-level design courses, such as the Junior/Senior Clinics [20]. In these courses, students work independently in teams on semester-long and sometimes multi-year projects. Many of the projects involve external funding, real clients and sponsors, and actual product development. For example, student teams under the supervision of chemical engineering faculty have worked on emerging topics including enhancing the compressive properties of Kevlar, examining the performance of polymer fiber-wrapped concrete systems, advanced vegetable processing technology, metals purification, combustion, membrane separation processes and other areas of interest. Every engineering student participates in these projects and benefits from hands-on learning, exposure to emerging technologies, industrial contact, teamwork experience and technical communication practice [21, 22].

These conditions make the Junior/Senior Clinics meaningful and exciting learning experiences, but the pressure derived from the intense and often unpredictable environment exacerbates the students' barriers to learning. Preferences for sequence and avoidance of chaos and risk leave students frustrated by what they see as the lack of structure of a real-world project. They are unsure how to cope in situations where clear instructions and step-by-step procedures have been replaced by multi-tasking, frequent shifts in direction, uncertain timelines, and inconsistent expectations. They may become impatient with learning patterns exhibited by team members that conflict with their own. The situation is further compounded by the high technical preference that many of them have, which in addition to the hands-on, problem-solving aptitudes listed above, has other significant hallmarks. Although the technical learner is distinguished by a love of challenges, which serves the Junior/Senior Clinic student well, he or she is also known for preferences that are not so compatible with this situation: working alone, keeping knowledge and/or feelings inside, and resisting changes to familiar or preferred patterns. These students are not likely to naturally communicate regularly with team members, nor reflect on or seek guidance about obstacles they are experiencing. Of particular interest to us is the technical learner's resistance to writing. Because technical learners keep information in their heads and do not readily volunteer it to others, they tend to write minimally, not seeing a need for a great deal of detail to be committed to paper.

An overwhelming majority of engineering students show preferences for technical learning. Of the more than 100 engineering students and professors who submitted LCI results, only two had an avoidance of technical (including one of the authors of this paper). While most teams were similar in technical, they range widely in the other three categories.

This situation is addressed by using writing to harness the metacognitive awareness yielded by the LCI. In large part because of what we know about technical learners and their particular barriers, we believe that focusing on writing will be a productive approach on multiple levels:

- To see that students get increased opportunities to write in their classes, both in order to communicate and in order to aid learning

- To develop further the leadership skills faculty need to sustain long-term writing across the curriculum projects and the evaluation and assessment skills they need to determine these projects' effectiveness [23]

The perspective available from the LCI is used to target the specific barriers to student learning that have been identified.

Methodology

During the Fall Semester of 2004, engineering teams in the Junior/Senior Engineering Clinics were broken into four categories. Category I teams received instruction in 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 enhance their awareness of teaming. These assignments included developing and ratifying a team charter and submitting biweekly reports on barriers to success and team dynamics. Category III teams received both the LCI training and participated in the structured writing assignments, while Category IV teams served as a control and participated in none of the activities.

The students in categories I and III met with Dr. Kevin Dahm and Dr. James Newell during the first weeks of clinic to discuss their LCIs and those of their team members. These discussions included strengths and weaknesses of each preference, possible sources of conflict, consideration of how different people process information and approach problems, and ways to bridge differences in learning preferences. As a specific example, when most members of a team have strong preferences for sequence (like most participants in this study) but one member has avoids sequence, the high sequence team members would likely view the other learner as lazy or a procrastinator. At the same time, the sequence-avoidance learner would view the rest of his team as anal retentive and bossy. Recognizing the potential for this conflict in advance and understanding its cause can help teams deal with it more effectively when it happens.

Because of the likelihood that team profiles are not balanced, students were counseled on the barriers presented by strong preferences for the technical learning pattern, so that team members would begin to fill the gaps created by lack of diversity. Technical learners prefer to dive in to hands-on work and are less likely to read directions or perform a comprehensive literature review first. While having technical learners is beneficially in the lab, someone needs to do the background work first. Groups with all technical learners were encouraged to appoint a member to start the literature review first, even though this meant working against their preferred pattern.

Category II and III teams produced bi-weekly status reports and team charters. Most faculty members, in supervising a clinic project, require some sort of periodic progress report or update. However, historically, there has been little coordination between faculty concerning the scope and format of these status reports. In the Fall 2004, faculty members supervising teams from Categories II and III required each member of each clinic team to answer the following questions, in the form of a written status report, 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 the journaling activities used at Clemson University [24] and the University of Texas at Austin [25] in which students write reflective pieces summarizing key concepts, discuss concerns, and (at UT Austin) create an analogy for the presented material. However, unlike these journals, the questions posed in the proposed status reports have the student focus on barriers to completing the project, team dynamic issues, and prioritization. They represented an effort to have the student evaluate not only whether they have made suitable progress, but also what issues are creating problems. Standardizing the status report across the department made it a more valid assessment instrument, as well as a useful aid to the supervisor for project management. An additional goal is to help students avoid hierarchical judgments and focus instead on what made their teams effective or ineffective. The questions were not graded (other than ensuring that they were submitted), but served as the basis for discussion in the ensuing meeting.

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 dealt with specific issues in team dynamics including the role of each individual, the responsibility of each individual to the team, the responsibility of the team to each individual, and an algorithm for dealing with potential future conflicts. Note that only chemical engineering faculty members participated in this preliminary test, so chemical engineering students who were working on projects supervised by faculty members in other engineering disciplines were not required to form a team charter or participate in any of the other activities described in this section.

There can be little doubt that writing within the engineering curriculum has intrinsic benefits of its own. Kranzber [26] reported that, for engineers who had been out of school for ten years, the most common answer to the question "What courses do you wish you had taken?" was English or writing courses. Both ABET and the Canadian Accreditation Board [27] now require the development of communication skills for engineering students. As a result, many engineering programs incorporate writing-to-learn in their curricula [28,29]. The ability to formulate a coherent written report requires that the student think clearly about the technical engineering problem [29-32]. In much the same way, requiring students to contemplate, in writing, their approach to problem solving and the barriers that they are facing will compel the same clarity of thought. This clarity is an essential component of metacognition.

Results and Discussion

All students participated in the following survey in the beginning of the semester and again at the end.

Student Opinions of Teaming and Team Dynamic Issues – End of Semester

Name: ___________________ **Project:** ___________________ **Date:** ________________________

	Strongly Disagree				Strongly Agree
I prefer working with a team to working alone	1	2	3	4	5
Personality conflicts are a major problem with teams	1	2	3	4	5
I can work with just about anyone	1	2	3	4	5
Learning to work effectively in teams is important	1	2	3	4	5
I have received training in working effectively in teams	1	2	3	4	5
Teams are a burden and I am more productive working alone	1	2	3	4	5
My previous team experience have been generally positive	1	2	3	4	5
Working on teams has helped me learn things about myself	1	2	3	4	5
I have had problems with lazy teammates	1	2	3	4	5
I have had problems with technically inept teammates	1	2	3	4	5
I have had problems with incompatible schedules	1	2	3	4	5
If I answered yes to any of the last three questions, I Felt like I handled the problems well.	1	2	3	4	5
I have had at least one very good experience with a project Team	1	2	3	4	5
I have had at least one very bad experience with a project Team	1	2	3	4	5
I would benefit from help in teaming	1	2	3	4	5
I would prefer to select my own team	1	2	3	4	5
I would prefer to be able to "fire" a team member	1	2	3	4	5

I would like more training in dealing with team dynamics	1	2	3	4	5
I felt more comfortable working in teams this semester	1	2	3	4	5

Comments:

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?

Although the sample size is too small to draw definitive conclusions, Category IV teams (the control group) were more likely to report problems with their teammates and/or faculty advisor. Encouragingly, several Category III members reported using skills that they learned about teaming with other teams in other classes. Final reports are currently being evaluated to assess the impact of the exercise on performance.

Student teams were also given the following survey to determine their opinion of the items (team charter, LCI, bi-weekly memos) used to improve their teaming skills.

Student Assessment of Status Reports, Team Charters, and LCI Meetings

Project: ___________________ **Date:** _______________________

	Strongly Disagree			Strongly Agree
The Team Charter helped my team define the Expectations for the team	1	2	3	4
The Team Charter made me think about team issues	1	2	3	4
The Team Charter helped avoid potential problems	1	2	3	4
I referred to the Team Charter during the semester	1	2	3	4
I would like to use a Team Charter again next semester	1	2	3	4

The biweekly status reports helped our group Identify priorities	1	2	3	4
The biweekly status reports helped with team dynamics	1	2	3	4
I was better able to identify barriers to success because Of the status reports	1	2	3	4

THE FOLLOWING QUESTIONS ARE ONLY FOR STUDENTS WHO WERE ON A JR/SR CLINIC TEAM LAST SEMESTER:

My project was more successful this year than last year	1	2	3	4
I had fewer problems with team dynamics this year than last year	1	2	3	4

THE FOLLOWING QUESTIONS ARE ONLY FOR STUDENTS WHO MET WITH DRS. DAHM AND NEWELL TO DISCUSS TEAM DYNAMICS AND LCI SCORES

I learned more about my teammates from the meeting	1	2	3	4
The meeting helped me understand differences in how My teammates approach problems	1	2	3	4
The Meeting was useful	1	2	3	4

Surprisingly, most Category II teams saw little value in the structured writing assignments even though they reported no teaming issues. Almost every student from Categories II and III agreed or strongly agreed that the LCI meeting was beneficial. All but one team from Categories II and III reported more successful projects this time.

The pilot study is not large enough provide conclusive evidence of anything, but it does imply that there is some benefit to the teaming activities. At minimum, the faculty must do a better job of explaining the benefits of the writing assignments to the students.

The rubrics used to evaluate performance more objectively have been published in *Chemical Engineering Education* [33].

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