Work-in-progress – Dealing with "Formulaholic" – The formulae syndrome of the new generation engineering students

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Abstract - A fundamental skill set in the practice of the engineering profession is critical thinking skill. Over the years, peculiarities of generations of engineering students have become distinctively noticeable. The new generations of students enrolling in engineering programs have increasingly demonstrated unusual dependency on formulae for solving analytical problems. The dependency has reached the proportion to qualify for classification as addiction - labeled as *"formulaholic"* and defined as "*the compulsive dependency on formulae to solve analytical problems to the subdual of critical thinking skills*." Impact of subdual of critical thinking skills also manifests in students' reduced metacognition abilities. A new growing challenge in engineering education is to change the freshman's mindset from formulae dependency to critical thinking. The principal project that included this issue implemented a peer group tutorial program with strong emphases on social integration. A pilot study between a test group and control group respectively, showed that participants in the peer tutorial program performed much better in the common Math course that both groups took. The work presented in this paper is a follow-up on the participants to assess the extent to which participation in the peer group tutorial has moderated their initial formulae dependent mindset. Survey results show that by learning to develop their critical thinking skills, the students gained higher confidence in their abilities as well as performed better in their courses.

Index Terms - Peer Group Tutorial; Peer learning; Critical thinking skills, "formulaholic"

INTRODUCTION – PROBLEM ADDRESSED

Formula dependency *(formulaholic)* negatively impacts students' critical thinking skills. It manifests in students' reduced metacognition abilities as displayed by students in taking tests involving analyses. Simple observational experiments of allowing students to take tests under "open book" and "close book" conditions respectively have shown some interesting observations. In the "close book" scenario, the typical test paper is full of jumbled scribbles and cancellations, suggesting uncertainties of ideas or inability to think through a problem first before offering the solution. In the "open book" scenario, the typical observation is the alarming rate at which students flip through book pages looking for formulae or prior examples that are similar to the test question.

Once they find such example, if they do, they proceed to script their solution in the exact manner as the example problem, unable in some cases to account for minor differences such as change in data values, polarity or orientation in figures between example problem and test question. If they don't find very similar example(s), the result is scribbles and cancellations in test papers as in the "close book" scenario. In both scenarios, students expend disproportionate length of time searching for previous patterns or formulae to solve problems that could have taken much shorter time, had they possessed and or applied critical thinking and metacognition skills in the solution process.

GROWING CHALLENGE IN ENGINEERING EDUCATION

A new growing challenge in engineering education is to change the freshman's mindset from formulae dependency to critical thinking. The work presented in this paper is an on-going follow-up on the peer tutorial participants to assess the extent to which participation in the tutorial has moderated their initial formulae dependent mindset.

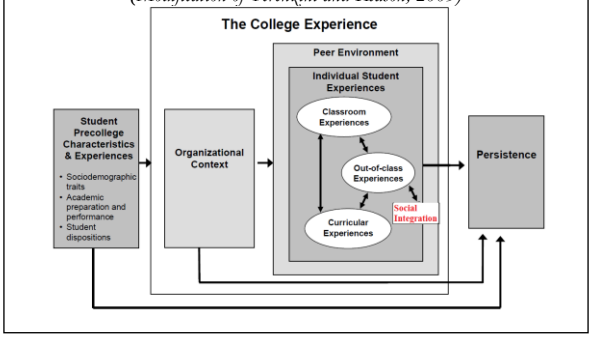
The Peer Group Tutorial was established to address the broader issue of persistence in engineering programs. Perhaps partly due to formula dependency, many freshmen have tough times passing prerequisite math courses needed to enroll in engineering courses. The attrition rate in the first two years of engineering programs therefore remains very high.

The study on persistence centered on identifying key factors that impacted low persistence in engineering programs and consequently explored ways for improvement. In the study on persistence, many learning models were investigated[1-8] but the Pascarella and Terenzini learning model of student learning and persistence was modified as shown in fig 1 and used as framework for the study.

The Tuskegee University model places strong emphasis on social integration. One outcome of the study on persistence was the implementation of a Peer Tutorial Program for the first two years of engineering study at

Tuskegee University in introductory Math courses which are prerequisites to Engineering Courses.

FIGURE 1
Tuskegee University Model of Student Learning and Persistence with emphasis on social integration
(Modification of Terenzini and Reason, 2005)



One key objective in structuring the peer tutorial program was to ensure that the program promoted the development of students' critical thinking skills. Deficiencies in these skills are already observable in engineering education including:

i. Inability to independently evaluate and solve problems
ii. Poor performances in analytical-based courses.
iii. Lack of engagement in engineering classrooms.
iv. Reduced persistence in engineering programs

CHANGES IN THE PEER TUTORIAL PROCEDURE

In general, peer learning is an educational practice in which students interact with other students to attain educational goals. Peer learning "exposes students to academics in a non-threatening and experiential mode. Emphasis is placed on process over product, on reasoning versus grasping for quick answers."[9] In peer learning, every student is both a peer and a mentor. The original procedure was to have the students in cohorts congregate in rooms to solve and share solutions to common Math problems. To develop critical thinking skills in the process, a mandatory procedure was introduced, i.e., individuals in each cohort would take leadership turn to discuss solution approach to a given problem. An upper class honor student is assigned to each group as Peer Tutor. The Peer Tutor listens to the solution discussions and gives freedom to the group to explore their imaginations. The Peer Tutor interjects into the discussion only if the group is drifting off course, or to emphasize a very important concept that the group articulated. When there is consensus on the solution approach, the lead student proceeds to script the solution on the board. This approach is in line with the "saying and doing" learning methodology which postulates[10] that learners retain:

"10 percent of what they read;
20 percent of what they hear;
30 percent of what they see;
50 percent of what they see and hear;
70 percent of what they say; and
90 percent of what they do and say"

With respect to development of critical thinking skills, the hypotheses are that the Peer Learning Tutorial with the "saying and doing" learning methodology will help students to:

a. develop increased confidence to pursue their academic programs
b. improve their learning
c. become more open in seeking and sharing knowledge with their peers.

TEST SURVEY AND RESULTS

To improve persistence, performances of engineering students are keenly tracked to enhance on-time intervention. In this regard, the College of Engineering has an arrangement with the Math Dept. to send test scores of engineering students enrolled in any of the gateway-to-engineering math courses to the Dean of Engineering. Those failing in the Math courses are required to attend the Peer Group Tutorial program offered by the College of Engineering. Non-failing students and encouraged to also attend the tutorial. Tutorial is held 2 hours per night, three nights per week. The surveys summarized in Tables 1 and 2 were sent to students who participated in the peer group tutorial in Spring 2016.

TABLE 1
SURVEY RESULTS – PERSONAL EXPERIENCES

On 0% to 100% scale: [0% = Strongly Disagree, 100% = strongly agree].		Pre Tutorial	Post Tutorial
		Avg. (%)	Avg. (%)
Q1	I regularly had study partner(s)	52.6	67.8
Q2	I easily asked for help to solve problems	66.7	85.3
Q3	I worry that I may not be able to complete my engineering program within 4-5 years	51.1	41.1
Q4	I find that helping other students with their Math problems also helps me understand Math better		83.2

TABLE 2
SURVEY RESULTS – PERFORMANCES IN MATH COURSE
(FROM INITIAL TEST SCORE TO FINAL TEST SCORE)

	NUMBER OF STUDENTS	% OF STUDENTS
My grade improved from **B** to **A**	7	38.9
My grade improved from **C** to **A**	0	
My grade improved from **D** to **A**	2	11.1
My grade improved from **C** to **B**	3	16.7
My grade improved from **D** to **B**	4	22.2
My grade improved from **D** to **C**	1	5.6
No Improvement	0	0.0
My grade declined from **A** to **B**	1	5.6
Total Respondents	18	

RESULT ANALYSES

For background information, Deans of academic programs, by responsibility, have been required to interview students dropping out of their programs to gather information relating to the dropout. One prominent reason for students dropping out of the engineering programs is isolation, particularly for first generation college students. Partly for this reason, the Tuskegee University model for student. Learning and Persistence shown in figure 1, emphasized social integration. The peer tutorial program was accordingly identified as an effective intervention learning model for its potential to promote social integration outcomes. The peer tutorial program encourages all students to feel free to ask questions and reach out to help other students.

Against the above backdrop, the results provide indications that participating students:

- Were more socially engaged in collaborative learning after the peer tutorial than before. (Indicators: Survey questions Q1, Q2 and Q4, Table 1)
- Developed increased confidence in their learning (Indicators: Survey questions Q3, Table 1)
- Possessed deeper understanding of what they learnt. To help someone else in solving problems, the helper must first understand how to obtain the solution. By inference, this suggests that the helper has developed some problem solving skills through critical thinking process rather than through formulae application only. (Indicators: Survey question Q4, Table 1)
- Have improved critical thinking skills (Indicators: Table 2).

RESULT ANOMALY

In table 2, all participants in the peer tutorial showed improvement in their Math scores except one student whose performance declined from initial "A" to a final "B" grade. Based on the overall trend of improvement by participants, the outcome of "A" to "B" is considered and anomaly. A possible explanation for this is that the particular student may have been over confident with the initial test score of "A" and failed to put forth the necessary effort to maintain the grade.

SUMMARY

A new growing challenge in engineering education is to change the freshman's mindset from formulae dependency to critical thinking. The Peer Tutorial program was established as intervention to address low persistence in the engineering programs. The tutorial structure was centered around the "saying and doing" learning methodology specifically to help student develop their critical thinking skills. The work presented in this paper aimed to assess the extent to which participation in the tutorial has mitigated their initial formulae dependent mindset.

Results so far provide indications that students who participated in the peer tutorial program were more socially engaged in collaborative learning,[11] developed increased confidence in their learning, possessed deeper understanding of what they learnt and demonstrated acquisition of some critical thinking skills as evidenced by their improved performances in the math course they enrolled in.

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