Establishing Learning Communities among Engineering Freshmen through Peer-group Tutoring Program

Ben Oni
Electrical Engineering Department
Tuskegee University
Tuskegee, AL, USA

Vimal Viswanathan
Mechanical Engineering Department
Tuskegee University
Tuskegee, AL, USA

Abstract**—** Personal observations of students in engineering programs in my institution show that they are very heavily formula driven and consequently deficient in the critical thinking skills to independently evaluate and solve analytical problems. The dependency on formulae is so pervasive that it qualifies to be classified as an addiction i.e., formulae addiction labeled in this paper as *"formulaholic"* and defined as "*the compulsive dependency on formulae to solve analytical problems to the subdual of critical thinking skills*". This formulae driven trait in these students results in poor performances in analytical-based courses. It also often leads to their lack of engagement in engineering classrooms. This problem is especially of critical concern in HBCU environments. In order to address this concern, the researchers are currently implementing a constructivism-infused peer learning approach for incoming engineering students. In this approach, the incoming freshmen are enrolled in specially designed peer-group tutorials that guide the participants to collectively solve problems by themselves. The performance of the students attending these tutorials was compared with a control group. The results showed that the students who attended the peer group tutorials performed significantly better in their class tests and analytical-thinking skills compared to the control group. Currently, the progress of these students is tracked through their engineering classes. Based on the feedback from the participating students, they found the group-learning method very effective. Further, they unofficially get together with their groups frequently to study for their exams in other classes. The preliminary data indicate that the peer-group tutorials are effective in creating learning communities within the engineering student population.

Keywords—Peer Group; Tutorial; Peer learning; Critical thinking skills, "formulaholic"

I. INTRODUCTION – PROBLEM ADDRESSED

The issue of persistence is of serious concern in many educational institutions, particularly in HBCUs or minority institutions in general. Persistence as with retention is a major goal for higher education institutions. Low persistence leads to attrition in student population due to increased dropout rate. For minority institutions, particularly those with low endowments, decline in enrollment poses serious financial challenges to the sustainability of the institution[1].

There is persistence driven by high college costs, and there is persistence driven by academic challenges. This work-in-progress addresses persistence driven by academic challenges. Two factors contributing to the academic challenges addressed in this work are (i) formulae dependent habits exhibited by students and (ii) social isolation in academic environments particularly of 1st generation college students.

Formulae Dependency When observed over decades of teaching span, the peculiarities of generations of engineering students become distinctively noticeable. The personal observation of the first author in the last decade is that the generation of students enrolling in engineering programs have increasingly exhibited unusual dependency on formulae for solving analytical problems. While the use of formulae has its place in problem solving, nevertheless, when dependency on formulae becomes very pervasive and without which students have extreme difficulty solving simple mental problems, such dependency qualifies to be classified as "addiction" i.e., formulae addiction. Formulae addiction is named in this paper as "*formulaholic*" and defined as "the compulsive dependency on formulae to solve analytical problems to the subdual of critical thinking skills". There are several reasons why "formulaholic" is of great concern in engineering education. The successful practice of the engineering profession hinges on the practitioner's ability to possess and apply critical thinking, metacognitive and problems solving skills in engineering practices. Deficiencies in these skills in engineering education lead to:

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

The Social Isolation Effect
A considerable number of students from economically distressed communities in the nation are first-generation college students with inadequate preparation for the College experiences. The inadequacy is not limited to academics in many instances; it is also social. Interviews of those students dropping out in their 1st or 2nd year in college reveal two basic predicaments: Isolation/loneliness and the absence of parents

telling them what to do. For such students, the social instinct is to "belong". This dilemma usually thrusts them into a state of perplexity and sometimes into the wrong crowd, whose focus may not necessarily be serious educational pursuit and before they can recover, they are already overwhelmed with academic challenges with which they are unable to cope.

II. UNDERSTANDING THE PROBLEM

A. Past Investigations

The issue of persistence has existed since the beginning of formal educational institutions. Persistence is an individual phenomenon. Therefore, students from different backgrounds (e.g., race, ethnicity, social economic status) will experience differently the forces within academic institutional environments that influence persistence.[2] A great deal of research has been conducted and many studies have been devoted to providing guidance for programs that aim to increase student persistence in higher education. To understand the factors impacting persistence, Tinto provided an integrated model for studying persistence. The model has been revised by Tinto and modified by other researchers[3-9] including Astin, A.W. Pascarella, E.T.; Berger,J.B., Milem, J. F., Braxton, J. M., Pascarella, E.T.; Terenzini, P.T., Reason, R. D.

B. Learning Models for persistence

Pascarella and Terenzini reviewed more than thirty years of research work regarding factors that influence learning and persistence [2][10,12]. From this body of work, Terenzini and Reason [9] refined the model of influences on student learning and persistence as illustrated in Fig 1. The model effectively identified the key factors within the Peer Environment that influence persistence. The model presented the factors in three clusters including: curricular experiences; classroom experiences, and out of class experiences for identifying key environmental factors that influence persistence – see Fig 1.

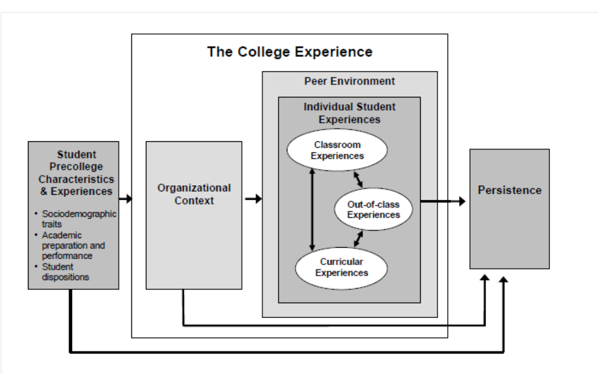

Fig 1: A Comprehensive Model of Influences on Student Learning and Persistence *(Adapted from Terenzini and Reason, 2005)*

It is noted from the model (Fig.1) that pre-college characteristics including social demographic, academic preparation and student disposition carry over to the peer environment and will impact the degree to which a student succeeds with intervention. Pascarella and Terenzini (1998) conclude, "*We cannot assume that any single intervention is effective for all students, nor should we assume that interventions influence students the same way or to the same magnitude.*"[12].

Further examination of Terenzini and Reason's clusters shows that socialization is mentioned placidly as part of the student's *curricular experiences* cluster. However, Braxton & Lee's assessment [2][13] of the link between social integration and student persistence is more emphatic. They suggest that the degree to which a given factor influences persistence has some dependency on context and environment. This view was also presented by Tinto (2006-2007) who, in his review of persistence-related research, pondered why improved understanding of what affects student persistence has not increased overall student retention rates appreciably. He wondered what needed to be done further to appreciably improve student retention. He arrived at two conclusions: (a) that students from different backgrounds (e.g., race, ethnicity, social economic status) experience differently the forces within academic institutional environments that influence persistence [2][14] (b) The process of student retention differs in different institutional settings.

In the context of an environment where socialization plays a critical role in persistence, as is suggested in the authors' institution, the Terenzini and Reason model (Fig 1) is consequently modified as shown in Fig 2 to address the impact of social isolation, particularly of 1st generation college students.

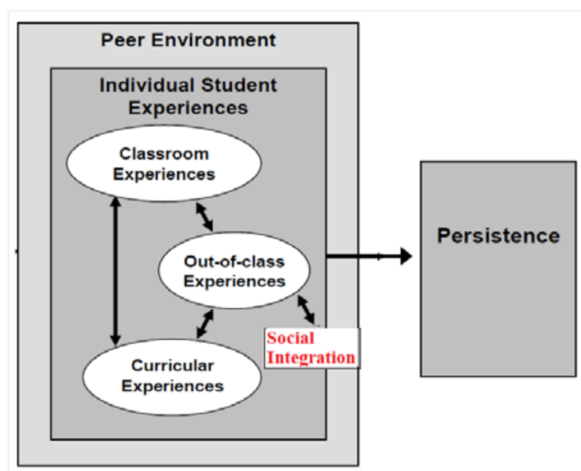

Fig 2 Tuskegee University Peer Environment Model of Student Learning and Persistence with elevated emphasis on social integration
(Modification of Terenzini and Reason, 2005)

III. SEEKING A SOLUTION

Proposed Intervention Model: The learning model proposed for intervention in this project is a hybrid of "Constructivism" and "Problem-based Peer Learning" Together, the model exemplifies potentials for critical thinking skills and social integration.

Constructivism is an approach in education that claims humans are better able to understand the information they have constructed by themselves. According to constructivist theories, learning is a social advancement that involves language, real world situations, and interaction and collaboration among learners. The learners are considered to be central in the learning process. A major theme in constructivist theory is that learning is an active process, whereby students learn best by constructing new ideas and building new schemas based upon current and past knowledge. The cognitive processes behind this construction draw heavy influence from cultural and social aspects of students' lives. Constructivism is based on key tenets of learning: including but not limited to: (1) the student must play an active role in constructing meaning from new information. (2) the students' prior conceptions form a basis for determining the meaning of new knowledge. (3) learning is an ongoing process that requires discussion, debate and opportunities to reconstruct ideas. The role of the community - other learners and teacher in the constructivism process is to provide the setting, pose the challenges, and offer the support that will encourage mathematical construction[15].

Peer learning - 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, on respecting the developmental level of each young person and on promoting a positive and collaborative social atmosphere. Each multi-age, multi-level group is an excellent format for fostering varied levels of intellectual development, because every child is both a peer and a mentor to fellow students" [16]

The notion that *"every child is both a peer and a mentor to fellow students"* has potential to minimize the impact of isolation/loneliness on new students, particularly first generation college students, while the opportunity for dialogue so that learners can construct their own knowledge - individually and collectively, should appreciably reduce "*formulaholic"* tendencies.

The tutorial program established to reduce formulae dependency and promote social integration in the STEM learning community is summarized in the pilot study report.

IV. PILOT STUDY

This study is designed to analyze two different effects of peer group tutorial program: the effect on students' academic performance and the effect on their social integration. As mentioned earlier in this paper, both issues are crucial factors that influence student persistence in engineering programs at Tuskegee University. This paper presents the results of the students' academic performance in the context of the peer tutoring program, while the social integration effects of said program are left for future work.

To qualify for the engineering programs, students are expected to have acquired the fundamental knowledge of mathematical concepts in their high school classes and enter an engineering program with this knowledge. Where the prospective engineering student has not acquired the necessary Math foundation, it is incumbent on the program to provide remedial courses for the students. In general, a student's success in engineering courses is highly correlated with his/her knowledge-base in mathematics

The study described in this paper was conducted in Summer 2015. The students who joined the school of engineering program through Tuskegee University's summer pipeline program (titled HEAD START) were required to take the pre-calculus course (Math 107). This program aims to provide a head start for engineering students. The program acts as a crash course for their first year math and engineering courses. The students in the Summer 2015 program were asked to participate in a peer-group tutorial program outside of their regular class hours and the investigators tracked their performances. The following hypothesis was evaluated in this paper.

Students who participate in peer-tutoring activities and help their peers will perform better in their introductory mathematics course compared to those who do not.

Study Procedure. The study group was comprised of the nine students enrolled in the Summer 2015 HEAD START program. The control group was comprised of students who were not HEAD START students but enrolled in the same pre-calculus class as the study group. The non-HEAD START students were college bound students from the same geographical recruitment pool as the HEAD START students (hence were expected to have comparable mathematical abilities to the study group). The pre-calculus class (Math 107) is a university course open to all students. Nine students in the study group enrolled in this course while nine students (as a matter of coincidence) in the control group also enrolled in the course.

The HEAD START students were required to attend peer-tutoring sessions outside their regular class hours while the control group students had the option to attend a regular university tutorial program. These peer tutoring sessions for the Math course ran for average of 1.5 hours per day, 4 days a week.

The peer tutorial program established for this study is operated on the foundation that we learn more and retain more of what we learn by "saying and doing". The tutorial format is as follows: Each student takes a leadership turn to address problems or issues by vocalizing the problem and solution approach with the other group members making contributions. An upper class honor student is assigned to each group as Peer Tutor. The Peer Tutor will listen to the discussions and give freedom to the group to explore alternate approaches to solve the problem. The Peer Tutor will interject into the discussion only if the group is drifting off course, or to emphasize a very important concept that the group articulated. At the conclusion of the discussion, the lead student goes to the board to write the solution.

The peer-tutoring sessions were monitored by student tutors and supervised by a faculty member. The student tutors were trained to guide the students in the right direction without directly solving the problems for them. The nine students in the study group were divided into two different teams to work on the problems. Two tutors were assigned for the guidance of these teams. The students were required to solve close-ended mathematical problems with practical engineering applications. In other words, they were required to relate the physical reality with the mathematical concepts for finding a successful solution to the problem.

The performance of the students in their mathematics classes was measured using their test scores. The course had four tests and one final exam. These tests consisted of short and long answer questions related to mathematical concepts they learned in the classroom. After each test, the grades of all the students were collected from the instructors and recorded.

Results. The HEAD START students performed significantly better than the non-HEAD START in their class, as predicted by the hypothesis. Figure 1 shows the average class score in each test.

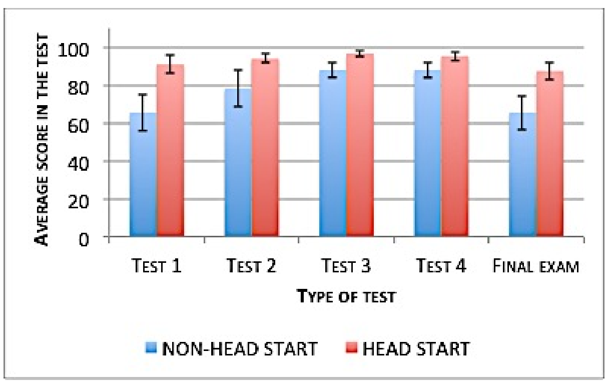

Fig 3. Average test scores for MATH 107 class. The test scores are out of 100. All error bars show (±) 1 SE

As data indicate, the HEAD START students performed better consistently in their tests and the final exam. As stated earlier, the two groups were recruited from the same geographical area and assumed to have comparable mathematical abilities. A statistical analysis is performed to compare the test scores of the HEAD START and non-HEAD START groups in the tests. A one-way ANOVA (Analysis of Variance) shows that the difference between the two groups is statistically significant ($F = 16.11$, $p < 0.01$) (The normality assumption for ANOVA was not satisfied by the data, but the data were homgeneous in variance. Hence the ANOVA was robust to the violation of normality). Post-hoc t-tests reveal that even for each individual test, these two groups performed differently, statistically (Table 1).

Conclusions. Overall, all the students who attended peer-tutoring sessions performed consistently better in the course. Based on the comparison between the performances of HEAD START and non-HEAD START students in the MATH 107 class, it can be concluded that the peer-group tutoring sessions enhanced students' learning of Math concepts by reasoning rather than by formulae. Overall, these results support the hypothesis presented earlier in this paper. As tracking of participants' performances in this on-going study continues, it is pertinent to observe that many members of the summer 2015 study group still study and socialize together. These social aspect of this study has been studied using a follow-up survey and the results are discussed in detail elsewhere [17].

TABLE I. COMPARISON OF HEAD START AND NON-HEAD START STUDENTS IN THE INDIVIDUAL TESTS IN MATH 107

Test	t-statistic	p
Test 1	2.77	0.02
Test 2	2.19	0.05
Test 3	2.66	0.02
Test 4	1.59	0.13
Final exam	0.62	0.02

V. SUMMARY

Two issues were targeted in this study – unusual formulae dependency by students to solve analytical problems and social isolation impact on learning, particularly for 1st generation college students. This issue of formulae dependency was observed to be so prevalent as to deserve a special name – "*formulaholic*". Factors that affect learning as modeled by past researchers in the topical area of persistence were reviewed. One of the models on persistence was modified to fit the observable situation in the Tuskegee University engineering community. The Tuskegee University modified persistence model emphasized social integration as part of a learning community. The educational models considered best suited to address the observable issues were the hybrid combination of Peer Group learning and the Constructivism models respectively. This hybrid-learning model was implemented using a special Peer Group Tutoring program. A pilot study undertaken to examine the concept shows that the Peer Group Tutoring program anchored on the concept of "saying and doing" was effective in addressing the issues targeted in the study. Quantitative data confirms the assessment.

VI. LIMITATIONS OF THE STUDY

The sample size of the current pilot study is only 18. The results serve as indications rather than solid conclusions. However, the authors intend to continue this study in the future HEAD START programs and analyze the data from those to improve the reliability of the results. No pre-screening of the mathematical abilities of the participating students was performed. However, this was not expected to cause any biased results as the paricipants were randomnly selected from the same geographic background.

ACKNOWLEDGEMENTS

This study is part of grant activities funded by the Department of Energy (DOE), Division of the National Nuclear Security Agency, (NNSA) Minority Serving Institutions Program Workforce Planning and Outreach Branch, Office of Human Capital Management. Funding support is to enhance STEM education and research at Tuskegee University under FAMU Project No. 004599 contract # C-4317. The authors are grateful to DOE/NNSA for the support and opportunities.

REFERENCES

[1] Lyken-Segosebe, D., Shepard, J.C., "Learning from Closed Institutions: Indicators of Risk for Small Private Colleges and Universities, Higher Education Leadership and Policy Studies, Peabody College of Education and Human Development, Vanderbilt University, July2013.http://www.ticua.org/public_policy/sm_files/Learning%20from%20Closed%20Institutions.pdf

[2] Reason, R. D., "An Examination of Persistence Research Through the Lens of a Comprehensive Conceptual Framework," Journal of College Student Development, 2009, 50 (6), 659-682.

[3] Tinto, V., "Dropout from Higher Education: A Theoretical Synthesis of Recent Research," Review of Educational Research, 1975 *45*, 89–125.

[4] Tinto, V., "Leaving College: Rethinking the Causes and Cures of Student Attrition" (2nd ed.), 1993, Chicago: University of Chicago Press.

[5] Astin, A. W., "Achieving Educational Excellence: A Critical Assessment of Priorities and Practices in Higher Education," 1985, San Francisco: Jossey-Bass.

[6] Astin, A. W., "What matters in college? Four Critical Years revisited," 1993, San Francisco: Jossey-Bass.

[7] Pascarella, E. T., "College Environmental Influences on Learning and Cognitive Development: A Critical Review and Synthesis," In J. Smart (Ed.), "Higher education: Handbook of theory and research" (Vol. I)., 1985, New York: Agathon.

[8] Berger, J. B., & Milem, J. F., "Organizational Behavior in Higher Education and Student Outcomes," In J. C. Smart (Ed.), "Higher education: Handbook of Theory and Research" (Vol. XV), 2000, New York: Agathon, 268–338.

[9] Terenzini, P. T., & Reason, R. D., "Parsing the First Year of College: Rethinking the Effects of College on Students," 2005, Annual Conference of the Association for the Study of Higher Education, Philadelphia, PA.

[10] Pascarella, E. T., & Terenzini, P. T., "How College Affects Students: Findings and Insights from Twenty Years of Research," 1991, San Francisco: Jossey-Bass.

[11] Pascarella, E. T., & Terenzini, P. T., "How College Affects Students. Vol. 2: A Third Decade of Research," 2005, San Francisco:

[12] Pascarella, E. T., & Terenzini, P. T., "Studying College Students in the 21st Century: Meeting New Challenges," 1998, The Review of Higher Education, 21, 151–165.

[13] Braxton, J. M., & Lee, S. D., "Toward a Reliable Knowledge about College Student Departure," In A. Seidman (Ed.), "College Student Retention: Formula for Student Success," 2005, Westport, CT: Praeger, 107–127.

[14] Tinto, V., "Research and Practice of Student Retention: What Next?," 2007, Journal of College Student Retention, *8*, 1–19.

[15] Pagán, B., "Positive Contributions of Constructivism to Educational Design," 2006, Europe's Journal of Psychology 2 (1).

[16] Gardner, H., "The Theory of Multiple Intelligences," 1993, Basic Books, New York.

[17] Oni, B., and Viswanathan, V., Baah, D., "Dealing with 'Formulaholic' – the Formulae Syndrome of the New Generation Engineering Students," 2016, First Year Engineering Experience (FYEE) Conference, Columbus, OH.

.