AC 2012-3499: IMPROVING STUDENT ENGAGEMENT AND OUTCOMES IN FIRST-YEAR ENGINEERING COURSES AT A HIGHLY DIVERSE, MULTICULTURAL URBAN UNIVERSITY

Dr. Katherine S. Zerda, University of Houston

Kathy Zerda is the Director of the Program for Mastery in Engineering Studies (PROMES), the multicultural learning community for undergraduates at the Cullen College of Engineering. She also directs the UH Women in Engineering program. Zerda is an Instructional and Research Assistant Professor for the college and serves as the Faculty Advisor for the student chapters of the Society of Women Engineers and the Society of Mexican American Engineers and Scientists. Before joining the University of Houston, Zerda worked as an Engineering Manager for Hewlett-Packard Company. She earned a bachelor's of science degree from the University of Notre Dame, her Ph.D. from Baylor College of Medicine, and a master's in business administration from Mays Business School at Texas A&M University. Zerda represents the University of Houston on the board of the Texas Alliance for Minorities in Engineering (TAME) and serves as current Board Chair.

Diana G. de la Rosa-Pohl, University of Houston

Diana de la Rosa-Pohl has been a lecturer in the Cullen College of Engineering at the University of Houston since 2003. She has worked with the PROMES program to develop project-based learning courses for the first-year curriculum. Currently, she is developing and evaluating project-based multidisciplinary courses for the engineering honors program.

Dr. Stuart A. Long, University of Houston

Stuart A. Long was granted B.A. and M.E.E. degrees in electrical engineering from Rice University, Houston, Texas, in 1967 and 1968, respectively, and a Ph.D. degree in applied physics from Harvard University, Cambridge, Mass., in 1974. He joined the faculty at the University of Houston, and served as Chairman of the Department of Electrical and Computer Engineering from 1984 to 1995 and as Associate Dean of the College of Engineering from 1995 to 2008. He was Interim Dean of the Honors College in 2008-2009. He also serves as Associate Dean of Undergraduate Research and the Honors College, and in this role oversees the undergraduate research programs for the entire campus. He is a professor in the Department of Electrical and Computer Engineering and a registered Professional Engineer. In 2010-2011, he served as Interim Vice Chancellor/Vice President for Research and Technology Transfer.

Dr. Fritz J. Claydon, University of Houston

Improving Student Engagement and Outcomes in First Year Engineering Courses at a Highly Diverse Urban University

Background

The Cullen College of Engineering at the University of Houston (UH) serves a diverse population of students including many First-Generation-in-College (FGIC) students, and many from groups traditionally underrepresented in engineering fields, i.e. African Americans, Hispanics, and females. The total enrollment of students seeking Bachelor's degrees in engineering was 2,571 in fall 2011. The demographics of this population include 7.2% African Americans and 27.6% Hispanics. Females represent 22.7% of the undergraduate population of the college. Over two-thirds of graduates from the Cullen College of Engineering are non-FTIC students, i.e. they are community college transfers or have transferred from other universities or other majors within UH. Additionally, well over 90% of graduates have attended classes on campuses other than UH during the course of their college studies. A majority of students commute to campus. Students generally must work to finance their education. As a result, four-year graduation rates are low, especially among African American and Hispanic students, and students more typically take five years or longer to attain the degree. In recognition of the unique needs of this population the college maintains a multicultural engineering program (MEP) to provide a success framework to help students persist to graduation. This learning community, the Program for Mastery in Engineering Studies (PROMES – pronounced "promise") is open to all undergraduate engineering intents, but specifically seeks to serve those students from under-represented groups who may not have access to college-educated role models within their families and who may not otherwise have access to professional and academic engineering mentors. PROMES was launched at the University of Houston in 1974 and incorporates key recommended structural elements such as a formal introductory course for new freshmen and incoming transfer students, clustering of students in common sections of their courses, a dedicated study center, and structured study groups.[1] In addition, peer mentors assist freshmen and new transfer students throughout the first year.

There is a second learning community within the College of Engineering that supports success for a different, although sometimes overlapping, cohort. This second community is the Honors Engineering Program (HEP), established to create a small-college atmosphere among students who join the university's Honors College in addition to enrolling in the College of Engineering. Honors students engage in an extended curriculum that supplements their specific disciplinary curriculum to provide a full-spectrum liberal education. As with the PROMES cohort, participating students represent all disciplines within engineering and enjoy a multidisciplinary first-year engineering experience. They also form a racially and ethnically diverse cohort that mirrors the demographics of the university as a whole. Unlike most members of the PROMES cohort who represent the first in their families to pursue a university degree, HEP members often have college-educated parents who can help them navigate the transition into university. Regardless of this apparent advantage, our experience is that Honors students too often leave without completing an engineering degree. Thus HEP students, just like their PROMES counterparts, benefit from participation in a community of peers and supportive faculty and staff irrespective of family support or financial circumstances.

Participation in both of these communities is voluntary and therefore one might argue that any differences in outcomes for participating students are a reflection of self-selection. Our data indicate that there is no significant difference between factors such as ethnicity, gender, age, or SAT scores between members of the participant groups and matched-control engineering students who do not participate in either the PROMES cohort or the HEP cohort. Moreover, for students who join these cohorts after they have already earned a University of Houston semester GPA, no significant difference in starting GPA is seen when compared to peers who remain unaffiliated with these learning communities. Clearly, though, willingness to join any learning community reflects an attitude of openness to engagement.

HEP and PROMES students are required to enroll in a two-semester freshman course sequence that includes introductory engineering course content along with content related to general academic success and personal skills development. The emphasis of the curriculum element is on experiential, hands-on learning. Students have the opportunity to develop competency in engineering design principles, basic project management, basic programming, teamwork and interpersonal skills, time management—all while forming a community of practice that will support them throughout their undergraduate studies. Many studies relate persistence of students in science, technology, engineering and math (STEM) majors to levels of student engagement in the classroom.[2,3,4,5] Hake reported on the impact of Interactive-Engagement (IE) strategies in the physics classroom compared with more traditional instructional methods, concluding that IE methods enhance problem-solving ability among students.[6] Many similar studies report results that emphasize student engagement and hands-on experiences as a way to let students connect theory with common daily experiences. Hutchison et al links student experiences with improved self-efficacy, i.e. students' beliefs about their capabilities to perform a task successfully.[7] The PROMES program has historically utilized experiential learning in the first-year curriculum in conjunction with other aspects of successful learning communities such as group study, course clustering, a dedicated advising staff, collaborative learning workshops, and peer mentoring. The HEP program utilizes similar strategies. While we have long believed in the success of this multifaceted approach (based upon apparent student success, feedback from alumni and hiring managers, and enthusiasm of the participants), this paper reports on data collected over several years to measure and demonstrate program outcomes.

PROMES-Specific Programming Elements

At the start of the 2007-2008 academic year we initiated an orientation event for incoming students that featured an inspirational keynote address by an alumnus of the PROMES program and a full-day study skills seminar presented by Donna O. Johnson, developer of the Guaranteed 4.0 Learning System[8] and nationally recognized speaker on academic success strategies for engineering students. The event was open to all incoming engineering students, but was mandatory for those entering the PROMES cohort because of the at-risk nature of many of these students. (Students in the HEP cohort were encouraged to attend, but attendance was not mandated for this group.) Principles of the study system were incorporated into the PROMES sections of the engineering course structure and reinforced by the peer mentors throughout the year. The orientation event was repeated the next fall semester for a new group of incoming students. Students who had previously attended the orientation program served as peer mentors for the new group and also were enlisted as peer mentors for a new voluntary pilot project that further emphasized the learning system components. The pilot was dubbed “PROMES PLUS”. Freshman and new transfer students who opted to participate in the pilot program met weekly outside of class with peer mentors and PROMES faculty and staff to reinforce the principles of the learning system and to provide a level of accountability in using the system. The goal of this pilot was to encourage students to incorporate the study methods into their daily routine and was an opportunity for us to assess the impact of the learning system on GPA and overall success of those students who participated in the project. Dow Chemical agreed to support the pilot by pledging two $500 scholarships for students who showed outstanding commitment to academic success through the weekly program. The Dow Chemical gift was announced at the launch of the pilot as an incentive for students. Our initial cohort in the pilot program numbered 43 students. The average cumulative GPA of this small group at the end of the pilot academic year was 3.19 compared with an average cumulative GPA of 2.61 for non-PROMES PLUS peers within the larger PROMES community. This result has encouraged us to continue to offer this program each year to students enrolled in the PROMES sections of the PBL courses, and to enlist upper division students as peer mentors. Dow Chemical has continued as a partner and has increased the number of scholarships to three per year. We encourage new and returning students to use the learning system and to commit to the weekly mentor meetings. We have also recently expanded the fall semester orientation event to include elements designed for returning students. These include professional and personal development workshops presented by corporate partners. Topics have included financial management, resume reviews, behavioral interview strategies, and advice for workplace success. Approximately 300 students have attended this event annually since its inception.

Historically, first-year retention has been more of a challenge within the PROMES cohort than with the HEP cohort. Admission requirements are higher for participation in the Honors College, and most Honors students enter university from academically strong high schools. In general this is not the case with students who enter the PROMES community, and that is why more time and attention has traditionally been given to exposing PROMES students to a system of Academic Best Practices as part of their First-Year Experience. Therefore, we have been interested in tracking the impact of this approach on the PROMES cohort over the course of the last five academic years. Figure 1 shows the average end-of- year cumulative GPA of five consecutive cohorts of First-Time-In-College (FTIC) PROMES freshman students who have attended the fall orientation study skills seminar and participated in the PBL introductory engineering curriculum. While the general populations of FTIC engineering students end the freshman year with a mean cohort GPA between 2.5-2.6, the PROMES cohort has consistently done better. The cumulative GPA averages for the PROMES cohort are trending up, while the averages for students not participating in PROMES have changed very little over the past five years. Last year for the first time, the PROMES FTIC cohort achieved an average GPA better than 3.0 on a 4.0 scale.

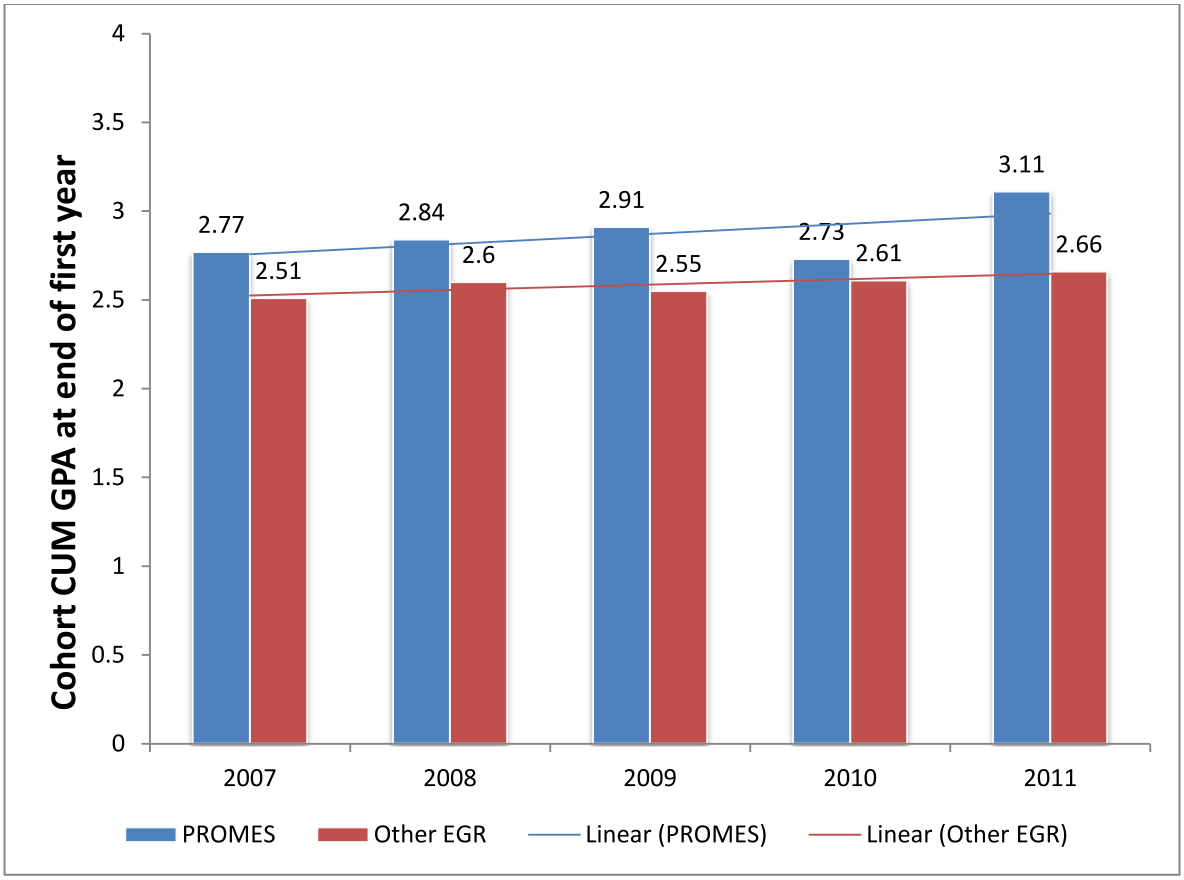

Figure 1. First-year average cumulative GPA results of five consecutive PROMES FTIC cohorts. The PROMES cohorts participate in a number of interventions which include special emphasis on Academic Best Practices, group study, course clustering, and peer and faculty mentoring. "Other EGR" indicates engineering FTIC freshmen who do not participate in the PROMES community.

Curriculum Design

In 2005 faculty from PROMES and from the Honors Engineering Program worked together to create new introductory engineering courses for use by both learning cohorts. The new curriculum emphasizes Project-Based Learning (PBL) and the role of peer mentors in the classroom. Peer mentors are students who are typically engineering sophomores or juniors. Each peer mentor guides 12-15 students, helping with project work and personal skills development. (Note: Peer mentors are students who are active in the learning community, have successfully completed their first-year coursework, and have gone through an application and interview process to determine their readiness for the role. Most students see this as a desirable role because it allows them to assist new students and stay connected with the community faculty and staff. Mentors also qualify for a stipend to offset some of their educational costs.) Peer mentoring underpins the learning community framework and aims primarily to address the issue of isolation often felt by students, especially minority and First-Generation-in-College students. This multifaceted approach for entering freshman and transfer students generates enthusiasm and a feeling of shared purpose and belonging. Among the projects used in the classroom are the popular *MacGyver Projects* developed at Virginia Polytechnic Institute and State University and described by York.[9] In addition we use other engineering design challenges (including Rube Goldberg devices) and robotics programming challenges using Lego Mindstorms kits and RobotC software.

In fall 2006 the redesigned curriculum was implemented for the first time. Instructors and peer mentors for PROMES and HEP sections of the course met together weekly to track progress, discuss weekly goals, align project launches, discuss challenges, and "tweak" the curriculum. By the fall of 2007 the curriculum was fully implemented. Table 1 shows a sample schedule of activities for the fall 2007 course. The PBL curriculum continues to evolve each semester.

Class	Activity	Class	Activity
1	Pre-course Survey Ice Breaker	15	Technical Writing presentation: Plagiarism
2	Engineering Decision Matrix	16	Departmental Lab Tours
3	Engineering Design Process Mini Project (The Great Egg Drop)	17	Final Project assigned: Rube Goldberg Challenge
4	MacGyver Project 1 assigned Team Charters Activity	18	Design Day for Rube Goldberg Challenge
5	Design Day for MacGyver Project 1	19	Career Development (Alumni Panel Presentation)
6	College Career Fair - all students attend Project timeline due for MacGyver Project 1	20	Design Day for Rube Goldberg Challenge
7	Student Engineering Societies Information Fair	21	Design Day for Rube Goldberg Challenge
8	MacGyver Project 1 due: Competition Day! Turn in Technical Report for Project 1	22	Technical Presentations: DOs and DON'Ts
9	MacGyver Project 2 assigned Refine Team Charters	23	Significant Figures and Engineering Estimation
10	Design Day for MacGyver Project 2	24	Data Analysis (Hands On Activity 1: Head Circumference measurement)
11	Design Day for MacGyver Project 2	25	Data Analysis (Hands On Activity 2: Paper Clip Bending)
12	Departmental Lab Tours	26	Engineering Estimation Activity: How much water does the campus reflecting pool hold?
13	MacGyver Project 2 due: Competition Day! Turn in Technical Report for Project 2	28	Final Projects Due Project presentations
14	Departmental Lab Tours	29	Project presentations completed Post-course surveys

Table 1. Sample semester schedule for the first semester PBL Introduction to Engineering course used for both the PROMES and HEP cohorts in the fall semester of 2007.

Since the initial implementation of the revised curriculum, HEP and PROMES versions of the courses have diverged as appropriate based upon the needs of the particular cohort. However, the fundamental elements remain very closely aligned. Currently, the Cullen College of Engineering accommodates forty percent of incoming freshman and transfer students in PBL introductory courses through either PROMES or HEP. The other sixty percent enroll in more traditional lecture-style introductory courses taught within their home departments. The demographics of participants are shown in Table 2 along with similar data for the college and for all University of

Houston STEM majors. The data confirm that demographics of the PBL cohorts are reflective of the college as a whole.

FALL 2011	African American	Hispanic	White	Asian	Other	Male	Female
PBL Introductory Engineering Classes (PROMES plus HEP)	12%	31%	29%	21%	7%	75%	25%
Cullen College of Engineering students	7%	28%	28%	23%	13%	77%	23%
University STEM majors	8%	32%	31%	26%	3%	57%	43%

Table 2. The demographics of UH STEM and Engineering majors compared with first-year Engineering students enrolled in PBL introductory courses in fall 2011.

Problem-Based Learning: Combined Outcomes for PROMES and HEP Cohorts

Members of the cohort of students who entered as freshmen in fall 2006 have begun to graduate. We compared retention of students who participated in a PBL First-Year experience in fall 2006 (through either the PROMES or HEP learning community) to peers who experienced traditional departmental introductory engineering lecture courses during that same semester. Four-year data for students in PBL and non-PBL cohorts indicate that students in the PBL cohort have persisted in their studies or have already graduated at a rate 10% higher than those of their non-PBL counterparts (Figure 2). This data is encouraging and aligns with published educational research which suggests that engaging students in meaningful hands-on projects early in their engineering curriculum promotes enthusiasm about the major and enhances persistence and student success[10,11]. Students report positive experiences with the project-based introductory engineering courses via end-of-course surveys. Likert Scale course evaluations over five consecutive years show that students enrolled in PBL courses gave an average rating of 4.24 out of 5.00 points when asked to evaluate “Overall quality of the course”. Their non-PBL counterparts rated their introductory engineering courses on average 3.75 out of 5.00 points for the same metric. In freeform feedback, students indicate a strong affinity for the design projects, teamwork, and interactive nature of the course. When asked to comment on what they liked most about the course, students responded:

- *“The course is hands-on and interactive. It gives you a chance to meet and work with other students as well.”*
- *“This course was very creative and taught me a lot about engineering at the same time.”*
- *“Design challenges and building models allow me to think about ideas and test their effectiveness.”*
- *“The MacGyver projects were fun and effective ways to introduce basic concepts of engineering.”*
- *“The projects taught me a lot about teamwork.”*
- *“Working in groups because it teaches communication and group skills”*

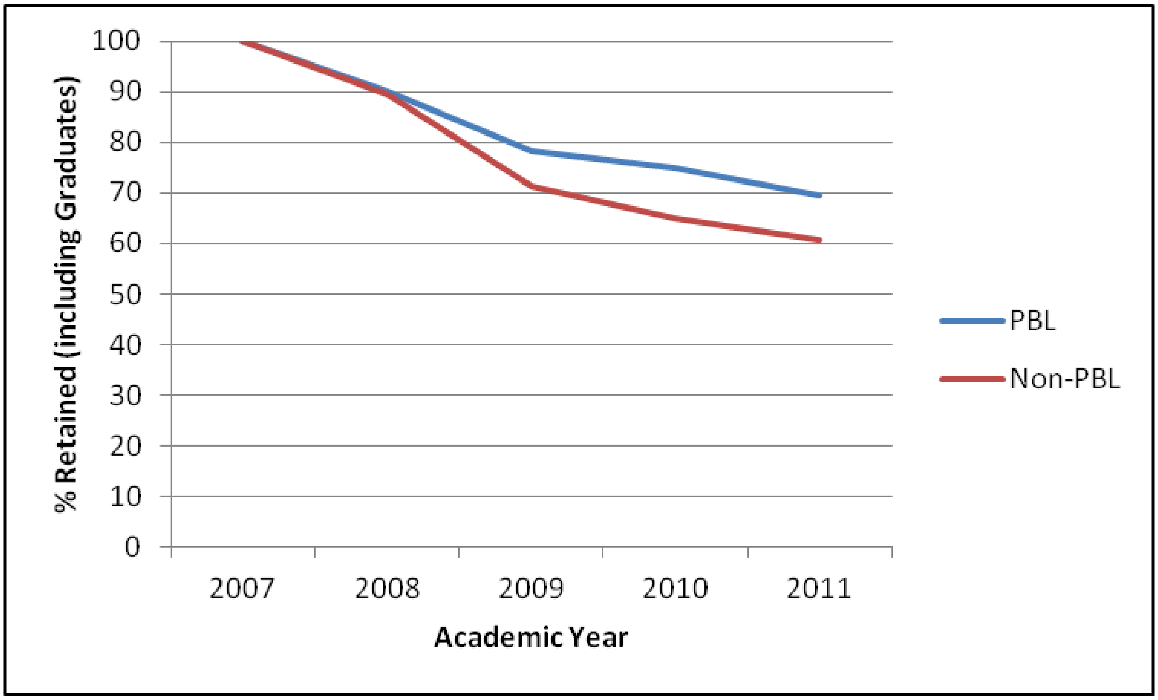

Figure 2. Persistence of FTIC Engineering students from the AY 2007 cohort enrolled in Project-based First-Year engineering courses compared to peers enrolled in non-PBL lecture format introductory courses.

Additional surveys indicate that PBL students perceive that they have gained both in technical competencies and in self-efficacy through their experiences in class. They express that they are more confident about their ability to succeed in engineering as a result of the courses. The most often heard negative reaction was reflected by one student who said, "Way too much work for a one-hour course!" This is a concern that is frequently discussed among the instructors, too. We continue to modify the schedule to include significant class time to complete project work and also to limit homework. However, despite our concerns about burdening the students with a workload that interferes with their other studies, we find that students get so involved with their projects that teams can regularly be found sitting throughout the engineering buildings working on their designs and testing their prototypes. They are a source of entertainment for other students and faculty who observe and share their enthusiasm.

Implementation of Peer Mentoring

Peer mentoring is an important element of our approach in building an effective learning community, and may in fact be the single most important component with respect to leaving a lasting impact on mentors and mentees. Peer mentoring has been fundamental to PROMES for many years, and has been implemented in HEP community over the past seven years. Peer mentors are selected from the pool of former students who have participated in the PBL courses. They are usually just one or two years older than the incoming freshmen, and are sometimes younger than other non-traditional incoming students. We select them based upon their ability to serve as role models for the Academic Best Practices which we promote and for their enthusiasm about helping others succeed. Prospective mentors are recruited from the learning community at the end of each academic year for the next year and often directly from the pool of students who are just completing their first year in the program. Candidates complete an application process, are interviewed by faculty and staff and are selected by the instructional team.

We have observed that students in our two learning communities utilize mentoring slightly differently. PROMES students rely mainly on mentors who are near to their own age and experience, and to those who "look like them." They seek out these peer mentors in class and also during after-class hours, and study and socialize with them in the PROMES study lounge. FGIC students, i.e. primarily the PROMES students, gravitate naturally toward the peer leaders but are especially reluctant to seek faculty mentoring. Conversely, we find that HEP students enjoy their in-class peer mentors, but are also very comfortable seeking out "older and wiser' mentors such as their professors and other faculty advisers.

An unexpected outcome of the peer mentoring model occurred in 2005 when a team of especially committed peer mentors decided to form a mentoring leadership organization called the PROMES Action Committee (PAC). Their goal was to provide support to the faculty and staff by overseeing mentoring activities and event planning on behalf of the PROMES students. PAC remains strong today and PAC leaders take responsibility for organizing PROMES social events, community outreach, and professional development activities for students within the community. The independent ideation and implementation of PAC by peer mentors suggests that they feel empowered and possess confidence, leadership and self-efficacy. The impact of peer mentoring is as important in the development of the mentors as it is for the mentees. When surveyed about their experiences, peer mentors from both PROMES and HEP expressed similar sentiments:

- "I feel being a mentor has helped me be more rounded personally and professionally. It has taught me how to give clear, precise direction. When I first started facilitating the class I would sometimes skip over things, assuming students were aware of things. But after some complaints, I learned that I have to be clear and direct."
- "Being a mentor has changed my perspective on how to study. I finally understand that I must practice what I preach, in other words, I must be committed to the [Guaranteed] 4.0 program. Helping students improve their schedule, and giving them the feeling that I have been through what they are going through, and giving them advice and hope is simply priceless. I cannot explain the satisfaction I get from watching the students I help succeed. It has taught me that I am capable of so much more. Teaching somebody something you know, or something that has worked for you has a degree of satisfaction that cannot be explained in words."
- "Being a mentor has sharpened my people skills and leadership skill. I learned to be more sensitive and responsible since I am giving someone my academic advice. It also encourages me to broaden my knowledge since I do not want to look clueless when my protégés ask me questions about internships, industry experience, facilitator roles, or being an organization officer. Watching my protégés take my advice seriously makes me feel really happy and rewarded."
- "Having input and being able to help create the materials that the students use to learn makes being a peer mentor extremely rewarding when I can see that students are actually learning important concepts. Being given the responsibilities of a mentor who actually

does a lot of things to run the class has helped me develop confidence in making decisions as a leader."

Concluding Remarks

We believe that our interventions and implementation of learning communities has indeed created an environment that allows engineering undergraduates to excel. Most importantly, learning communities and interactive, hands-on learning experiences make a difference in the lives of individual students. A recent graduate sent an update on her future plans that captures her feelings about the learning community she experienced as an undergraduate. This student participated in the Project-based Learning curriculum as part of the AY 2007 cohort. She writes:

"I have wanted to get in touch with you to tell you about my future plans.... I'd like to tell you ahead of time that you and PROMES have majorly influenced my life over these last four years, and I cannot thank you enough for all the accomplishments I have now and those to come. You will be happy to know that I will be attending graduate school this fall at [university] *as part of the Endocrinology and Reproductive Physiology Ph.D program. In addition to getting into the program, I received the Advanced Opportunity Fellowship that the university offers to increase the racial and ethnic diversity of their graduate student population. A really cool thing about this fellowship, in addition to it funding my 1st and 3rd year, is that it places me in the Graduate Research Scholar program whose goal is to help first-generation college graduate students succeed in graduate school by creating a community of scholars for the purposes of professional development, mentoring, and other community-building activities. Even though this is a 5 year commitment away from home, after being in* [city] *this past summer I know I can do it. I want to thank you and PROMES again for all that you all have done for me. I will be sure to give back to PROMES once I can."*

Bibliography

[1] May, G.S., and D.E. Chubin. 2003. A retrospective on undergraduate engineering success for underrepresented minority students. Journal of Engineering Education 92 (1): 27–39.

[2] Seymour, E., and N. M. Hewitt. 1997. Talking about leaving: Why undergraduates leave the sciences. Boulder, CO: Westview Press.

[3] Sheppard, S., C. Atman, R. Stevens, L. Fleming, R. Streveler, R. Adams,and T. Baker. 2004. Studying the engineering student experience: Design of a longitudinal study. In Proceedings of the American Socity for Engineering Education Annual Conference and Exposition. Salt Lake City, UT.

[4] Eris, O., D. Chachra, H. Chen, C. Rosca, L. Ludlow, S. Sheppard, and K. Donaldson. 2007. A preliminary analysis of correlates of engineering persistence: Results from a longitudinal study. In Proceedings of the American Society for Engineering Education Conference and Exposition. Honolulu, HI.

[5] Ohland, M. W., Sheppard, S.D., Lichtenstein, G., Ozgur, E., Chachra, D. and R. Layton. 2008. Persistence, Engagement, and Migration in Engineering Programs. Journal of Engineering Education Vol. 97 (3): 259-278.

[6] Hake, R. 1998.Interactive-engagement versus traditional methods:a six thousand student survey of mechanics test data for introductory physics courses. American Journal of Physics 66 (1):64-74.

[7] Hutchison, M.A., Follman, D.K., Sumpter, M. and G.M. Bodner, 2006. Factors Influencing the Self-Efficacy Beliefs of First-Year Engineering Students. Journal of Engineering Education, Vol. 95 (1), pp. 39-47.

[8] Johnson, Donna O. and Y.C. Chen, 2004. Guaranteed 4.0: Follow our 3-step plan and if you don't make all A's, we will give you $100!, JCYC Studio, Dallas.

[9]York, Steven C. 2004. Using Design-Build Projects to Teach and Reinforce Engineering Skills to First-year Engineering Students. Proceedings of the 34th Annual Conference of Frontiers in Education.

[10] Olds, B.M,. and Miller, R.L., 2004. The Effects of a First-Year Integrated Engineering Curriculum on Graduation Rates and Student Satisfaction:A Longitudinal Study, Journal of Engineering Education, Vol, 93,No. 1, pp.23-35.

[11] L.E. Carlson D.W. Knight and J.F. Sullivan. Staying in engineering: Impact of a hands-on, team-based, first-year projects course on student retention. In *Proceedings of the ASEE conference and exhibition*, page Session 3553. ASEE, 2003.