

AC 2007-2180: THE TEAMS PROGRAM: A STUDY OF A GRADES 3-12 ENGINEERING CONTINUUM

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The TEAMS Program: A Study of a Grades 3-12 Engineering Continuum

What is TEAMS?

For the last eight years, the University of Colorado, College of Engineering and Applied Science's Integrated Teaching and Learning (ITL) Program has been involved in K-12 engineering outreach. One component of the ITL's outreach initiative is engaging engineering undergraduate and graduate engineering students in K-12 science, math and technology classes to serve as engineering role models.

Partially funded by the National Science Foundation GK-12 and U.S. Department of Education FIPSE grants, the ITL outreach program refined the focus of its engineering initiative in 2000 to target the student populations of the Lafayette, Colorado, schools due to their diversity and low academic performance. This endeavor led to the TEAMS — Technology and Engineering to Advance Math and Science — initiative, partnering with six Lafayette schools: four elementary and one middle school that feed into a high school with a four-year pre-engineering program. Our approach is to make engineering exploration part of every child's educational experience in grades 3-12. Through weekly hands-on, inquiry-based engineering instruction, TEAMS Fellows work alongside partner teachers to integrate real-world engineering content with age-appropriate pedagogy through relevant classroom interactions to cement science and math concepts.

To further enhance this program, the Boulder Valley School District (BVSD) developed a widely-advertised engineering magnet program — focusing on their six Lafayette neighborhood schools — with the intent to increase student accomplishment, enrollment into and graduation from Centaurus High School. BVSD established the Centaurus Pre-Engineering Academy to create a unique and challenging learning opportunity for its high school students — a student body comprised of 39% minority students, and 30% from low-income families. This initiative to increase performance and close the achievement gap has, principals report, resulted in more parents open enrolling their students into Lafayette's schools — reversing the historical “white-flight” from the area schools.

During 2005-2006, the graduate and undergraduate TEAMS Fellows impacted 1,865 students weekly via the instruction of engineering curriculum in 68 classrooms: four elementary schools (710 students); one middle school (915 students); and one high school (240 students). Fellows also led five before- or after-school TEAMS clubs. The Fellows' sought-after hands-on activities have become an integral teaching component for teachers and an anticipated thrill for the students.



Figure 1. Students in the TEAMS program explore biomedical engineering.

Program Goals

The goals of the TEAMS program include the development of an engineering continuum of grades 3-12 learning that culminates in greater numbers of students from populations typically underrepresented in engineering — girls, students of color, low-income youth, and first-generation college-bound students — prepared for and enrolled in the engineering pipeline. By engaging students early on in engineering activities and helping them understand the real-world applications of STEM learning, we hope to inspire today's youngsters to prepare themselves to enter the engineering/technology workforce. Other program goals include modeling a replicable school district/university partnership, enriching STEM learning by K-12 students and teachers, enhancing the instructional capabilities of the TEAMS Fellows, and developing engaging grades 3-12 engineering curricula.

Each goal is broken down into objectives, and performance criteria are specified for each objective. Assessment methods target specific performance criteria designed to ascertain if program goals and objectives were met. Data analysis and evaluation of the assessment results from participating students, teachers, principals and graduate Fellows is extensive and imperative to our data-driven improvement and success of the program.

Program Assessment

Throughout the TEAMS initiative, an emphasis is placed on a continuous evaluation cycle, with quantitative and qualitative assessment methods employed to assess the initiative's success in meeting its goals. The analysis incorporates student attitude and content assessment and examines the effect of exposure to engineering weekly in grades 3-8 on student enrollment into high school engineering courses and interest in collegiate-level engineering.

Quantitative methods include:

- Student content testing –With support from teachers, Fellows create tests and quizzes that specify and measure lesson concepts. They use multiple choice, matching, true/false and fill-in-the-blank formats. Tests are administered pre- and post-instruction.
- Student attitude surveys – All grades 3-8 students participating in the TEAMS program rate their level of interest in engineering and confidence in their knowledge of engineering as a career. Students rate their attitudes on five-point Likert-type scales. Surveys for elementary students use age-appropriate terms and questions are often read aloud.
- Rating of Fellow teaching skills – Teachers, Fellows and ITL program staff provide feedback on Fellow teaching skills, including content knowledge, classroom management and ability to integrate engineering curriculum into the K-12 classroom. This feedback is compiled to provide more accurate assessment.

Qualitative assessment methods include:

- Open-ended survey questions for teachers and Fellows – These questions provide a richer data set than quantitative questions alone and are useful for supplementing and explaining numerical results. Teachers and Fellows report on the strengths, challenges and suggestions for improving the program and are prompted to provide anecdotal feedback.

- Fellows' and principals' focus groups – Focus groups are useful for exploring a structured set of open-ended questions. Participants are guided through discussion on introductory, key and closing questions, such as “Why did you get involved in the program?” “What do you feel you're getting out of the program in terms of your own development?” and “Are there any other suggestions you have for improving the program?”
- Observational feedback on lesson activities – Teachers provide formative feedback on the activities taught by the Fellows in the classroom. Teachers fill out an observation form and provide their top suggestion for improving the activity or getting candid feedback on delivery of the curriculum from the Fellow. This process opens dialog between Fellows and their partner teachers and promotes real-time improvement of lesson delivery. For example, after an activity on earthquakes, one teacher suggested, “Show pictures of design options from cities with engineering codes such as San Francisco and Japan.”

Assessment data are collected from K-12 students, teachers, principals, TEAMS Fellows and program staff, and includes annual pre-, mid- and post- attitude and interest tests, with student content testing conducted pre- and post-lesson delivery. Assessment results are documented and presented throughout the year as formative assessment, and as summative assessment results at a year-end debrief session during which all partners evaluate the results in meeting program goals. Lessons learned are incorporated back into the program each year.

Assessment Results

Examples of assessment results, shown in Figures 2-5, illustrate the evaluation cycle. These results span 27 graduate and 15 undergraduate TEAMS Fellows who were partnered with 38 teachers in six different schools within the Boulder Valley School District in Lafayette, CO, during the past three academic years. These results demonstrate whether or not engineering exposure weekly in the classroom increase knowledge of and interest in engineering in grades 3-12 students.

Student *knowledge of engineering* is assessed through student content testing, student attitude surveys, open-ended questions for teachers and Fellow focus groups. Fellow-created content knowledge tests are given before and after a curricular unit is taught. Figure 2 presents results collected across three years from grades 3-12. Results from 1,288 matched pre- and post-lesson content tests reveal significant ($p < .05$) content gains each year.

As our program assessment has evolved and become more in-depth, our analysis now includes gender data from student attitude surveys to assess students' confidence in their knowledge of engineering as a career. Figure 3 displays results from 2005-2006 assessment in which students rated their confidence on a 1-5 scale with 5 equal to a rating of highly confident. These results reveal significant ($p < .05$) gains from the beginning to the end of the year with girls (+41%) out gaining boys (+26%) in confidence.

Qualitative data support these results with one Fellow commenting in the focus group, “I love when they build something and get excited about what they're building. Their eyes light up and they get it!” Similarly, one teacher provided this response to an open-ended survey question, “I think it's great to be bringing engineering projects into the math classroom — the students enjoy them and it helps them see that math is relevant and fun.”

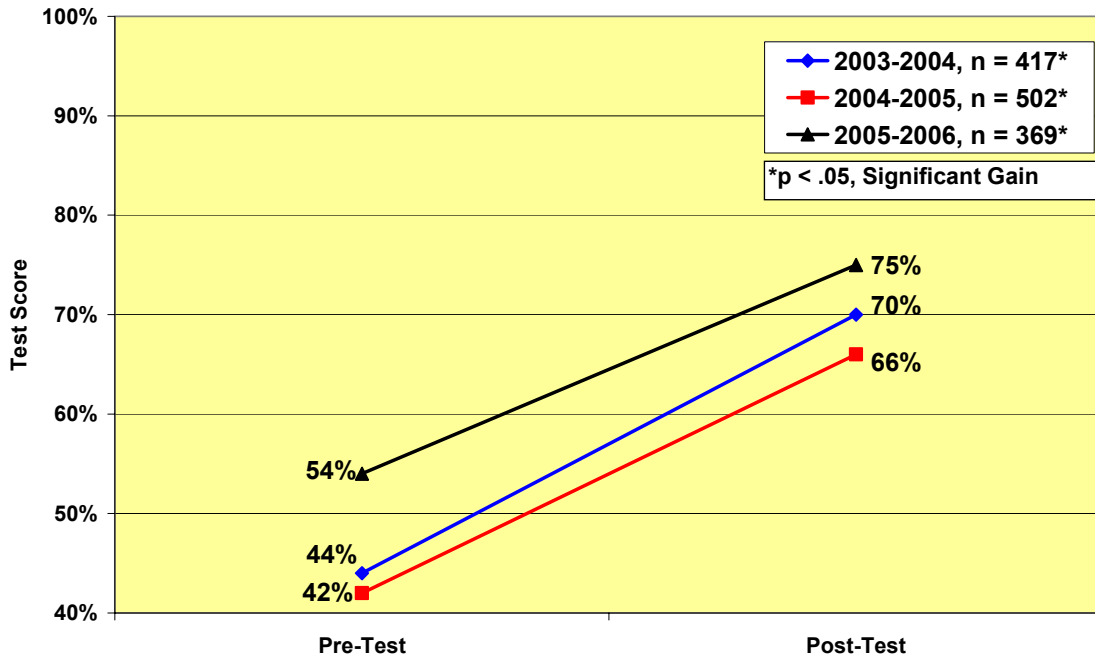


Figure 2. Results from pre-/post-student content testing during a three-year period.

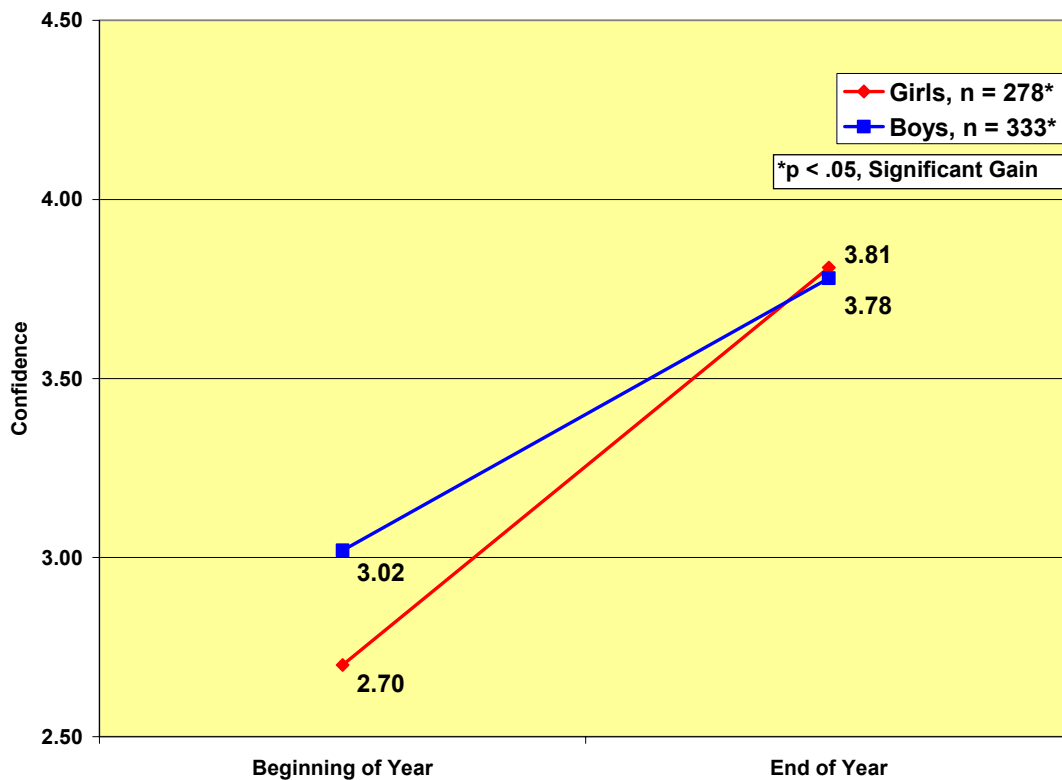


Figure 3. Confidence in knowledge of engineering as a career by gender (2005-2006).

Student interest in engineering is assessed by student attitude surveys as well as enrollment into, and graduation from, the high school Pre-Engineering Academy. Students rated their interest in

engineering and science on a 1-5 scale with 5 equal to “definitely interested.” Figure 4 presents results collected on student interest in engineering across three years from grades 3-12. Results from 1,416 matched pre- and post-year surveys revealed stable interest levels in the first two years of the program (i.e., statistically flat) in which students displayed a moderate level of interest at the pre-assessment, and this level of interest was maintained. In 2005-2006, significant gains in interest were found in which students began with a moderate level of interest at the pre-assessment and moved to “interested” at the post-assessment, which we interpret to mean that the TEAMS program is raising awareness of engineering in our partner schools. Figure 5 depicts these significant gains in interest broken down by academic level. Significant gains in interest are seen at the elementary and the middle school level while a higher level of interest is maintained in students taking the high school engineering courses.

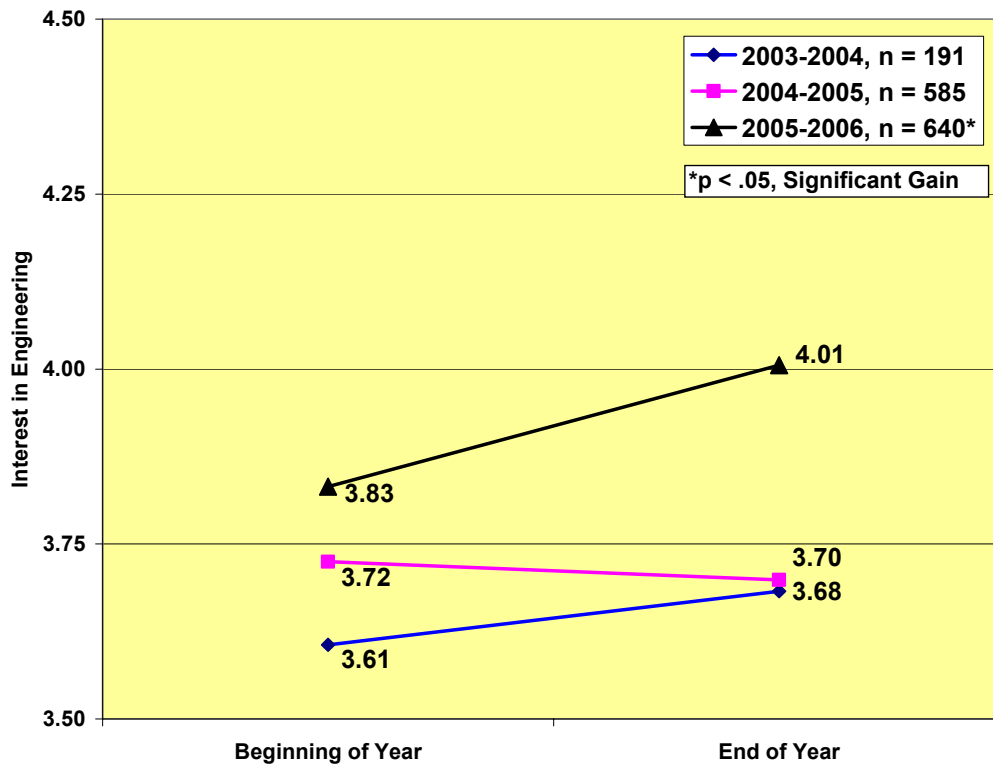


Figure 4. Results from student interest surveys during a three-year period.

Interest data was also collected from enrollment and graduation results from the Pre-Engineering Academy, as 2006 marked the first year that Lafayette TEAMS students — who had the opportunity to take up to four years of high school engineering electives — graduated. Of the 30 2006 seniors who remained engaged in Pre-Engineering Academy (PEA) classes, 21 enrolled in engineering colleges in fall 2006, 13 of which are now at the University of Colorado at Boulder (10 in engineering and 3 building their academic foundation in order to transfer into engineering). Success comes slowly from K-12 engineering programs, but we are pleased that enrollment in our ninth-grade fall 2006 class is the highest ever (~66), with 32% females.

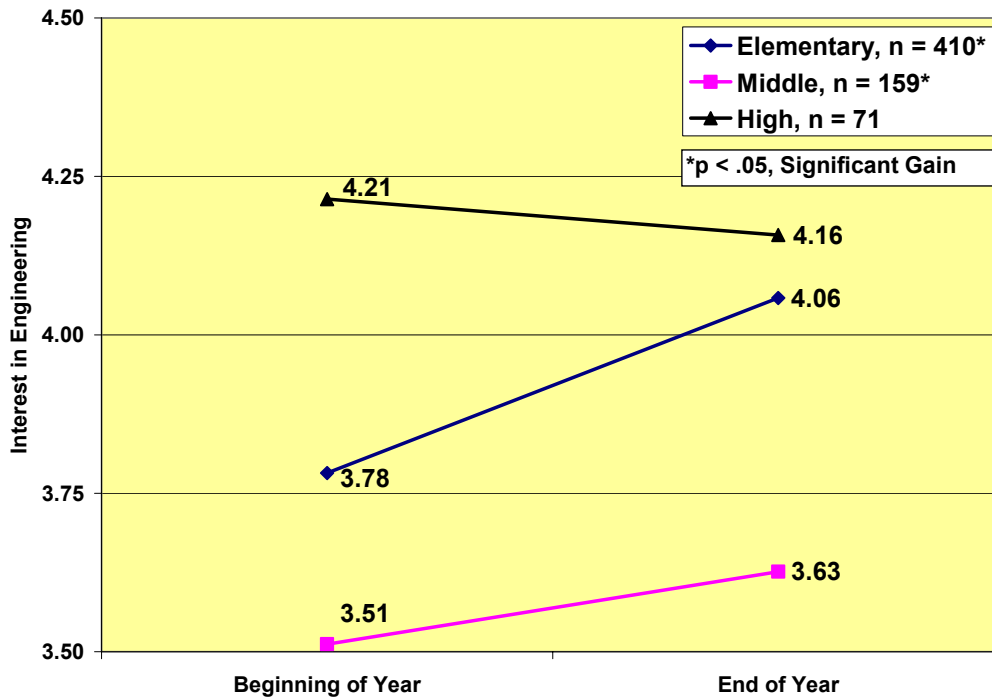


Figure 5. Pre-/post-interest in engineering (2005-2006) by grade level.

To further engage students once they arrive at CU-Boulder and knit our college more closely with the K-12 community, we formed the “Centaurus TEAMS Posse” to send former PEA students back into their community to teach engineering. To that end, several former Centaurus students now attending CU’s College of Engineering enthusiastically participate in the TEAMS Posse. Their responsibilities include planning, organizing and delivering hands-on engineering activities for the before- or after-school TEAMS Clubs — an academically-enriching hour in which engineering comes to life for young, impressionable girls and boys.

The integration of these current undergraduate engineering students as TEAMS Posse members in their former elementary schools has its challenges, but appears to be a success. Teachers report that the undergraduate TEAMS students bring a sense of “local academic heroism” into their classrooms through their deep connections to the schools in which they are teaching. In future years, we will continue to involve Centaurus high school graduates in the TEAMS program — a model we believe positively impacts youth by taking the mystery out of engineering and encouraging students to step up to the academic challenges of an engineering future.

TEAMS Resources

A well-honed foundation — established through many years of experience — is necessary for the TEAMS program to run smoothly. Much ongoing support is required to provide overall administration, copious logistics and classroom support for Fellows and teachers. As with any successful program, TEAMS’ well-structured foundation endures challenges and setbacks that ultimately aid in our continuous program improvement. Each cohort of new, or returning, graduate Fellows requires a period of adjustment to the hectic schedule of teaching youngsters.

In addition to classroom teaching, the graduate TEAMS Fellows have the responsibility for developing publishable engineering lesson plans for grades 3-12. Fellows use the already-developed *TeachEngineering* curriculum in their instruction — innovative hands-on engineering curricula on topics mapped to grades 3-8 state science and math standards. This collection serves as a nationwide resource for K-12 engineering curricula and is available free to educators at <http://TeachEngineering.org>, an online, standards-based, searchable digital library.

The comprehensive and engaging engineering lesson plans and associated activities serve as the primary content resource supporting the implementation of the TEAMS program. Each lesson is comprised of hands-on, inquiry-based activities, background and motivational information, and assessment, as well as a myriad of other components. The curricular collection is continually revised as TEAMS Fellows gather feedback from teachers and students on what did and did not work within the lessons and activities.

Program Evolution

The TEAMS program is continuously growing, including the commitment of the six schools in Lafayette to the integration of *TeachEngineering* curricula into their science classes. Partnership and program improvement is dependent upon feedback received from teachers, Fellows and principals throughout the year. As many suggestions as possible are incorporated back into the program as soon as is feasible.

The *TeachEngineering* digital library content was aligned with the educational content science standards for each grade 3-8, and the best grade level fit for each curricular item was determined. We then used this as the guidepost for joint curriculum planning for the school year, requiring that all engineering curriculum taught come from the alignment document.

As more K-12 students rise through the TEAMS program, we improve the program based on their suggestions as well. Focus groups and surveys ask former Pre-Engineering Academy students to help us learn more about how best to encourage students towards the engineering pipeline. One valuable piece of advice we received was to help students fully understand the high school course choices they need to succeed in college. In response, we developed posters and dedicated time to work with the students on their course selection and the college application process.

Change in Culture

After many years, our TEAMS program has begun to change the culture at CU-Boulder and has raised awareness of the College's leadership team to the challenges involved in preparing K-12 youth — especially those from populations underrepresented in engineering — for a future in engineering. Together, we refined a guaranteed admissions agreement with the high school to help students aim and meet well-defined academic standards for admissions to CU-Boulder's College of Engineering.

Lafayette teachers, principals and BVSD are also committed to this 10-year continuum, as evidenced by the December 2006 decision to reform the grades 6-8 science curricula to become *Science and Engineering* — making engineering the central theme for every students' education.

Conclusion

Has the TEAMS program made enough of a difference? Assessment results indicate participating TEAMS students increase their performance on engineering content tests, are more interested in engineering, more confident in their engineering knowledge and more likely to choose engineering as a career. Simply put: we have built a program that is recognized for its value in the community, is widely endorsed by the school district and publicly touted by school officials. We believe we have created a model suitable for other schools, in any state.

Results from the current PEA high school seniors indicate that more of them are choosing engineering, and a record number have applied to CU-Boulder's College of Engineering for fall 2007 than in previous years. Unfortunately, not all PEA students are academically prepared to enter engineering college; they are interested in engineering, but have not consistently performed in high school, or have made course selections that do not adequately prepare them for an engineering education. Thus, rigorous course selection beyond engineering electives is key for high school students in preparing them for engineering college. Unfortunately, appropriate course selection support is not pervasive. Increased focus will be made in future years to better educate students on the choices they need to make in order to academically prepare them for an engineering education.

As the program continues to grow and solidify in the Lafayette-area schools, we are hopeful that students will come to equate engineering as a desirable career choice. Students from grades 3-12 have begun to identify with the TEAMS program as part of their academic routine — a cool outcome by any measure.



Figure 6. An undergraduate TEAMS Fellow assists middle school students with an electrical engineering project.