A Strategic Plan to Improve Engineering Student Success: Development, Implementation, and Outcomes

Dr. Jerome P. Lavelle, North Carolina State University

Jerome P. Lavelle is Associate Dean of Academic Affairs in the College of Engineering at North Carolina State University. His teaching and research interests are in the areas of engineering economic analysis, decision analysis, project management, leadership, engineering management and engineering education.

Dr. Matthew T. Stimpson, North Carolina State University

Matthew Stimpson is the Director of Assessment in the Office of Undergraduate Academic Affairs at NC State University.

A Strategic Plan to Improve Engineering Student Success: Development, Implementation, and Outcomes

Abstract
Motivated by flat undergraduate student performance metrics, and an ever-increasing focus on student success at University and state levels, a benchmark study found that best-practice student success processes had not been adopted in the College Engineering at NC State University. A structured strategic plan to improve these metrics was developed and implemented for the Fall 2012 cohort. This paper describes the strategic and tactical elements of the linked college-specific changes implemented. Included is a description of the intended purpose of each link and the observed impact on student performance metrics. This paper should be a great value to engineering programs interested in understanding the student success strategies implemented at NC State University and their impact.

A. Introduction

In the College of Engineering at NC State University, measures of student success such as retention, matriculation, and graduation rates had remained largely unchanged for decades. A benchmark study, and review of the literature, on student success in undergraduate engineering education revealed several practices not adopted within the college. From this insight a set of processes/programs aimed at pre-college, first-time fulltime, and transfer students were developed into the *College of Engineering Student Success Strategic Plan*. In developing the strategic plan four organizing themes emerged: messaging, structural, support, and community. Table 1 provides details of the strategic plan themes.

B. Strategy Details

The structure chosen to improve student experiences and performance in the college included elements as given above in Table 1. Details are provided below.

B.1. Messaging Theme

This theme concerns how the college messages about engineering to various audiences. This includes the type of work engineers do, studying engineering, preparing for careers in engineering, the nature of engineering work and its impact, and how engineers intersect with others in society to drive progress and prosperity. In this regard, the 2008 NAE publication *Changing the Conversation: Messages for Improving the Public Understanding of Engineering* [1] both informed and motivated thinking about how the college interacted with constituencies and intended and unintended messages. The 2008 report, which itself builds on the 2002 NAE Report *Raising Public Awareness in Engineering* [2] is summarized as follows [3]:

> The overall conclusion of this report is that the public image of engineering and engineers must appeal to the optimism and aspirations of students and must be all inclusive. In the past, the image of engineers has been focused mostly on white males and messages have emphasized the preparation necessary for engineering careers, especially math and science. This NAE report […] recommends the engineering community begin immediately to plan and initiate a coordinated communications campaign to interest young people from all backgrounds in engineering careers by appealing to their desire to find hands-on solutions to problems that can make a difference in the world and improve people's lives.

Table 1: Linked Student Success Strategies

Strategic Theme	Phase/Interaction	Activities/Programs	Purpose
Messaging	Pre-College	• K-12 outreach activities • Engr. summer camps • Teacher training	• Change messaging • Change culture • Educate and enable • Promote competency
	Application Process	• University application for admissions	• Promote broad thinking • Break unhealthy affinity
	First Year Engineering	• E101/E102 courses	• Educate on nature of engineering informed by Grand Challenge framework
Structural	Matriculation into Degree Program	• Process for meeting minimum standard • Standing in matriculation process	• Focus on success variables • Raise standards/expectations • Establish std. processes • Improve communications
Support	Course options	• E102/E102 and E201 • E122 • E144/E145	• Maintain connections • Intentional reflection
	Active advising	• Proactive intervention	• Early identification • Course correction
	Residence life	• Engineering Village • WISE Village	• Positive link, academic and student life • In-residence programs
Community	Various programs and events throughout	• Orientations, E101/E102 • COE Welcome, FEDD • Career Fair, Grad. Event • Student Groups	• Connection to college • Connection to other students, faculty and staff

In addition, the NAE 2008 report *The Engineering Grand Challenges for the 21st Century* [4] was important from a messaging perspective (see Figure 1 for listing of the Grand Challenge areas). This report profoundly affected the College Name's overall approaches to education, research and engagement broadly. Lavelle [5] describes the college's use of the NAE report framework in messaging:

- Communicate the wonder, opportunity, and excitement of careers in the engineering fields,
- Illustrate the breadth of problem types that engineers work on,
- Emphasize the systems-thinking construct needed to develop solutions to solve these problems,
- Reflect on the historical role of the engineering disciplines compared to the modern and developing role for engineers on multi-disciplinary teams,
- Restate the need for engineers to obtain 21st century skills related to communication, leadership, and cultural, humanities, and ethical sensitivities,
- Provide opportunities for students to gain in-depth experiences in Challenges areas, as a mechanism to prepare them for engineering careers broadly, and to prepare them to be the future innovators to help solve these challenges.

Figure 1: National Academy of Engineering, Engineering Grand Challenges

Below are details of the implementation of strategic messaging in K-12 programming, the application process, and first-year engineering program in support of improving student performance metrics:

B.1.1 Pre-College Programs: The College of Engineering at University Name has a substantial PK-12 outreach and extension mission, touching nearly 20,000 students and teachers annually in a variety of programs. *The Engineering Place* [6] serves as the organizing umbrella for these activities, and the mission/vision speak to goals of educating "through hands-on, inquiry- and problem- based programs and informational workshops and tools" such that "every student, educator and parent … will know the definition of engineering and the impact that engineering has on everyday life." PK-12 programs and initiatives supported include:

- Summer programs
- Family STEM Nights
- Engineering Bits/Bytes
- Solar House
- Engineering on the Road
- Teacher Workshops
- PLTW
- Future Cities

The focus of *The Engineering Place* programs, curricula, publications, and materials is consistent with the goals of the strategic plan relative to *messaging*. Approaches include:

- Promoting competency while making engineering fun,
- Focus on the process-oriented nature of engineering (engineering design cycle, engineering habits of mind [7]),
- Represent diverse populations and problem-types in engineering,
- Focus on the innovation and creativity aspects of engineering,
- Utilize the NAE construct for engineering as a means to communicate that engineers make the world a better place through helping people.

The 2009 NAE report *Engineering in K-12 Education* [8] defined the "engineering habit of mind" as (1) systems thinking, (2) creativity, (3) optimism, (4) collaboration, (5) communication, and (6) attention to ethical considerations. To these six the College adds "persistence." This construct also plays a role in shaping the college's approach to K-12 programming. Figure 2 below gives the engineering design process used by *The Engineering Place* in its outreach and engagement work across all platforms. This work was adapted from the Museum of Science program *Engineering is Elementary* [9].

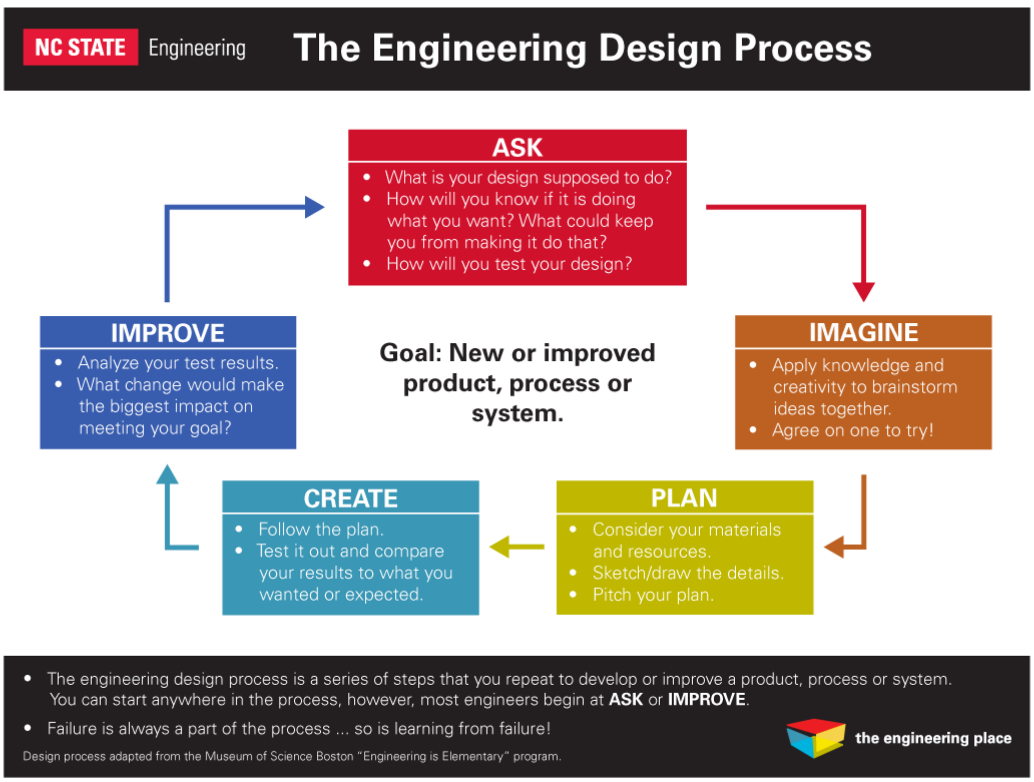

Figure 2: *The Engineering Place* Engineering Design Cycle

B.1.2 Application Process: An important messaging goal under the strategic plan is related to how prospective engineering students understand that engineering is made up of various disciplines. Montford [10] suggests that "secondary students rarely know what engineering is, or what engineers do." Below is a description of the changes made as part of the strategic plan and why these were important from a *messaging* perspective.

Pre-2012 Approach: At NC State University high school applicants were asked to specify a major when applying to the university. For engineering students this meant the selection of a particular engineering discipline. The result of this "forced choice" was to promote a narrowing in student thinking, and a psychological attachment to a particular engineering discipline, prior to engaging in an exploration of the disciplines through the first-year engineering curricula. The result was that students were less likely to engage in broad thinking about their interests in the various engineering disciplines at NC State University. This "attachment" to a certain discipline in some cases blocked consideration of others that were a better fit and better aligned with student interest and aptitudes.

Post-2012 Approach: Starting in 2012, in part due to a change in the admissions software vendor at the university, the College of Engineering implemented a change in the way that incoming new students were designated in the admissions system. All students when applying to any of the 19 ABET accredited programs were designated as Engineering First Year (EFY) students. This small, but nuanced change, was consistent with our approach in the First Year Engineering program—namely, asking our students to "think broadly" about career options during the first year. Being designated as an EFY students explicitly indicates to students that their job is to investigate the majors and find the option that is best for them, rather than make a forced choice that may not.

B.1.3. First Year Engineering: The two primary goals for students in the First Year Engineering (FYE) [11] program at NC State University are making a successful transition to the university, and choosing a best-fit engineering major. Messaging in these two domains is vitally important relative to student performance measures, and is conducted throughout new student orientation, the required first-year engineering courses, in advising sessions, and other interactions. Below are details on each element from a messaging perspective.

Making a successful transition: There are many reasons high school students do not make a successful transition to college, and the strategic plan was not developed to address all of these. However, from a messaging perspective the FYE program focus is on students' (1) *understanding the rules of engagement*: the policies, rules, and procedures of living on campus and engaging in and out of the classroom with others, (2) *knowing their new job as a scholar*: orienting students toward their role in the community of scholars at university, and understanding that this includes the following behaviors: academic integrity, respect for others, and intellectual curiosity, (3) *gaining knowledge of their strengths and blind spots*: developing in students a self-awareness of their goals and aspirations, appreciating that what worked in high school might not work in college, and developing an intentional plan to get from where they are to where they want to be, and (4) *understanding the we:* stressing the need for, and making available, positive connections in academic and student affairs spaces throughout campus.

Choosing a best-fit engineering major: College of Engineering students at NC State University enter in the FYE program, but ultimately matriculate and graduate from one of the available disciplines. The messaging object in the FYE program is the promotion of broad disciplinary thinking, and in particular broad thinking about engineering from the perspective of the NAE Engineering Grand Challenges. From this construct students learn about engineering and the central challenges facing mankind, and as a result are then able to better evaluate their disciplinary interests and compare options and opportunities. A messaging theme stressed to students is that there are many disciplines working on each of the 14 Grand Challenge areas. Figure 3 below is used to highlight that notion by demonstrating the connections of the disciplines to the Grand Challenge problem areas. Figure 4 is used to further enforce the concept by adding a third dimension to the "engineering workspace" that includes engineering life cycle activities as well as other career areas that engineers work such as technical sales, management, government and regulation, and legal.

● MAJOR	◆ CONTRIBUTING	■ AFFILIATED

NAE Grand Challenge	Engineering Disciplines															
	AE	BE	BME	CBE	CE	CEM	CPE	CSC	EE	ENE	ISE	ME	MSE	NE	PSE	TE
Make Solar Energy Economical	◆			●			◆		●	●	■	◆	■	■		
Manage the Nitrogen Cycle		●		■						●	◆				◆	
Advanced Health Informatics		■	●					●			●					
Prevent Nuclear Terror							◆	◆	◆	◆	◆		◆	●		
Advanced Personalized Learning	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Creating Energy from Fusion		◆							◆					●		
Provide Access to Clean Water		●			●	●								◆	◆	◆
Engineering Better Medicine	◆	◆	●								◆					
Secure Cyberspace			■				■	●	■		◆			◆		
Engineer the Tools of Scientific Discovery	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Develop Carbon Sequestration Methods		■	■		●		■	■		●					◆	◆
Restore and Improve Urban Infrastructure					●	●						●	◆			
Reverse Engineer the Brain		●	●								■	●				
Enhance Virtual Reality	◆	◆	◆	◆	◆	◆	●	●	●	◆	◆	◆	◆	◆	◆	◆

Figure 3: Mapping Engineering Grand Challenges to Engineering Disciplines

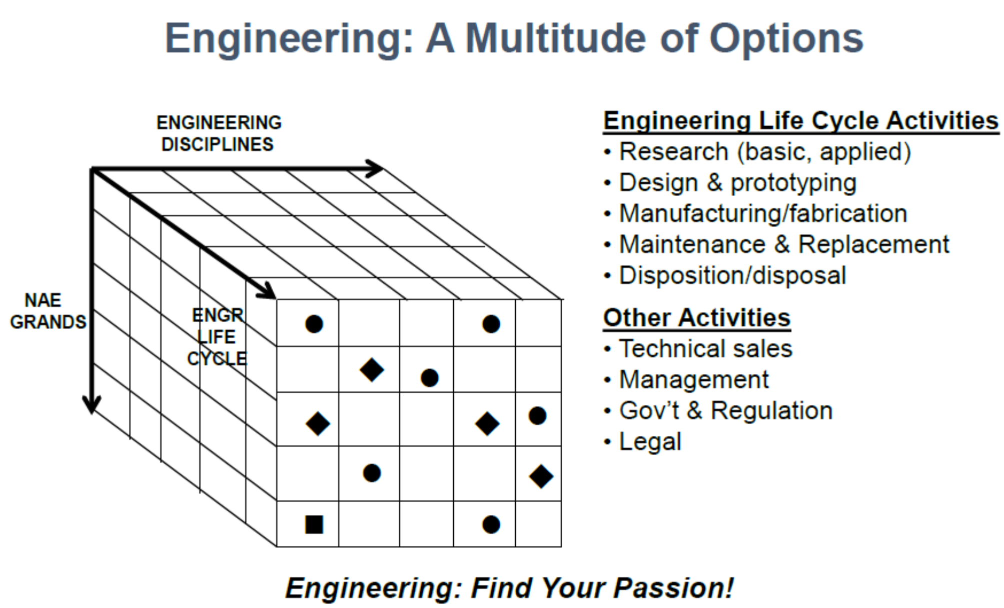

Figure 4: A Three Dimension Representation of the Engineering Workspace

Figures 3 and 4 provide an excellent mechanism to *message* to students about the broad thinking approach to engineering. The general process can be expressed as follows:

1. Students learn about engineering broadly through the Grand Challenge construct;
2. Students critically review their interests, aptitudes, opportunities, and goals;

3. Students understand the nature of the connectedness of the disciplines and that many backgrounds work on the same problems;
4. Students find the engineering discipline that is their best fit.

B.2. Structural Theme

This strategic theme is concerned with the rules, practices and policies that govern students in the College. Issues addressed here include access and support, setting clear expectations, and open and full communication.

B.2.1 Matriculation to a Discipline: For the 2012 entering engineering cohort at NC State University a new system was implemented for managing the movement of students from the First Year Engineering program (and academic status) into one of the engineering disciplines in the college. This system, called CODA (change of degree application) was designed to be a standard process that is well understood and communicated to students and parents, that is fair and designed ultimately to best promote student success. Specifically, its goals were to:

1. Manage student movement into degree programs to balance the capacity in departments with student demand and available resources.
2. Establish academic standards for students and their eligibility for movement into programs.
3. Standardize processes across the board and communicate a common and fair process to students, parents, faculty, and staff.

These components of the CODA system are described as flows:

Management of movement: Prior to implementing CODA there was no real management of student movement from FYE status into an engineering program. A rolling matriculation process was used throughout the year and students were moved as they became eligible. Nominal program capacity levels existed however these never factored into student movement decisions. The CODA system was designed to address the issue of capacity and student flow. Highlights of the system include:

- Program capacities were set for all engineering majors
- Students eligible to CODA expressed their top-3 choices
- A central college staff member made all movements and decisions
- Programs and dean's office balanced student levels and resources

Establish academic standards: Prior to implementing CODA the college required that a set of matriculation courses be passed by all students prior to movement into an engineering discipline. This list included calculus I and II, physics I, chemistry I, first-year composition, introduction to computing environments, and the E101 course. Students were required to achieve a grade of C- or better in these courses, and upon which they were eligible to move to the major of their choice. In establishing standards and processes with the new CODA system an analysis of historical student data revealed several components that were incorporated, as given in Table 2.

Table 2: Data Analysis and CODA Processes

Data analysis revealed….	CODA rule implemented
Students with a grade of C or better in the set of required math and science courses were retained and graduated at higher rates.	Students required to obtain a grade of C or better in a set of *Engineering Success* courses: • Calculus I and Calculus II • Physics I and Chemistry I
Students that had not moved into an engineering discipline before 4 semesters had lower graduation rates	Students are given a maximum of 4 semesters to meet the *Engineering Success* course requirement, and pass the first-year composition, introduction to computing environments, and E101/E102 courses.
Early movement into engineering disciplines from the FYE program promotes graduation	Students are required to apply to the CODA system immediately upon qualifying

Standardize and Communicate: Despite efforts, historically within the college there was a lack of understanding by students admitted into the college as to their enrollment status (am I not in a major yet?) and what and how they were to move from the First Year Engineering program into an engineering discipline. The CODA system was designed to add clarity for students (and parents). Processes were standardized and communicated through various channels. These include:

1. Students' academic status upon admission placed them in First Year Engineering program (and coded as EFY, engineering first year students) rather than being affiliated with a specific engineering discipline.
2. Clear communication about the CODA requirements, including:
   - CODA requirements of grade of C or better in the *Engineering Success* courses,
   - Four semester limit in EFY status,
   - Student selection of 1st, 2nd and 3rd choice majors,
   - Use of *Engineering Success Score* (GPA in these courses) and other variables included in the decision of placement in majors, and
   - Requirement to CODA as soon as requirements are met.

B.3. Support Theme

This theme concerns how students are supported in their goals.

B.3.1. Course Options: The College offers several courses to orient, educate, and support students in pursuit of their goals within the college. The catalog of each is given below:

E101: Introduction to Engineering & Problem Solving: An introduction to the College of Engineering as a discipline and profession. Emphasis on engineering design, interdisciplinary teamwork, and problem solving from a general engineering perspective. Overview of academic policies affecting undergraduate engineering students. Exposure to College of Engineering and university-wide programs and services. [1 credit hour, required]

E102: Engineering in the 21st Century: This interdisciplinary course will provide an overview of the fourteen engineering grand challenges of the 21st century and their relationships to all of the separate engineering disciplines in the College of Engineering. The lectures will incorporate examples, guests, and specific readings on the challenges in sustainability, health, vulnerability, and the joy of living to advance civilization into the next century. Students will gain an appreciation for the methods in which engineers, in each discipline, acquire knowledge and design tools or interdisciplinary solutions essential to meet society's future needs. Course is available to 25% non-engineering students. [2 credit hours, required]

E122:Engineering Academic Success: This 8-week course is designed to teach students a variety of proven strategies for creating greater academic, professional, and personal success. Enrollment is required of students in the College of Engineering who were unsuccessful in completing E101 and/or have an earned GPA less than 2.0 after the first semester of the freshman year. Topics include: time management, goal setting, stress management, study skills, learning styles, and campus resources using a platform of lectures and guest speakers. [1 credit hour, required of student who fail to pass E101 in fall semester]

E144: Academic and Professional Preparation for Engineers I: Assist new freshmen engineering students in the transition from high school to the collegiate environment. Cover critical-thinking; problem solving techniques; academic skills and time management. [1 credit hour, elective]

E145: Academic and Professional Preparation for Engineers II: Engineering as a field of study and profession. Career and professional development, goal setting, decision making and effective communication strategies. [1 credit hour, elective]

E201: Engineering Transfer to Success: This 8-week course will provide an overview of the NC State University policies and procedures, organizations, and resources available for enhancing the academic success of new transfer students in the College of Engineering. Lectures and discussion from departmental representatives will focus on requirements and availability for financial aid, cooperative education, career services, and campus student organizations. Emphasis will be placed on acclimating student through teamwork and academic achievement within the first year of transfer. [1 credit hour, elective]

B.3.2. Active Advising: Each student in the college maintains a primary academic advisor throughout their time on campus. Depending on the program the models vary, however there is always a specific person each student is assigned to and develops a relationship with. Advising at this level usually involves course selection advice, conversations about academic options and goals, and general mentoring. Along with the general advising the college utilizes *active advising* to identify and proactively intervene with students at risk. Below are programs aligned around this approach:

Academic Intervention: An analysis has identified a strong positive correlation between grades in the *engineering* success courses (math and sciences) and academic outcomes. Students who do well in calculus, physics and chemistry tend to matriculate into a major and graduate at higher rates. Thus, the focus on making in-semester corrections especially in the first semester is important. With this in mind, the college has partnered with the College of Sciences to tracks grades and attendance for first semester students in these key courses. The current process is built on work from Lavelle [12], with the overall goal of making students aware of resources on campus (academic and non-academic) to assist them in making a course-correction and move toward their goals. Students' academic advisors are looped into this strategy and serve as an important resource.

E122 Engineering Academic Success: After completing the first semester, students who under-perform academically are required to enroll in the E122 course in spring semester as part of their CODA requirements. Begun as a voluntary program with a wide coalition of campus partners [13], the course is now housed and run in the college. The course challenges students to reflect on sources of their first-semester performance, and evaluate personal choices to get them back on track toward achieving their personal and academic goals.

Engineering Cares Team: This team is made up of engineering faculty, counseling center staff, program directors, assessment personnel, and students. The overall goal of the team is to create a learning environment that promotes students' emotional wellness. Programs support both university initiatives as well as engineering-only initiatives. Examples include identifying students at risk, advisor awareness, intervention, and others.

B.3.3. Residence Life: Created in Fall 2013 the *Engineering Village* is a dorm-based living and learning educational community for first-year engineering students [14]. This program was envisioned and created in support of the strategic plan to provide students a positive living environment that explicitly promotes success in engineering. Village Programs in the village include live-in mentors, tutoring, social and professional development, faculty-in-residence, externships, alternate spring break experiences, block scheduling and more.

B.4. Community and Engagement Theme

The sense of community and belonging is associated with increases in retention and graduation in higher education [15]. This theme relates to programs and events designed to create a sense of community among engineering students at Large University. Activities designed for this purpose as part of the strategic plan include:

New Student Orientation: Engineering students are cohorted together during the summer new student orientation sessions. The college holds welcome, advising and enrollment sessions and promotes connectedness and the concept of the Engineering Family.

E101/E102 Courses: These required courses in the fall (E101) and spring (E102) allow the college of maintain connectedness with students during the critical first year.

College of Engineering Welcome: This event is held within the first weeks of the fall each year for all new engineering students. The goals are to promote the community of Engineering Family, reinforce success strategies, and host a noted keynote speaker [reference here].

First Year Engineering Design Day (FEDD): Associated with the fall E101 course this end-of-semester design day event is modeled after a capstone design event. FEDD is a single-day event where ~350 student teams present and compete with their semester design projects. Promotes connectedness to the college, each other (teaming), and their prospective major.

Grand Challenge Research Poster Day: Like the E101 design project promotes student connectedness through a team research project focused on the NAE Grand Challenges.

Celebration of Graduation Event: In the College of Engineering at NC State University individual departments hold graduation ceremonies. This event serves as the College's year-end event, which includes Order of the Engineer and Pledge of the Computing Professional ceremonies. Faculty, administration, alumni join graduates and guests in this college convocation event.

Engineering Career Fair: The College of Engineering hosts the semi-annual job fair for students in the college and beyond. This fair, open to the general public attracts ~4000 students a day and over 200 companies. The fall event is two days and the spring event one. The event builds community in the college, with attendees ranging from first-year students, graduate students and alumni. Most recruiters are alums adding to the family atmosphere.

Student Groups: There are several student groups supported at the college level, each creating an opportunity for students to be connected with each other and engaged outside their curricula. These include Engineering Ambassadors, Engineers Council, Engineers Without Boarders, Women in Engineering, National Association of Black Engineers, Society of Hispanic Professionals, American Indian Society of Engineers and Scientists, Ben Franklin Scholars program, Engineering Grand Challenge Scholars program, Engineering Entrepreneurs, Tau Beta Pi, Theta Tau, and Alpha Omega Epsilon.

C. Data and Results

The first phases of the College Name Student Success Strategic was implemented for the fall 2012 cohort of new students. The sections and tables below provide a view of the impact that changes have made on student enrollment and profile, retention rates, and 4- and 6-year graduation rates.

C.1. Enrollment and Student Profile:

Table 3 below provides the enrollment and admissions data for cohorts of new engineering students from 2009 to 2017—cohort size does vary somewhat. Looking at cohort data there has been a general subtle increase in the admissions profile of students over time.

Table 3: New First Year Enrollment and Profile by Year (mean and std deviation)

Year Cohort	Cohort Size	Weighted HSGPA	SAT Total	SAT Math	SAT Verbal	ACT Comp	ACT Math
Fall 2009	1387	4.33 (0.31)	1251.39 (119.87)	657.87 (63.93)	593.52 (76.41)	26.78 (3.50)	28.60 (3.59)
Fall 2010	1337	4.40 (0.31)	1252.41 (116.50)	657.17 (62.78)	595.24 (73.90)	27.21 (3.43)	29.03 (3.27)
Fall 2011	1358	4.44 (0.29)	1256.53 (113.85)	657.60 (62.65)	598.93 (72.23)	28.02 (3.69)	29.61 (3.65)
Fall 2012	1373	4.53 (0.28)	1281.84 (104.27)	671.25 (56.82)	610.59 (68.39)	28.30 (3.30)	29.69 (3.21)
Fall 2013	1190	4.62 (0.26)	1304.00 (94.44)	680.32 (53.98)	623.68 (66.16)	28.70 (3.03)	29.72 (3.08)
Fall 2014	1465	4.61 (0.28)	1303.00 (100.26)	679.34 (54.49)	623.66 (71.25)	28.88 (2.99)	29.60 (3.11)
Fall 2015	1331	4.62 (0.26)	1322.26 (94.85)	685.32 (55.33)	636.94 (65.41)	29.62 (2.97)	30.25 (3.11)
Fall 2016	1370	4.27 (1.41)	1330.78 (97.89)	688.46 (55.64)	642.32 (67.75)	30.17 (2.93)	30.43 (3.01)
Fall 2017	1429	4.49 (1.03)	1286.01 (117.93)	663.08 (63.40)	622.92 (76.43)	30.21 (2.79)	30.28 (2.88)

C.2. Retention Rates:

Retention rates capture the persistence of students in the program from year to year. As a result retention is a leading measure toward graduation. From Table 4 retention rates in the college have increased significantly. This increase is noted in the 2nd year rate (% of students persisting from the first year into the second year), as well as the 3rd year rate. Since implementation of the strategic plan in fall 2012 a nominal 2nd year rate of ~90%+ has been achieved.

Table 4: Retention by Year*

Cohort Year	Cohort Size	% cohort retained into ….		
		2nd Year	3rd Year	4th Year
2009	1387	83.7%	69.2%	63.2%
2010	1337	86.7%	67.7%	62.0%
2011	1358	88.4%	73.4%	64.8%
2012	1373	88.7%	76.6%	69.9%
2013	1190	91.3%	78.4%	71.8%
2014	1465	90.2%	75.7%	69.7
2015	1331	91.5%	78.7%	-
2016	1370	88.9%	-	-

*retention reported here is students starting in engineering and remaining in engineering

C.3. Graduation Rates:

From Table 5, graduation rates show a similar pattern to retention rates. Overall 4-year graduation rates have increased almost 14% compared to the 2009, and over 7% compared to 2011 (the year before many elements of the strategic plan were implemented). In May 2018, 6-year graduation rates will be available for the 2012 cohort. It is anticipated that this graduation rate will be in the range of 67-70%, which constitutes a 15-20% increase since the time the strategic plan programs were being conceived in the late-2000's.

Table 5: Graduation Rate by Year*

Cohort	4-yr rate	6-yr rate
2009	22.9%	54.7%
2010	23.9%	56.3%
2011	27.4%	59.5%
2012	34.7%	
2013	36.1%	

* Rate given is for students who start in engineering and graduate in engineering

C.4. Summary of Results:

Although cause-and-effect would be difficult to assign, there has been a marked improvement in student performance as measured by retention and graduation rates after the implementation of the strategic plan in Fall 2012. The college is attracting a higher profile student, retaining them in the early years of the program, and graduating them at a higher rate.

C.5. Disparate Impact:

Although the student performance metrics have increased for the general engineering student body, the impact has not been uniform across gender and ethnic minority classifications. Below is data detailing this effect.

C.5.1. Impact and Enrollment: From Table 6, first-year women engineering student enrollment has increased significantly in the college, both in terms of number and percent. In the fall of 2009, 18% of the incoming engineering class were women, compared to 27.8% in 2017. This equates to a more than 58% increase in an eight year period.

Table 6: New Engineering Student Enrollment by Year and Gender

Year	Men	Women	Total
Fall 2009	1137 (82.0%)	250 (18.0%)	1387
Fall 2010	1074 (80.3%)	263 (19.7%)	1337
Fall 2011	1102 (81.1%)	256 (18.9%)	1358
Fall 2012	1075 (78.3%)	298 (21.7%)	1373
Fall 2013	912 (76.6%)	278 (23.4%)	1190
Fall 2014	1102 (75.2%)	363 (24.8%)	1465
Fall 2015	987 (74.2%)	344 (25.8%)	1331
Fal 2016	1026 (74.9%)	344 (25.1%)	1370
Fall 2017	1032 (72.2%)	397 (27.8%)	1429

From Table 7 the overall number of students from underrepresented minority (URM) groups increased to 153 in Fall 2017. This includes an increase to 76 Hispanic students, but a decrease to 56 African Americans. This later number explained in part by the increase in unknown and 2-or-more categories.

Table 7: New Engineering Student Enrollment by Race/Ethnicity and Year

Race/Ethnicity	Fall 2009	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016	Fall 2017
Nonresident Alien	41	22	32	63	65	76	94	166	71
Unknown	41	25	23	25	18	23	26	54	64
Hispanic	49	39	53	51	46	68	49	49	76
American Indian	4	4	4	4	9	5	1	6	3
Asian	68	65	76	81	62	81	72	100	125
African American	83	95	57	61	34	58	54	43	56
Native Hawaiian	0	1	0	1	2	1	1	0	0
White	1065	1056	1077	1037	915	1095	973	908	977
Two or More	19	18	22	33	28	33	35	27	39
Two or More URM	17	12	14	17	11	25	26	17	18
Total URM	70	150	128	133	100	156	130	115	153
Total Cohort Size	1387	1337	1358	1373	1190	1465	1331	1370	1429
% Cohort URM	5.0	11.2	9.4	9.7	8.4	10.6	9.8	8.4	10.7

C.5.2. Impact and Retention: Although overall retention rates have improved, as described earlier, the effect is not observed uniformly. Tables 8 and 9 provide the data by gender and ethnicity respectively. From theses tables one can observe that men tend to be retained at marginally higher rates than women, and African American and Hispanic rates tend to be lower than overall rates. In general, retention rates across ethnic classifications are more variable year-to-year due to the smaller population sizes.

Table 8: Retention by Year and Gender

Cohort		2nd Year	3rd Year	4th Year
2009	Men	83.9%	69.7%	63.5%
	Women	82..8%	67.2%	61.6%
	Overall	83.7%	69.2%	63.2%
2010	Men	85.1%	71.5%	64.0%
	Women	82.8%	67.2%	61.6%
	Overall	86.7%	67.7%	62.0%
2011	Men	88.4%	73.8%	64.6%
	Women	88.3%	71.9%	65.6%
	Overall	88.4%	73.4%	64.8%
2012	Men	88.6%	77.0%	70.7%
	Women	88.6%	74.5%	67.1%
	Overall	88.7%	76.6%	69.9%
2013	Men	92.0%	80.5%	73.7%
	Women	89.2%	71.6%	65.8%
	Overall	91.3%	78.4%	71.8%
2014	Men	90.7%	75.4%	69.5
	Women	88.7%	76.6%	70.2
	Overall	90.2%	75.7%	69.7
2015	Men	91.5%	79.2%	-
	Women	91.3%	77.0%	-
	Overall	91.5%	78.7%	-
2016	Men	90.1%	-	-
	Women	85.5%	-	-
	Overall	88.9%	-	-

C.5.2. Impact and Graduation: As described previously graduation rates are up significantly since the strategic plan implementation in 2012—this is true for both women and men. Historically, 4-year and 6-year graduation rates for women have been higher than those of men, with over 40% of women starting in engineering now graduating in engineering within 4 years. As in Table 10, a 6-year graduation rate is not available for the Fall 2012 cohort—this is due in May 2018. The 6-year graduation rate for women is likely to be at or above 70%.

Table 9: Retention by Year and Race/Ethnicity

Cohort		2nd Year	3rd Year	4th Year
2009	Nonresident Alien	78.0%	61.0%	58.5%
	Unknown	85.4%	68.3%	56.1%
	Hispanic	87.8%	79.6%	73.5%
	American Indian	75.0%	25.0%	0.0%
	Asian	75.0%	64.7%	58.8%
	African American	83.1%	69.9%	55.4%
	Native Hawaiian	-	-	-
	White	84.4%	69.5%	64.5%
	Two or more	80.6%	69.4%	55.6%
	Overall	83.7%	69.2%	63.2%
2010	Nonresident Alien	81.38%	72.7%	59.1%
	Unknown	95.0%	72.0%	68.0%
	Hispanic	92.3%	87.2%	76.9%
	American Indian	100.0%	100.0%	100.0%
	Asian	87.7%	81.5%	73.8%
	African American	84.2%	64.2%	50.5%
	Native Hawaiian	100.0%	100.0%	100.0%
	White	84.8%	69.8%	63.2%
	Two or more	93.3%	73.3%	76.7%
	Overall	85.4%	70.8%	63.6%
2011	Nonresident Alien	81.3%	68.8%	75.0%
	Unknown	91.3%	73.9%	69.6%
	Hispanic	92.5%	67.9%	54.7%
	American Indian	75.0%	75.0%	50.0%
	Asian	89.5%	77.6%	64.5%
	African American	91.2%	73.7%	59.6%
	Native Hawaiian	-	-	-
	White	88.4%	73.6%	65.4%
	Two or more	86.1%	75.0%	66.7%
	Overall	88.4%	73.4%	64.8%
2012	Nonresident Alien	88.9%	84.1%	76.2%
	Unknown	84.0%	80.0%	76.0%
	Hispanic	80.4%	68.6%	54.9%
	American Indian	100.0%	100.0%	100.0%
	Asian	96.3%	91.4%	85.2%
	African American	88.5%	62.3%	47.5%
	Native Hawaiian	100.0%	0.0%	0.0%
	White	89.0%	76.4%	70.4%
	Two or more	80.0%	72.0%	66.0%
	Overall	88.7%	76.6%	69.9%

Table 9 Continued: Retention by Year and Race/Ethnicity

2013	Nonresident Alien	90.8%	80.0%	72.3%
	Unknown	100.0%	83.3%	83.3%
	Hispanic	87.0%	69.6%	67.4%
	American Indian	88.9%	88.9%	55.6%
	Asian	93.5%	82.3%	74.2%
	African American	91.2%	73.5%	55.9%
	Native Hawaiian	100.0%	50.0%	50.0%
	White	91.4%	78.7%	72.8%
	Two or more	89.7%	74.4%	64.1%
	Overall	91.3%	78.7%	71.8%
2014	Nonresident Alien	88.2%	84.2%	78.9%
	Unknown	87.0%	82.6%	69.6%
	Hispanic	89.7%	77.9%	69.1%
	American Indian	60.0%	60.0%	20.0%
	Asian	92.6%	82.7%	76.5%
	African American	91.4%	69.0%	62.1%
	Native Hawaiian	100.0%	100.0%	100.0%
	White	90.7%	75.2%	69.6%
	Two or more	84.5%	67.2%	62.1%
	Overall	90.2%	75.7%	69.7%
2015	Nonresident Alien	90.4%	77.7%	-
	Unknown	96.2%	76.9%	-
	Hispanic	87.8%	71.4%	-
	American Indian	100.0%	0.0%	-
	Asian	97.2%	87.5%	-
	African American	90.7%	77.8%	-
	Native Hawaiian	0.0%	0.0%	-
	White	91.2%	78.8%	-
	Two or more	93.4%	77.0%	-
	Overall	91.5%	78.7%	-
2016	Nonresident Alien	88.6%	-	-
	Unknown	88.9%	-	-
	Hispanic	83.7%	-	-
	American Indian	83.3%	-	-
	Asian	92.0%	-	-
	African American	81.4%	-	-
	Native Hawaiian	-	-	-
	White	89.3%	-	-
	Two or more	88.6%	-	-
	Overall	88.9%	-	-

Table 10: Graduation by Year and Gender

Cohort		4-year rate	6-year rate
2009	Men	21.5%	54.6%
	Women	29.6%	55.2%
	Overall	22.9%	54.7%
2010	Men	22.2%	55.9%
	Women	31.2%	58.2%
	Overall	23.9%	56.3%
2011	Men	26.6%	58.2%
	Women	30.9%	65.2%
	Overall	27.4%	59.5%
2012	Men	33.1%	
	Women	40.6%	
	Overall	34.7%	
2013	Men	34.6%	
	Women	40.6%	
	Overall	36.1%	

The improvement in graduation rates, however, are not observed for all racial/ethnic categories as in Table 11. While the improvement in the 4-year graduation rate for majority students was substantial, more than 6% points, the graduation rate for African-Americans moved very little. The graduation rate change for Hispanic students was mixed, declining in one cohort year and increasing in a separate cohort year. Again, rates for many of the ethnic categories are affected by small numbers and thus more variable year-to-year.

E. Conclusion

Student academic performance metrics had been relatively flat throughout the 2000s in the College of Engineering. A benchmarking study, and review of the literature lead to the development of the *College of Engineering Student Success Strategic Plan*. This plan included several linked themes meant to improve student retention and graduation rates in the college. The following observations are given for each the strategic areas:

> <u>Messaging:</u> The messaging theme was informed how we communicated to our constituents, including students and teachers in K-12, current and prospective engineering students, faculty, parents and other stakeholders. This theme was influenced by several NAE reports and focused on engineering from systems-thinking, bigger-picture, humanistic and excitement/innovation perspectives. The impact on the college’s students has been positive in that they better understand engineering and their potential role in it. The messaging theme has promoted positive outcomes with all constituent groups.

Table 11: Graduation by Year and Race/Ethnicity

Cohort		4-year rate	6-year Rate
2009	Nonresident Alien	19.5%	63.4%
	Unknown	34.1%	78.0%
	Hispanic	26.5%	73.5%
	American Indian	25.0%	75.0%
	Asian	30.9%	70.6%
	African American	15.7%	63.9%
	Native Hawaiian		
	White	31.3%	77.6%
	Two or more	19.4%	61.1%
2010	Nonresident Alien	40.9%	59.1%
	Unknown	32.0%	76.0%
	Hispanic	17.9%	66.7%
	American Indian	0.0%	100.0%
	Asian	16.9%	66.2%
	African American	10.5%	41.1%
	Native Hawaiian	0.0%	0.0%
	White	25.3%	55.8%
	Two or more	26.7%	66.7%
2011	Nonresident Alien	37.5%	62.5%
	Unknown	43.5%	60.9%
	Hispanic	15.1%	47.2%
	American Indian	25.0%	50.0%
	Asian	34.2%	64.5%
	African American	17.5%	49.1%
	Native Hawaiian	-	-
	White	27.9%	60.5%
	Two or more	13.9%	50.0%
2012	Nonresident Alien	50.8%	-
	Unknown	44.0%	-
	Hispanic	21.6%	-
	American Indian	50.0%	-
	Asian	61.7%	-
	African American	14.8%	-
	Native Hawaiian	0.0%	-
	White	33.4%	-
	Two or more	32.0%	-
2013	Nonresident Alien	30.8%	-
	Unknown	44.4%	-
	Hispanic	30.4%	-
	American Indian	22.2%	-
	Asian	33.9%	-
	African American	17.6%	-
	Native Hawaiian	0.0%	-
	White	37.9%	-
	Two or more	28.2%	-

Structural: The structural components of the strategic plan related to student movement into and out of the First Year Engineering Program. CODA has been very successful in placing students in best-fit majors. Time to graduation and average GPA in the college have been positively impacted by this new structure, as have retention and graduation rates overall.

Support: Themes in the strategic plan related to support were important from an access and success perspective. As a land-grant university not all students entire with the same backgrounds, thus support programs are vital in connecting students and their ultimate success. A broad range of programs exist and students are challenged in their first year to develop goals and strategies to attain those goals.

Community: Community aspects of the strategic plan reinforce the other themes by creating a network on connectedness for students. Education research shows that connected and engaged students are happy students and successful students. The community connections options and programs in the college have helped create an environment where although our college is big, it doesn't feel like it.

Implementation of the strategic plan coexisted with improvements in retention and graduation rates in the college. This includes improvement in women enrollment percentage. Results were mixed for other demographic categories.

References

[1] National Academy of Engineering, *Changing the Conversation: Messages for Improving Public Understanding of Engineering*, Washington, DC, The National Academies Press, 2008.
[2] National Academy of Engineering, *Raising Public Awareness of Engineering*, Washington, DC, The National Academies Press, 2002.
[3] National Academy of Engineering website at: https://www.nae.edu/19582/Reports/24985.aspx, accessed March 16, 2018.
[4] National Academy of Engineering, *NAE Grand Challenges for Engineering* website at: http://www.engineeringchallenges.org, accessed February 5, 2018.
[5] J. Lavelle and L. Bottomley, "NAE Grand Challenges and Academic Culture in Engineering Education at NC State," *Proceedings of 2011 ASEE Southeast Section Conference*, The Citadel, Charleston, SC, March 2011
[6] NC State University, *The Engineering Place* website at: https://www.engr.ncsu.edu/theengineeringplace/ accessed February 5, 2018.
[7] LinkEngineering, *Engineering Habits of Mind*, website at: https://www.linkengineering.org/Explore/WhatIsEngineering/5808.aspx accessed February 5, 2018.
[8] National Academy of Engineering, *Engineering in K-12 Education: Understanding the Status and Improving the Prospects*, Washington, DC, The National Academies Press, 2009.
[9] Boston Science Museum, *Engineering is Elementary* website at: https://www.eie.org/, accessed January 31, 2018.

[10] D. Montford, S. Brown and V. Whritenour, "Secondary Students' Conceptual Understanding of Engineering as a Field," Journal of Pre-College Engineering Education Research, 3:2 (2013) 1-12.
[11] NC State University, *First Year Engineering Program* website at: https://www.engr.ncsu.edu/academics/undergrad/firstyear/ accessed February 5, 2018.
[12] J. Lavelle and D. Keltie, "Calculus Intervention for First Year Engineering Students," *Proceedings of 2005 ASEE Annual Conference*, Portland, OR, June, 2005.
[13] J. Lavelle, D. Raubenheimer, M. Leach, S. White, P. Moses, "Engineering Student Success: An Intervention Course," *Proceedings of 2011 ASEE Annual Conference*, Vancouver, CAN, June, 2011.
[14] NC State University, *Engineering Village* website at: https://housing.dasa.ncsu.edu/living-and-learning-villages/find-a-village/engineering-village/ accessed February 5, 2018.
[15] O'Keeffe, P. "A Sense of Belonging: Improving Student Retention," College Student Journal, Vol. 47, No. 4, Dec. 2013, pp. 605-613(9)
[16] NC State University, *College of Engineering Welcome* website at: https://www.engr.ncsu.edu/academics/undergrad/firstyear/welcome/, accessed March 16, 2018.