Paper ID #19363

Attracting and Retaining a Diverse Cohort of Engineering Majors: Building a Program from the Ground Up

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In Fall 2016, Campbell University welcomed its first cohort of engineering majors, the culmination of fourteen months of planning and recruiting. Building a new school of engineering affords a number of unique opportunities, including the chance to develop a program based on best practices, engineering education research, and the recommendations of national reports such as "Educating the Engineer of 2020," among others. Central to starting a new engineering program is crafting a unique business case, complete with a marketing and recruiting plan designed to attract a cohort of students willing to partner with the faculty and staff to create the communicated vision. In this paper, we identify some of the key obstacles to attracting a diverse cohort of students to a new program, along with evidence-based strategies used to tackle those obstacles in recruiting for the new engineering program. We report here on the diversity of our newly admitted students. We will also report on retention efforts, derived from best practices, and enrollment data at the end of the first semester, as well as examining an early snapshot of the second cohort of entering students.

Background

Campbell University has a long history of excellence in the health sciences, with doctoral programs in pharmacy, medicine, physical therapy, as well as physician assistant and nursing programs, pre-pharmacy, pre-med, etc. Other areas of strength include trust and wealth management, PGA golf management and law, among others. In the interest of diversifying offerings, and in response to ongoing interest from prospective students in engineering, the University decided to launch an eighteen-month study on the feasibility of starting a new School of Engineering. The recommendation from the external consultant's report was in support of a general engineering program with concentrations in mechanical engineering and a second area aligned with the university's strong health science focus. The Board of Trustees approved establishment of the degree program in 2014. After a national search, the inaugural dean was hired in 2015 with the initial cohort of faculty and staff brought on board at the beginning of 2016. After fourteen months of planning, curricular development, facilities renovation and recruiting, the program was launched with an initial class of approximately 100 first-year students in fall of 2016.

Building a new school of engineering affords a number of unique opportunities, including the chance to develop a program based on best practices, engineering education research, and the recommendations of national reports such as "Educating the Engineer of 2020,"[1] among others. It also provides the opportunity to recruit and graduate a more diverse cohort of engineers, by taking into account research on attracting and retaining a broad spectrum of students. Given the dean's personal passion about and expertise in creating a culture of success for a broad spectrum of students, diversity was quickly added to the list of program goals.

Those goals (summarized, by priority, in Table 1, below) include innovation; engineering education best practices; preparing students using a hands-on, project-based approach; integrating the traditional lecture format and laboratory experiences into a seamless "class-lab" format; strong professional development and service learning components; and an emphasis on a broad base of core skills, complemented with depth in focused concentrations: mechanical engineering (manufacturing focus) and chemical engineering (pharmaceutical focus). The initial concentrations reflect regional and state engineering employment opportunities, the university's historic strength in the health sciences, a forward-looking view of engineering in the 21st century, and a desire to attract a strong cohort of both male and female engineering majors (based on national data of engineering majors by gender[2]).

Program Goals
innovation in curricular design, course and study spaces, content delivery, professional development and service, etc.
use of best practices from engineering education research, national reports for changes to engineering education
hands-on, project-based approach throughout curriculum to integrate content and application
use of a combination class-lab approach (vs. separate lecture and lab courses)
strong professional development and service learning components
Emphasis on broad base of core skills
depth built in focused concentrations

Table 1 – Program Goals, by Priority

Business Case, Key Obstacles and Evidence-Based Strategies

Central to starting a new engineering program is crafting a unique business case, complete with a marketing and recruiting plan, designed to attract a cohort of students willing to partner with the faculty and staff to create the communicated vision. Key to this process identifying the key obstacles to attracting a diverse cohort of students to a new program, along with the evidence-based strategies used to tackle those obstacles in recruiting for the new engineering program. It should be noted that the terms "diverse" and "diversity" as applied to our engineering majors are viewed broadly, to include gender, race/ethnicity, socio-economic status, age, community-college background, first-generation college status, veterans and family members of veterans (given the proximity to a major military base), etc.

One of the first obstacles to attracting a diverse cohort is **entering student interest** (or lack thereof) in specific engineering focus areas. Stereotypes about who can do engineering and who is interested in engineering do impact student interest and enrollment in engineering, long before they reach the university level. Therefore, utilizing historic enrollment data on self-selection of areas of engineering interest, as noted above[2], the school selected a mix of concentrations designed to appeal to both male and female students. The mechanical concentration has a modern manufacturing focus, which might seem inherently male, but which includes a makerspace (housing a variety of 3D printers, an embroidery machine and a vinyl cutter for making stickers), starting in the first-year. Note that the makerspace is free and open to students five days a week, with first-year engineering student workers (50% of whom are female) to assist students in utilizing the equipment, creating and implementing their designs, etc. There is also a fabrication lab which all students are trained to use (and which includes a laser cutter capable of implementing intricate designs on a variety of materials, also open five days a week and supported by the same student workers). The chemical engineering concentration has a pharmaceutical focus, with ties to the strong health science programs on campus which boast strong female enrollments.

In addition to selecting the concentration areas for the program with diversity as one of the key considerations, a unique business case for the program was developed that addresses a number of other diversity obstacles suggested by the literature in attracting and retaining a diverse cohort of engineering majors. The goal of addressing each of these diversity obstacles is to enhance the success of women, under-represented minorities, first-generation college students, veterans, non-traditional students, community college transfers and low socio-economic students. Note the diversity obstacles and solutions are summarized in Table 2, below.

- Diversity Obstacle: curricula catering to a narrow range on the spectrum of learning styles
  Strategy: utilize on a **hands-on project based approach** that incorporates more traditional content knowledge and theory with a variety of hands-on applications[4, 5]

- Diversity Obstacle: assumptions of a prior familiarity and expertise with programming, robotics, machining, tool usage, etc.
  Strategy: start all students off at "ground zero" and emphasize collaborative peer support networks vs. competition[4, 5]

- Diversity Obstacle: failure to paint a broad picture of employment and career opportunities in engineering
  Strategy: offer a **general engineering degree inside a traditionally liberal arts institution** that requires all students to complete a **broad common core**[7, 8] and emphasizes **content integration** across disciplines[6], in addition to the variety of career options as well as self-expression

- Diversity Obstacle: lack of robust student support systems and on-boarding initiatives; lack of communication about expectations; lack of understanding about expected behaviors and compliance with "unwritten rules"
  Strategy: offer **small classes taught by experienced faculty focused on teaching, mentoring, and engineering education research**[3, 4, 5]

Strategy: disseminate weekly **communications about expectations, deadlines, opportunities, availability and types of support**[3, 4, 5]

- Diversity Obstacle: lack of motivation, inability to see "impact" of content and "connection" between subjects
  Strategy: use a **class-lab approach** to boost not only lab experiences but also the ability to incorporate **hands-on projects and demonstrations** in almost every course[4, 5]
- Strategy: emphasize professional licensure and **internships**, starting in the first-year,[4] along with software certification

- Diversity Obstacle: failure to develop an engineering identity
  Strategy: required first-year participation in **professional development** (through professional engineering organizations and targeted workshops)[3] and **service**[9] activities, as well as curricular emphasis in the first-year engineering seminar course

- Diversity Obstacle: **microinequalities and microaggressions that occur between students in teams**
  Strategy: ongoing emphasis by faculty and administration; incorporating content into teaming and course expectations; all students participated in a one-hour effective teaming training session which discusses the value/business case for diversity, implicit bias and strategies for managing around these issues[10, 11]; approximately one-third of students attended an optional 3-hour workshop on how to work in teams which contained a more in-depth look at bias and related issues, together with success strategies and hands-on activities for participants[12]

Diversity Obstacles	**Solutions**
curriculum catering to a narrow range of learning styles	hands-on project-based approach incorporating content in context
assumptions of background knowledge	start at "ground zero," emphasize collaboration vs. competition
narrow picture of employment & career opportunities	general engineering curriculum in liberal arts environment, broad common core, integrate content across STEM disciplines in first-year engineering
lack of motivation, inability to see impact of content and connection between subjects	integrated class-lab approach (vs. separate lecture and lab classes) to boost lab skills and ability to incorporate hands-on projects and demos
	emphasis on professional licensure, first-year internships, software certification
weak student support systems & on-boarding initiatives, poor	small classes, experienced faculty, focus on mentoring, weekly communications

communication about expectations, unfamiliarity with expected behaviors and "unwritten rules"	about expectations/deadlines/ opportunities/support
failure to develop engineering identity	required first-year professional development and service activities
microaggressions and microinequalities on student teams	multiple team-training initiatives, including required training focused on diversity, implicit bias, stereotypes, etc.

Table 2 – Summary of Identified Research-based Diversity Obstacles and Solutions

In addition, the program also elected to not implement a selective admissions process, whereby students admitted to the university must pass a second, more rigorous entrance hurdle in order to be allowed to declare engineering as a major. Instead, a tiered approach to the curriculum was designed to enable any student admitted to the university to declare engineering as a major, with specific pre-requisite courses developed for these students to not only provide needed content knowledge, but also to begin equipping them with bonafide engineering skill sets and actively incorporate them into the school in an effort to develop a strong engineering identity in these under-prepared students[13]. In addition, non-engineering majors (both freshmen and upperclassmen) who have appropriate pre-requisites are encouraged to take the first-year engineering design sequence as a "safe" way to explore engineering without being required to change majors.

Given the strong network of community colleges in the state (where the majority of our students live) together with the likelihood that first-generation, under-represented minority and low socio-economic students are all more likely to start their post-secondary education at a community college, a curricular pathway specifically for community college students was developed.

Research cited above suggests that these approaches support a broader spectrum of learners, enhance the success of groups such as women, under-represented minorities, first-generation college students, and low socio-economic students. It is our hope that these strategies will assist in the school's efforts to attract and retain a more diverse engineering student body.

A marketing and recruiting plan was implemented to communicate the unique aspects of the business case for the program. These efforts were informed by findings from studies such as the NAE's Changing the Conversation[14] and efforts at CU Boulder[15], as well as language and materials from the NAE Grand Challenge Scholars initiative, the NAE, Royal Academy of Engineering, IWITTS, and IEEE WIE. Images on the website, print materials, posters in the hallway, banners, logos, marketing materials, etc., intentionally portray a diverse cohort of students, steer away from stereotypical images of engineering and toward sustainability-inspired images, feature faculty-student interactions, student teams and hands-on activities. Messaging focuses on making a difference, broad career opportunities, leadership and innovation which is aimed at attracting and retaining more women and underrepresented students in engineering, as suggested by the research literature.

Diversity of First Cohort

The goal was to attract an initial cohort of 50 students. The initial cohort of students who *enrolled* in a first-year engineering course was composed of 101 students, with 84 of those declared engineering majors as of the beginning of the fall semester (74 in the mechanical engineering concentration, 10 in the chemical engineering concentration). Seventeen students not majoring in engineering enrolled in a first-year engineering course. These students had declared majors of math (18%), undecided/general college (35%), sport (6%), kinesiology (6%), pre-med (6%), trust and wealth management (6%), business administration (6%) and unknown (18%)). Nonmajors constituted a larger than expected percentage (17%) of enrolled students. Informal feedback suggested that some of the nonmajors planned to change majors into engineering but hadn't done so yet, some were curious and wanted to take a course or two before deciding whether to change majors, some wanted some exposure to engineering concepts to compliment their selected majors, and at least one was unable to declare engineering as a major due to restrictions of a scholarship but intends to complete all engineering requirements.

Of the students in this cohort, 18% self-reported as first-generation college students, 64% self-identify as non-first-generation and the first-generation status is not known for 14% of the cohort. Thirty-one percent of the students in this cohort receive federal financial aid, 59% do not receive federal financial aid and the federal financial aid status of 11% of the cohort is not known (see Table 3). Breaking this data down into those who were "underprepared" in mathematics (those who needed to take one or more prerequisite mathematics courses) versus those who were "prepared" (started at or beyond precalculus mathematics), 22% of underprepared students were first-generation and 43% receive federal financial aid while 16% of the prepared students self-identified as first-generation and 25% receive federal financial aid. If we interpret qualification for federal financial aid as one possible indicator of socio-economic status, we would expect more "underprepared" students to receive federal financial aid and be first-generation than "prepared" students, given that students from lower socio-economic backgrounds and with fewer college-educated immediate family members are less likely to have had the same pre-college experiences and opportunities as students from more affluent and better educated families. Given that a number of our students come from rural communities, the relatively small difference between "underprepared" and "prepared" students who self-identify as first-generation is also not particularly surprising. Federal comparison data is not available. Note, however, that research suggests that first-generation students are, among other things, often less academically prepared when they start college[16] and are less likely to have taken algebra I or II and advanced math in high school[17, 18], so these trends in the data are not unexpected. According to the National Association of Colleges and Students 2016 Student Survey, only 4.7% of engineering majors identified as first-generation, while 9.9% of non-first generation students selected engineering as a major[19]. Research does show that engineering ranks in the top 10 intended majors of first-generation college students who have taken either both AP and SAT exams and those who have taken only the SAT exam, although it ranks lower for first-generation (4th for AP and SAT takers, 7th for SAT takers only) than non-first generation students (2nd for AP and SAT takers, 5th for SAT takers only)[18].

Campbell University Initial Cohort	**First-Generation**	**Receive Federal Financial Aid**
Prepared (on-track in math – precalculus or above)	16%	25%
Underprepared in math (below precalculus)	22%	43%

Table 3 – First Generation, Receipt of Federal Financial Aid vs. Math Preparation

Self-reported data from student records on gender, race and ethnicity for the initial cohort of 101 students enrolled in a first-year engineering course are listed in Table 4, below, along with the nearest national data available[20]. A significant number of students either did not provide either race or ethnicity information or provided only ethnicity information. Designations for race, ethnicity and gender are those used on university forms. Race and ethnicity percentages are reported as a percent of the gender/major (i.e., female mechanical concentration, male nonmajor, female chemical concentration, etc.). For example, male students make up 88% of the students majoring in the mechanical concentration. Of males majoring in the mechanical engineering concentration, 62% self-identified as white, 5% self-identified as black, 3% as American or Alaskan Native, etc. National data was taken from the NSF Science and Engineering Indicator Report for 2011 (the last year for which such disaggregated data is available). Data for “other” engineering majors was used as the closest available comparison for “general engineering” (which was not available), although “other” engineering likely contains also a number of identified subfields such as biomedical engineering not included among the seven listed in the national data set. National ethnicity data grouped students of “unknown” ethnicity together with students of “other races” (such as Hawaiian/Pacific Islander) under “Non-Hispanic/Latino”. Therefore it is not possible to compare national data for Non-Hispanic/Latino and students of unknown ethnicity against Campbell University data, which lists students whose ethnicity is unknown separately. Therefore no attempt was made to compare local and national ethnicity data for Non-Hispanic-Latino(a) and unknown students. The number of students in some subgroups (i.e., the chemical engineering concentration) are small and therefore sensitive to small variations. Note that totals in this section may exceed 100% due to rounding.

Univ. X Initial First-Year Cohort – Fall 2016 vs. 2011 National Data on Majors		Mech. Conc.	Chem. Conc.	NonEngr Majors	Nat'l Mech.	Nat'l Chem.	Nat'l Other
Male		88%	50%	65%	89%	69%	77%
Race	**White**	62%	40%	9%	70%	54%	89%
	Black or African American	5%	0%	9%	3%	3%	4%
	American or Alaskan Native	3%	0%	18%	0%	0%	0%
	Hawaiian/ Pacific Islander	3%	0%	0%	N/A	N/A	N/A
	Unknown	28%	60%	64%	N/A	N/A	N/A
Ethnicity	**Hispanic/Latino**	9%	20%	18%	8%	5%	8%
	NonHispanic	88%	60%	27%	*	*	*
	Unknown	3%	20%	55%	*	*	*
Female		12%	50%	35%	11%	31%	23%
Race	**White**	89%	40%	67%	62%	53%	79%
	Black or African American	0%	0%	0%	5%	5%	7%
	American or Alaskan Native	0%	0%	0%	1%	0%	1%
	Hawaiian/ Pacific Islander	0%	0%	0%	N/A	N/A	N/A
	Unknown	11%	60%	33%	N/A	N/A	N/A
Ethnicity	**Hispanic/Latino**	33%	20%	0%	10%	8%	10%
	NonHispanic	67%	60%	67%	*	*	*
	Unknown	0%	20%	33%	*	*	*

Table 4 – Inaugural Cohort by Concentration, Gender, Race, Ethnicity
***national data grouped these two ethnicity categories together**

Male students in the first cohort at Campbell University are generally more diverse, with the exception of the number of male black or African American students in the Chemical Engineering concentration which is below the national average. The largest differences are seen in male American or Alaskan Native (particularly among those students who are non-engineering majors) and male Hispanic students in the Chemical Engineering concentration and non-engineering majors. Data for female students, however, at Campbell University is generally less racially diverse, although there are somewhat fewer white women in chemical engineering than reflected in the national data. As with the data on male students, Campbell University has a much larger percentage of female Hispanic students than the national average. Large numbers of unknown students, particularly in the chemical engineering concentration and non-engineering major categories where the total number of students is small, could mask trends that are different from those reflected in the data, above.

For a different comparison (see Table 5, below), nationally 13.2% of students graduating in 2015 with a BS in Mechanical Engineering were female; 32.4% of BS in Chemical Engineering graduates were female; 26% of BS in General Engineering graduates were women[21]. Generally, the number of students who graduate with a undergraduate degree in engineering is somewhat less than those who start in engineering as a freshman, but data on first-year students majoring in engineering by subdiscipline and gender is not available. Our data shows the percentage of women in our mechanical engineering concentration (12%) is slightly less than the national percentage (13.2%) of female mechanical engineering graduates and a good bit less than the percentage (26%) of women general engineering graduates, while the percentage of women in our chemical engineering concentration (50%) is significantly larger than both the national percentage (32.4%) of BS in Chemical Engineering graduates who are women and the percent (26%) of women graduating with a BS in General Engineering. One possible hypothesis for these variances is the strong health science focus of the chemical engineering concentration (pharmaceutical) versus the more stereotypical manufacturing focus of the mechanical engineering concentration. Our students think of themselves by concentration (i.e., mechanical engineering or chemical engineering), which may account for the lower percentage of women than are seen in general engineering programs without standard subdisciplinary concentrations. General engineering programs vary widely in focus and some have broad and even non-stereotypical foci, such as sustainability, liberal arts, other non-STEM/non-engineering concentration options (such as arts, dance, music, theater), which may explain the higher percentage of female graduates in these types of general engineering programs.

Univ. X First-Year Cohort – Fall 2016 vs. 2015 BS Graduation Data	**Mech. Conc.**	**Chem. Conc.**	**Nat'l Mech. BS Grad. Data**	**Nat'l Chem. BS Grad. Data**	**Nat'l BS Gen. Engr Data**
Female	12%	50%	13.2%	32.4%	26%

Table 5 – Inaugural Cohort of Women vs. 2015 Graduation Data for Women by Concentration

Thirty-six percent of the students in this inaugural cohort were "underprepared" in mathematics. These students were enrolled in either fundamentals of mathematics or college algebra and the introduction to engineering applications course. Sixty-four percent of the inaugural cohort were "on track" in mathematics. These students were enrolled in precalculus, calculus I, II or III or differential equations and the first-year engineering course.

The entering class did include some diversity of age, particularly for women in the chemical engineering concentration versus the mechanical concentration (see Table 6, below). Given the small number of students in the chemical engineering concentration (as compared to the mechanical engineering concentration), such variations may not be consistent over time or reflect substantial differences between the two student populations.

		Mechanical Concentration		**Chemical Concentration**	
		Male	**Female**	**Male**	**Female**
Age					
	16-22	91%	100%	100%	80%
	23-29	6%	0%	0%	0%
	30-up	2%	0%	0%	20%

Table 6 – Inaugural Cohort of First Year Students by Age

The inaugural class also included a number of university athletes (15%). Twenty-eight students were sophomores. Some of these students started at the university the year before the engineering program started, intending to switch majors at the beginning of their sophomore year so that they could join the new program. Others were undecided students who elected to switch to engineering once it came on board. Five percent were listed a juniors and three percent as seniors. Some of these were community college transfers, others are students pursuing a second bachelor's degree.

Enrollment at the Beginning of the Second Semester

At the beginning of the second (spring) semester, we had 80 engineering majors (63 males and 17 females), as compared with the 84 declared engineering majors (70 males and 14 females) at the beginning of the fall semester, for a net loss of 7 males and a net gain of 3 females (see Table 7, below). Some students left the university by the end of fall (some of whom were successful in engineering but left for other reasons and some of whom were not academically successful). Some students switched their concentration (from mechanical to chemical or vice versa). Other students switched their major (either from engineering to another major at the university or from another major at the university to engineering). Some of the non-engineering students who were enrolled in an engineering class in the fall switched their major to engineering by the spring. Two students (one male, one female) transferred into the program mid-year from community college, starting the engineering program in January.

At the beginning of the second semester, 81% of the students were enrolled in the mechanical concentration and 19% in the chemical concentration. Overall, 79% of the students were male and 21% female, with 14% of the mechanical concentration students being female (up slightly from 12% in the fall) and 43% females in the chemical concentration (down some from 50% in the fall). Note that the larger number of students in the mechanical concentration and small number in the chemical concentration make the chemical data more sensitive to small changes than the mechanical data.

Campbell University First-Year Enrollment by Gender	Mech. Conc. Males (vs. 2011 Nat'l Mech. Data)	Mech. Conc. Females (vs. 2011 Nat'l Mech. Data)	Chem. Conc. Males (vs. 2011 Nat'l Chem. Data)	Chem. Conc. Females (vs. 2011 Nat'l Chem. Data)	Overall Males	Overall Females
Fall 2016 Semester	88% (89%)	12% (11%)	50% (69%)	50% (31%)	83%	17%
Spring 2017 Semester	86% (89%)	14% (11%)	57% (69%)	43% (31%)	79%	21%

Table 7 – Comparison of Fall and Spring Semester Enrollment by Gender

Early Snapshot – Second Cohort

While it is early in the recruitment year for our second cohort of entering students, to date applications, acceptances and deposits have all been running between even and +30% over the same date last year. A large number of students do not make deposits (the most reliable indication of their intention to attend the university) until late spring/summer before their entering fall term. For our first cohort, the percentage of deposited students who enrolled and attended in the fall was around 90%. This is considerably higher than for other majors at the university, which lose up to one-third of their deposited students.

Data on race/ethnicity of the accepted students is not yet available. The most recent data on gender of accepted students shows a breakdown of 62% male and 38% female in the chemical engineering concentration versus 86% male and 14% female in the mechanical engineering concentration (see Table 8, below). These numbers are close to that of the first cohort in mechanical engineering (12% female) but somewhat less than the percent of women in the first cohort of chemical engineering (50%). It is unclear whether the existence of a sizeable number of sophomore students in the first cohort inflated the percentage of women and what the impact of a larger group of community college transfers might have on the diversity of the engineering student body. The breakdown between the mechanical engineering concentration and chemical engineering concentration for the second cohort of accepted students is virtually identical to that of the first cohort (75% mechanical, 25 chemical). It is not known what percentage of these accepted students will come to the university nor how the next eight months of the student application process might vary from the first four months, from which this data is drawn. Trends about whether males or females are more or less likely to apply early or late in the application season are also unknown.

Campbell University Fall 2017 Data to Date	Mech. Conc. (vs. Nat'l Mech. 2011 Data)	Chem. Conc. (vs. Nat'l Chem. 2011 Data)
Male	86% (89%)	62% (69%)
Female	14% (11%)	38% (31%)

Table 8 – Current Gender Breakdown of Accepted Students for Fall 2017 (incomplete data from Campbell University – acceptance window does not close until summer 2017)

Conclusion

Campbell University welcomed its inaugural class of first-year students in Fall 2016. Goals for the new program were to incorporate best practices, engineering education research, and the recommendations of national reports such as "Educating the Engineer of 2020," as well as attracting a diverse cohort of students. Attempts were made to identify obstacles in the literature to recruiting and retaining students traditionally underrepresented in engineering and implement evidence-based strategies to ameliorate these issues. The first cohort of accepted students does suggest greater racial diversity, particularly for male students in mechanical engineering, and ethnic diversity (for both male and female students) when compared against national data. Enrollment at the end of the first semester was encouraging, with little attrition and actually a net gain of 3 female students. Initial data on recruitment of our second cohort suggests a class similar to (although perhaps larger) than the initial cohort in terms of gender and breakdown by concentration. We will continue to track retention of students and diversity through graduation. Student feedback, additional data analysis and additional recruiting efforts will continue to help us shape and improve the diversity of our student body. Future work could include an examination of curricular design, particularly student exposure to hands-on activities in the makerspace and fabrication laboratory in the first year, and its impact on retention.

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