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Engineering Program Growth with Mesh Network Collaboration

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Abstract

Small Colleges and Universities (SCU) are an untapped resource for holistic Engineering Education, creative entrepreneurial "big ideas", and growth of national science, technology, engineering, and math (STEM) literacy in a competitive global market. This paper helps to clarify and examine some of the tradeoffs for existing and proposed two, four, and five year SCU engineering programs and suggest ways to support future growth and improve the quality of existing programs with proven adaptive mesh network architecture. Analogous to a wireless mesh network, a communication topology is implemented between universities (each like a mesh node) that can relay data across the network with a clearly defined protocol (standardization and articulation agreements).

Existing SCU programs and in particular Liberal Arts Colleges and Universities (LACU) Engineering Physics Programs have many advantages over large engineering schools. However, they may be weaker in the number of class offerings, available ABET BS majors, department distinctive capacities, low upper class enrollments, facilities and equipment, and job opportunities and fairs. Presently, there exist a number of weakly connected 3+2 programs, transfer programs, 2 year Engineering Technology programs, and non-accredited programs.

A baseline 2 year freshman and sophomore curriculum program is proposed based on case studies, on research, and on alumni questionnaires. After a decade of SCU Engineering Physics teaching experience it was also found effective by faculty to give closure to the 2 year program curriculum with a sophomore-type "Cornerstone" class called "Principles of Engineering". This integrative class is essential for 2 year students to be effective in the workforce as an Engineering Technologist job applicant, as a competitive summer intern applicant, and in deciding on a specific Engineering major. As a result, students obtain job ready skills and project abilities in 2 years that can greatly leverage their early learning and focus.

In a multi-university collaboration, all participants gain in shared information including: articulation agreements, ABET start-up templates and shared consultant advice, summer internships, legal forms, competitions, joint projects and other synergistic areas. Using a collaboration mesh network strategy coupled with hybrid technology and proven teaching strengths, a more efficient program is planned for pilot testing for SCU consortiums toward further feasibility assessment.

1.0 Introduction

Major advances can be made at the undergraduate level in STEM education. Large gains are expected in program quality and growth by setting high standards, inculcating ABET and Fundamentals of Engineering (FE) exam learning outcomes[1], enhancing competitive skills, mentoring students, and working as a network of universities. Using an industry project environment for teaching improves students' preparation and fit for new jobs or graduate appointments. The target outcome is for undergraduates to be at a master's thesis level (academically, with publications, and project-wise) when they graduate equipped with on-job skill sets. As an undergraduate SCU Liberal Arts school Taylor University has successfully competed with many large graduate engineering schools in student competitions over the past 15 years, including: the University Nanosat program[2,3,4] (UNP-3 and UNP-8), with NASA in the student ElaNa[5] and Microgravity programs, with the DOE solar car challenge, and with ASEE in student poster and academic paper competitions.[6,7,8]

With manifold new teaching tools, equipment advances, software analysis tools, search engines, 3-D printers, and better ways of teaching, our goals should move beyond conventional engineering BS degrees, Fundamentals of Engineering (FE) proficiency exams and ABET accreditation learning outcomes. A three year BS engineering degree with one year of distance or online classes (and proficiency exam) could be envisioned that results in students achieving the desired learning outcomes at an exceptional level and provides value added job-ready skills acquired through the completion of "Big Ideas" projects.(See Appendix 3 for developing a strong Department). This will also substantially address the unsustainable increase in academic costs.

In this paper the importance and value of collaboration between universities is emphasized, particularly SCU schools, in order to reach more students with quality engineering education preparation and experiences. Many benefits should be realized from enabling and establishing articulation and standardized testing agreements between universities, including: the development of a creative curriculum that includes classes, projects, summer in-residence and online courses as well as fosters the opportunity to develop quality control processes that result in certified learning and secure online standardized testing. The ultimate goal of this effort will be to increase the number of students earning a quality BS degree in engineering while reducing the time and cost for them to achieve this important goal.

In short, the ultimate goal of the competitive engineering department of the future[9] is to provide leadership skill opportunities, "Big Ideas" projects, and lab classes taught by expert faculty who not only teach but also mentor their students. During this time, students also make use of excellent online options for predominantly classes that require factual content knowledge material and do not require much discussion, problem solving, or labs. A number of general education classes and a few science classes may fit into this category based on the student's maturity and ability. After 2 years of core fundamentals, students have the option to transfer easily into specific majors at other SCU schools using a mesh network articulation protocol[10].

Recent data (2013 EPI paper[11]) indicate that there is a significant downward trend in the number of Engineering BS Degrees (see Figure 1). In the EPI paper, Sulzman, Kuehn and Lowell find evidence that only one of every two STEM college graduates is hired into a STEM job each year. For engineering graduates the percentage of engineers going into engineering jobs is high (for our ABET graduates it is about 95%). However, some students pursue and are employed in non-STEM jobs after graduation where they receive higher salaries as a result of the high quality engineering and business expertise. There is a strong national trend to increase the number of Science, Technology, Engineering, and Math (STEM) majors since these fields have a direct bearing on the U.S. economic engine and world leadership[12]. There is projected 17% STEM growth in employment in next 10 years compared to 9.8% for non-STEM fields[13]. There are now more strategic efforts in engineering to address society problems, liberal arts literacy, the "big ideas", innovation and entrepreneurship, and interdisciplinary studies related to engineering (called STEAM by including the ARTS). Some large engineering schools in their strategic plans are now including growth in these areas to impact society (e.g. Purdue, Iowa, Texas A & M).

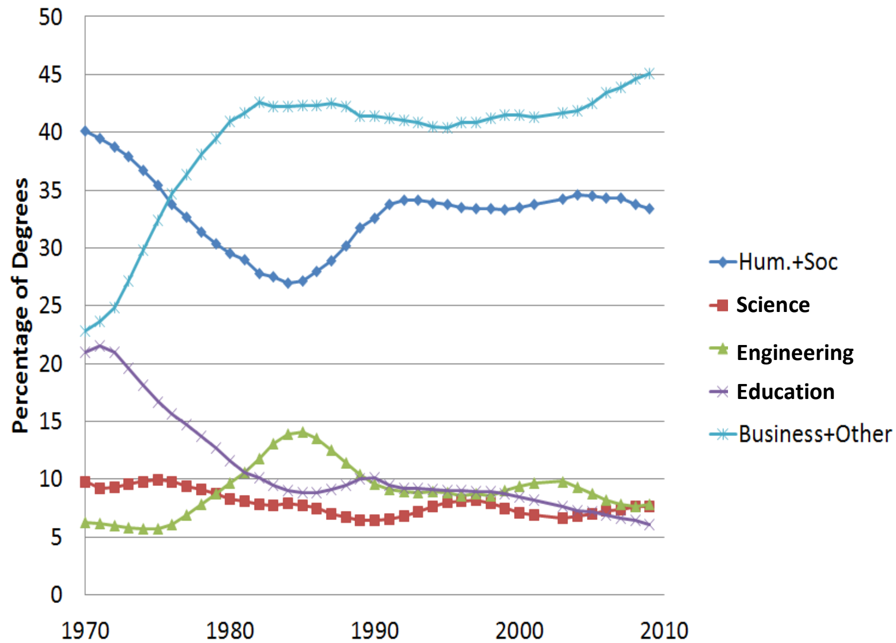

Figure 1. National College and University BS Degrees

2.0 Unique Vision and Calling for SCU Liberal Art Schools

A few sectors of the STEM market and associated salary may be weak and connected to weak STEM skills, work ethic, and too many product engineer type graduates looking for high paying jobs but who are unprepared to make "Big Idea" innovative and entrepreneurial contributions that R&D firms value and need. Entrepreneurial engineers enjoy creating and following through with new enterprises that advance society and improve competitiveness. For every one successful R&D type entrepreneurial engineer many "product type" design engineers are required. For every product in the pyramid there are many more manufacturing engineers and labor workers. Additional jobs are then associated with the supply chain of raw materials.

Finally there is a large segment supporting infrastructure jobs. This basic idea of a Gemstone of jobs that emanate from "Big Ideas" and entrepreneurial character strength is captured in Figure 2. In the engineering teaching environment students should be made aware of the impact they can have if they have entrepreneurial gifts and a broader understanding of culture combined with strong engineering and business skills.

Small Colleges and Universities and in particular Liberal Arts are poised as agents for engineering innovation and public awareness of STEM. Only about 10% of engineers are innovators who produce new products and develop technology[14]. For a vibrant economy we need engineers that are creative, innovative, and well-rounded in a broader education that can address societal needs and complete a job from the beginning of the design process to the end. Universities that target "Big Idea" projects and also have strong underpinnings of engineering fundamentals and liberal arts skills will better stimulate growth and success.

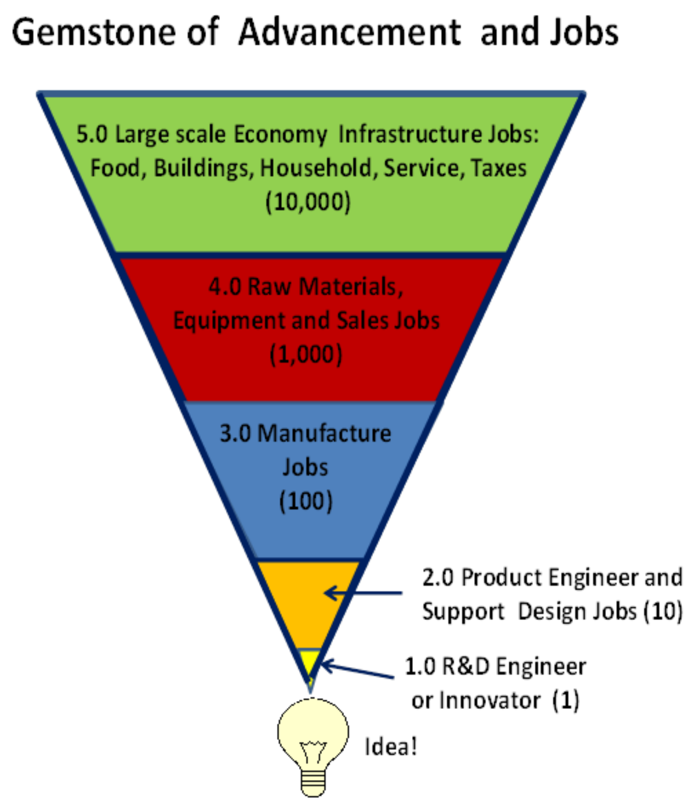

Figure 2. Gemstone of Advancement and Jobs

A quote[15] from William A. Wulf, president of the National Academy of Engineers and George M.C. Fisher who retired CEO of Eastman Kodak and Company, says

"*What's needed is a major shift in engineering education's 'center-of-gravity', which has moved virtually not at all…Today's student-engineers not only need to acquire the skills of their predecessors but many more, and in broader areas. As the world becomes more complex, engineers must appreciate more than ever the human dimensions of technology, have a grasp of the panoply of global issues, be sensitive to cultural diversity, and know how to communicate effectively. In short, they must be far more versatile than the traditional stereotype of the asocial geek.*"

Many existing undergraduate Engineering Programs in SCU have many advantages over large engineering schools as summarized in Appendix 1. The SCU Liberal Arts School advantages include: engineers equipped with liberal education program outcomes and skills, i.e. problem solving, analytical thinking, communication, and collaborative group work, higher quality big picture education, more interactive student body, and the intentional character building foundation.

3.0 Problem Statement

Small, private colleges have played a historic and critical role in American higher education in the past 300-plus years. However, today the very essence of these unique institutions is being threatened in the changing and complex higher education landscape[16]. While these colleges pursue their specific mission, their leadership is struggling to find new opportunities that will provide new revenue streams without compromising their mission and to make education more affordable for students.

One area that is lacking in many small, private colleges is a robust science, technology, engineering, and math (STEM) program. Historically, the science and math departments have been support programs for the general education core curriculum. While majors have been developed over time, their success is limited due to the type of student these programs attract. Additionally, engineering and technology is often missing due to the cost of specialized facilities and faculty.

Programming for engineering and technology has primarily become a collaborative initiative with partnership at large, public universities taking on the form of a three-plus-two program or preferred admittance into a graduate program. While this has provided avenues for SCU students, the model has fallen short in the present environment with emphasis placed on demands to finish in four years and opportunity costs associated with longer programs.

SCU engineering departments may also be weaker in the number of class offerings, the number of available ABET BS majors, the number of department distinctive capacities, low upper class enrollments, ample facilities and equipment, job opportunities and fairs, and documentation overhead. In addition there are a number of weakly connected three plus two year programs, transfer programs, two year Engineering Technology programs and non-accredited programs (see list in Appendix 1).

4.0 Collaboration Network Principle

SCU engineering schools have a critical role to play in creating well balanced and creative individuals who are able to problem solve, see the big picture, and follow through with strong character qualities. The idea of a SCU consortium that shares similar general education and core requirements is likely much stronger if it partners together. A main problem with such a network is that communication, politics, and logistics can impede success. Using the idea of a mesh network with many nodes may greatly help the network adapt to working communication and implementation pathways. A mesh network concept for a group of schools is illustrated in Figure 3 below. A digital mesh network is a proven engineering communication network that is used for multi-node communications, such as cell phone networks and for many types of data bidirectional communication paths in a complex node matrix. If a major node (Main node) or a minor node (Basic node) breaks down in a network the data flow continues to self-adjust to find another efficient way back to any node of the collaboration mesh.

If common regional and national engineering standards and assessments can be developed in the various SCU consortia for the first two years of a four year general engineering degree then students would have more options for articulation and feeding into other Main Node consortium schools (e.g. Aerospace BS, Mechanical BS, Civil BS, etc. vs. General Engineering BS degree).

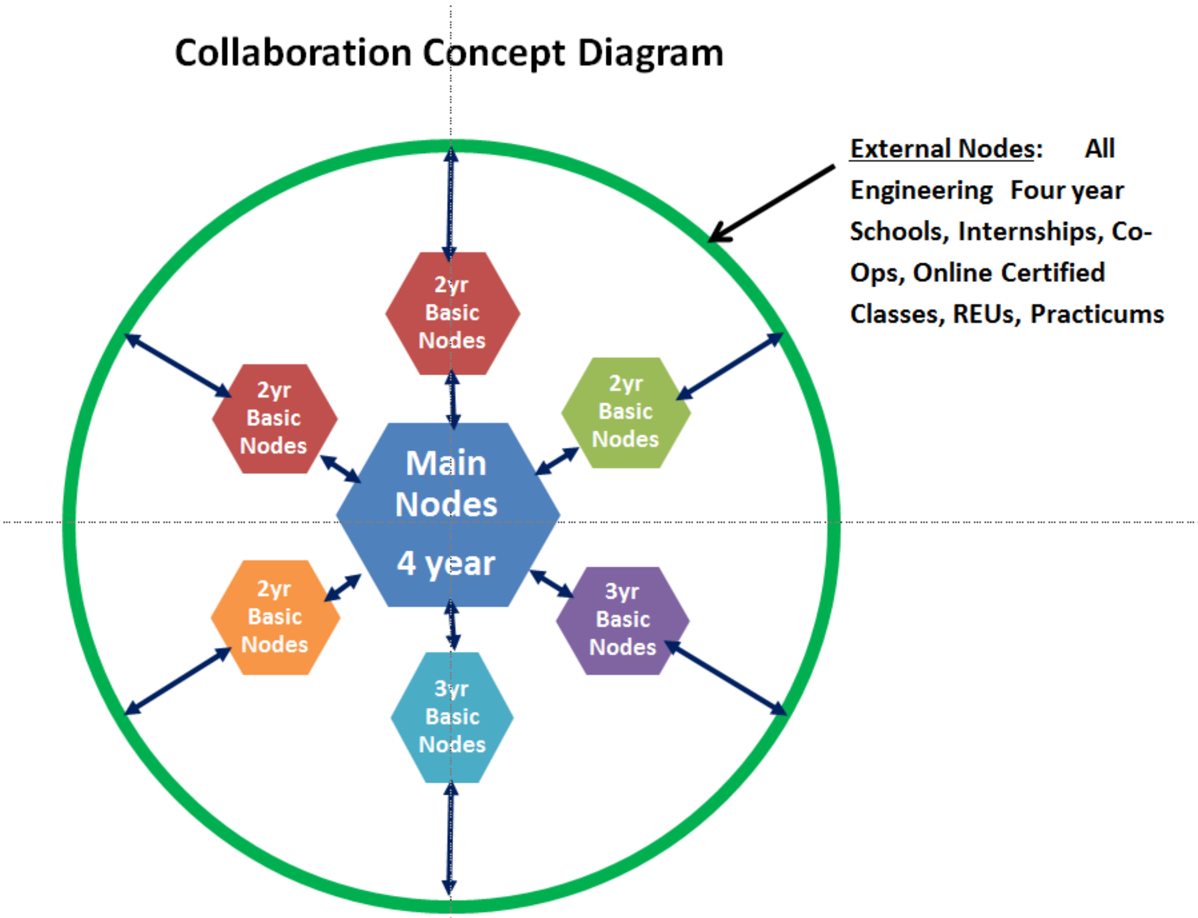

Figure 3. Collaboration Concept Diagram

By pooling resources and developing a standardized consortium template and articulation plan for a general two-year ABET program, SCU schools that aspire to start an engineering department could assure students of matriculation after two years into a large pool of consortium Main Node schools[10]. The facilities and equipment requirements for the first two years in an engineering program are relatively simple compared to the upper level facilities and teaching requirements. Two year start-up programs called Basic Nodes would feed the full ABET 4-year programs (Main Nodes). Basic 2 yr. Nodes could also offer an associate's degree with standardized outcomes and assessment template[17]. ABET will accredit a two-year associate of applied engineering program[18]. The student can terminate his or her education and work as an engineering tech or continue on for a BS in engineering.

In Figure 4 below a timeline example for the Individual SCU School is shown for how growth occurred (start-up) in an entrepreneurial engineering department between 1996 to 2006 (which is still poised for more growth with ABET accreditation and a new science building). In addition, the proposed consortium idea section illustrates how two year or four year engineering consortium schools can transfer students between them for making SCU more attractive and streamlined for opting their unique degree options. Students could also articulate into a non-consortium school or into an acreditted general engineering school, as indicated, but would likely have to take more classes and have initiative to piece together their new degree requirements.

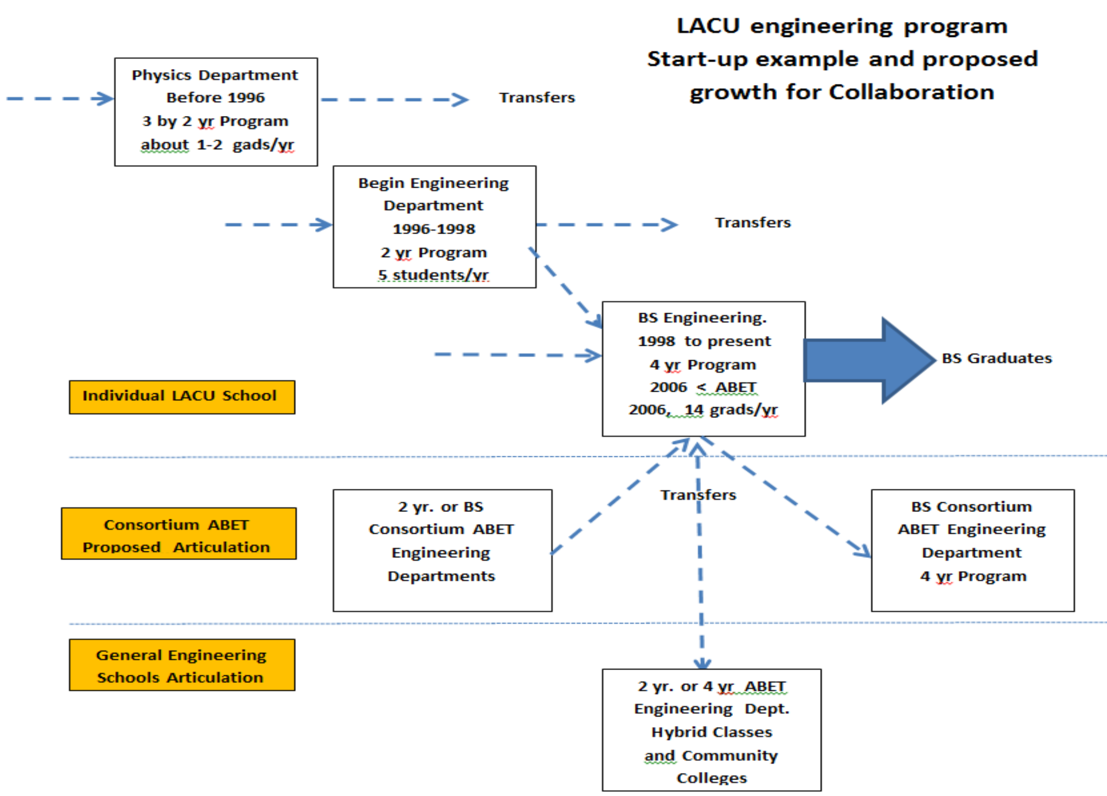

Figure 4. Small University LACU start-up example

5.0 Proposed Two Year Standardized Curriculum and Assessment

Proposed freshman classes would include Introduction to Engineering, Software, and Ethics (3 hrs.), Calculus (8 hrs.), University Physics (8 hrs.), and 16 hours of other courses. Proposed sophomore classes would be Chemistry (4 hrs.), Programming (3 hrs.), Differential Equations (4 hrs.), Principles of Engineering (4 hrs.), Introduction to Electronics or Statics/Dynamics-B (3 hrs.) and Digital Circuits or Strength/Materials (2 hrs.) and 15 hours of other courses (Figure 5 below).

A sophomore "Capstone-like" class (better named a Cornerstone class), called Principles of Engineering (ENP252), includes strategic labs designed to qualify students for early summer engineering internships or jobs, introduce them to the basics in upper level classes, and teach them essentials of the design process. ENP 252 integrates hands-on skills with the similar conservation governing equations for Statics, Dynamics, Circuits, Fluids, Heat Transfer, and Engineering Economics. Many of the Main Node schools cover similar intro content (e.g. Introduction to Conservation Laws, Introduction Survey class and Introduction Engineering Lab classes).

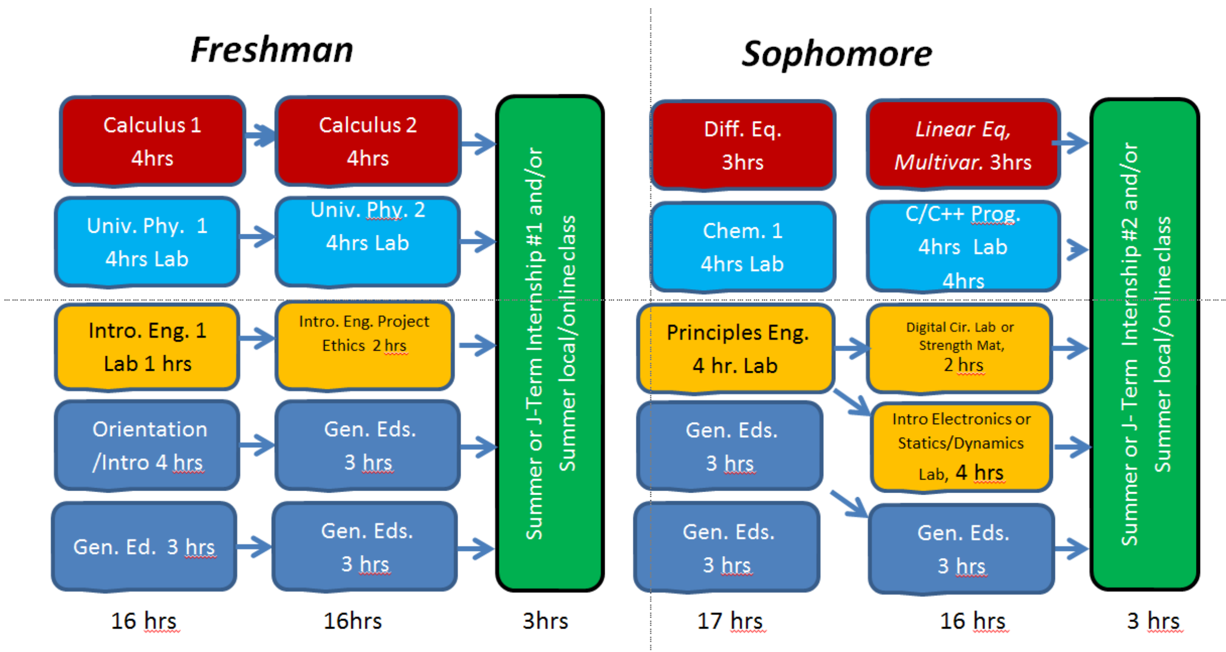

Figure 5. Proposed Freshman- Sophomore curriculum

6.0 Sophomore Cornerstone Class: Principles of Engineering

An integrative sophomore "Cornerstone" class was developed when we first started the 2 year engineering program to bring students to a level of understanding and apply their knowledge to solving real engineering problems in classwork, labs, major design project, skills, and valued summer job search/find. The class knits together much of the material in a fundamentals of Engineering class with the desire to fill in as many gaps so that sophomore graduates can take an FE assessment test for articulation and proficiency and/or secure an ABET 2 year degree or secure an engineering internship. The class is 4 load hours (3 hours of lecture and 1 hour of lab where lab is 2 class hours). The syllabus for this class is given in Appendix 3. The FE Exam assessments to find curriculum gaps and other outcomes for the Principles class to help mediate are given in Appendix 4 and 5.

This key class is essential for a 2 year program and for a 4 year program to bring students to a high level for the following reasons:

- It helps glue together the various engineering fundamentals (1.0), labs and design (2.0), STEM skills (3.0), and ideas of creative design (4.0) as illustrated in Figure 6 below.
- It gives students the necessary skills to qualify for good summer internships. A resume is required and part of the homework assignments.
- The course gives closure to the two year experience so students can begin to create, design, and build their own projects.
- It prepares the students for the FE exam and gives them a good understanding of the ABET outcomes a-k.
- Students become competitive and successful for transfer to other universities.
- Additionally, it is beneficial for planting entrepreneurial and big picture seeds.

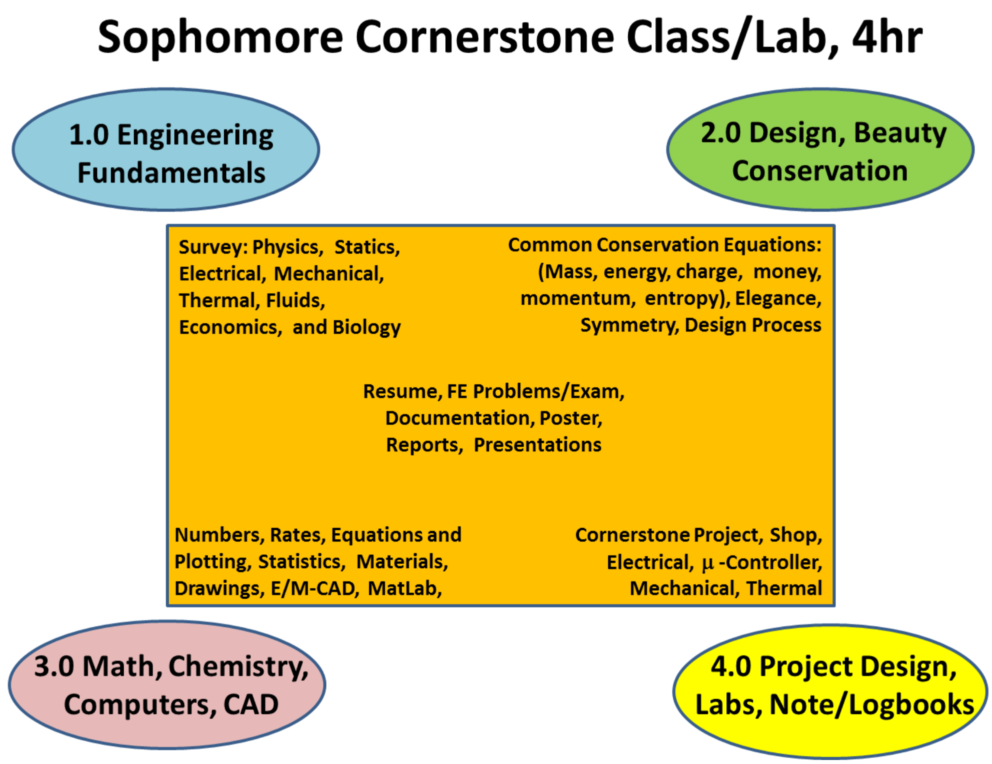

Figure 6. Sophomore Principles of Engineering Cornerstone Class/Lab

7.0 Five Case Studies within our LACU/SCU Consortium

Four types of collaboration plans were investigated with five case studies. Case studies were undertaken at SCU in our consortium by traveling to schools in Minnesota, California and Indiana to help get Department Chairs, faculty, and Division Dean Inputs for improving student education and school efficiency. The following outlines are designed to help vet some of the ideas for consideration when designing individual programs:

A. Two year Basic Node Collaboration

(or starting an ABET two-year engineering degree program)
To start an engineering major within a smaller SCU the Basic Node collaboration model is best suited and has the lowest start-up cost/risk. It is also a good way for a university to gauge the market and unknowns in their specific program. Some of the tradeoffs for a two year Basic Node model are listed below.

Two year Basic Node Collaboration Positives:

- Relative low cost and risk for SCU start-up (about 30% of four year program start-up).
- Articulated four year degree options for students.
- ABET two year Associates Degree option with FE exam assessment[18].
- This option gives a four year path for students to obtain an ABET BS degree in a specific field with the option of going on for a Master's Degree in their fifth year (MS usually paid for with assistantship).
- Basic nodes could share a common ABET template with self-study advisor. Collaboration here helps to streamline and implement the ABET requirements without much internal faculty learning curve.
- Results in a rigorous two year engineering program for internships, jobs, and transfers.
- Two year feeder school for producing more Associates and BS ABET degrees.
- Seamless transfer to Main Node schools for desired ABET BS major.
- More options for sophomores to pick their ABET specific major.
- Program results in more STEM awareness on SCU campus.
- Liberal art student advantages over many engineering schools (see Appendix 1).
- Attract more top SAT students into the university.
- Engineering program is usually easier to implement in schools with strong SCU nursing programs. More male students to SCU schools.

Two year Basic Node Collaboration Negatives:

- May likely be fewer engineering distinctives within a smaller department to attract students.
- Likely need some part time experienced engineers/faculty to augment some design classes.
- May be inconvenient for some students to transfer after 2 years to a Main Node school with an ABET BS major unless a path is predefined by the school.

Case Study for two year Basic Node in a smaller LASC College in Minnesota

The proposed Basic Node model provides the SCU program a way to explore opportunities in the STEM area with modest investments. The proposed programming is a win-win scenario with an increased revenue stream for the Basic Node and the Main Node. The Basic Node attracts students in a new area, and the Main Node has a new feeder program with little or no recruitment costs associated with high-demand students.

B. SCU 3 year by 2 year program

Students receive 2 BS degrees in five years, e.g. Physics and ABET BS engineering degrees. For starting a prominent engineering major within usually SCU the Basic Node collaboration model is best suited. With the lowest start-up cost/risk, it is also a good way for a university to gauge the market and unknowns in their specific program. Some of the tradeoffs for a 2 year Basic Node are similar to Case Study #1 above and are listed below.

Collaboration Positives

- Relative low cost and risk for SCU start-up (about 30% based on our experience of 4 year program start-up). Articulated 5 year degree options for students.
- ABET 2 year Associates Degree option with FE exam assessment.
- This option gives a 5 year path for students to obtain an ABET BS degree in a specific field with the option of going on for a Master's Degree in their 6th year (MS usually paid for with assistantship).
- Basic Nodes could share a common ABET template with self-study advisor. Collaboration here helps to streamline and implement the ABET requirements without much internal faculty learning curve.
- Results in a rigorous 3 year engineering program for internships, jobs, and transfers.
- 3 year feeder school for producing more Associates and BS ABET degrees with Liberal Arts experience.
- Seamless transfer to Main Node schools for desired ABET BS major.
- More options for juniors to pick their ABET specific major.
- Program results in more STEM awareness on SCU campus.
- Liberal art student experience and broad view will have an advantage over many engineering schools (see appendix 1).
- Attract more top SAT students into the University.
- Engineering program is usually easier to implement in schools with strong SCU nursing programs. More male students to SCU schools.

Collaboration Negatives

- Extra year of classes and tuition but two BS degrees.
- May likely be fewer exciting projects with a smaller department to attract students.
- Likely need some part time experienced engineers/faculty to augment some design classes.
- May be inconvenient for some students to transfer after 3 years to a Main Node school with a specific ABET BS major unless school predefines the options.

Case Study for 3 year Basic Node in a LASC College in CA

C. SCU 2 by 2 or 4 year program with Hybrid classes (Basic plus remote Node)

Students receive first two years of instruction. Remaining two year instruction is also at the institution using a combination of standard classroom instruction, lab and virtual lab classes, and remote lecture classes with nearby ABET main node universities. The remote classes use two way audio and video so that students/professor can interact with internal and remote class.

Collaboration Positives

- Lower cost for SCU 4 year start-up (about 60% of 4 year program start-up) by sharing professor classes with other universities and using hybrid classes of various forms.

- Students exposed to video conferencing for workforce and lifelong learning.
- ABET 2 year Associates Degree option and/or 4 year BS degree with FE assessment.
- Remote nodes could share a common ABET self-study template with advisor.
- More STEM awareness on SCU campus.
- Student liberal arts experience advantage over engineering school (see appendix 1).
- Attract more top tier students with high SAT scores.
- Complement many strong SCU nursing programs with engineering programs. More male students to SCU schools.
- Both schools share strengths to offer a broader constellation of engineering specialties.
- Close cooperation between SCU schools becomes a model for other small schools to contain costs by working together.
- Students at both schools have broader undergraduate research opportunities.
- Opportunity for split teaching assignments, allowing students access to broader faculty teaching expertise.

Collaboration Negatives

- Remote lectures may be less engaging and require time to coordinate.
- Likely fewer engineering distinctives with smaller department.
- Athletic competitiveness between schools could be a disruptive influence on collaborative efforts.
- Greater complexity in scheduling classes and labs.
- Possible budget pressure to over-virtualize labs, reducing students' hands-on experience.

D. SCU 2 year or 4 year program to 4 year ABET Collaboration Program (Main Node)

(Main node schools agree to support Basic and Remote school nodes through transfers and/or remote classes.)

A) Case Study for 2 by 2 year Basic Node to a 4 year Main Node in a LASC College in CA

B) Case Study for 4 year ABET program to a Main Node Collaboration in a LASC in IN

Collaboration Positives

- Lower cost for existing SCU 4 year engineering departments by having more upper level students (2 year feeder schools).
- Fuller or more frequent upper level classes.
- More upper level students for mentoring younger students and for Jr. and Sr. projects.
- Students exposed to video conferencing for workforce and lifelong learning.
- More STEM awareness on SCU campus.
- We are currently implementing a remote learning experience with some of our upper level Physics and Engineering classes.

Collaboration Negatives

- Work of ensuring quality of incoming junior students with assessment and adjustments.

8.0 Additional Assessment Results

The Engineering Physics program at a small teaching focused Liberal Arts University start-up and growth curve for 1997-2005 is shown in Figure 7 below and illustrates how a 3 x 2 year Program gracefully moved into a 2 x 2 year Program and then into a 4 year Program and is now in theory poised for becoming a Main Node 4 year Program. Only one engineering faculty, one adjunct, and two physics faculty maintained the growth. At this time we had an old science building, no ABET accreditation, little equipment and other resources. However, "Big Ideas" of the Solar Car Project and Satellite projects helped recruit and retain students to eventually become a stable ABET engineering program in 2008. Many other factors are involved in building a functional department as outlined in Appendix 2.

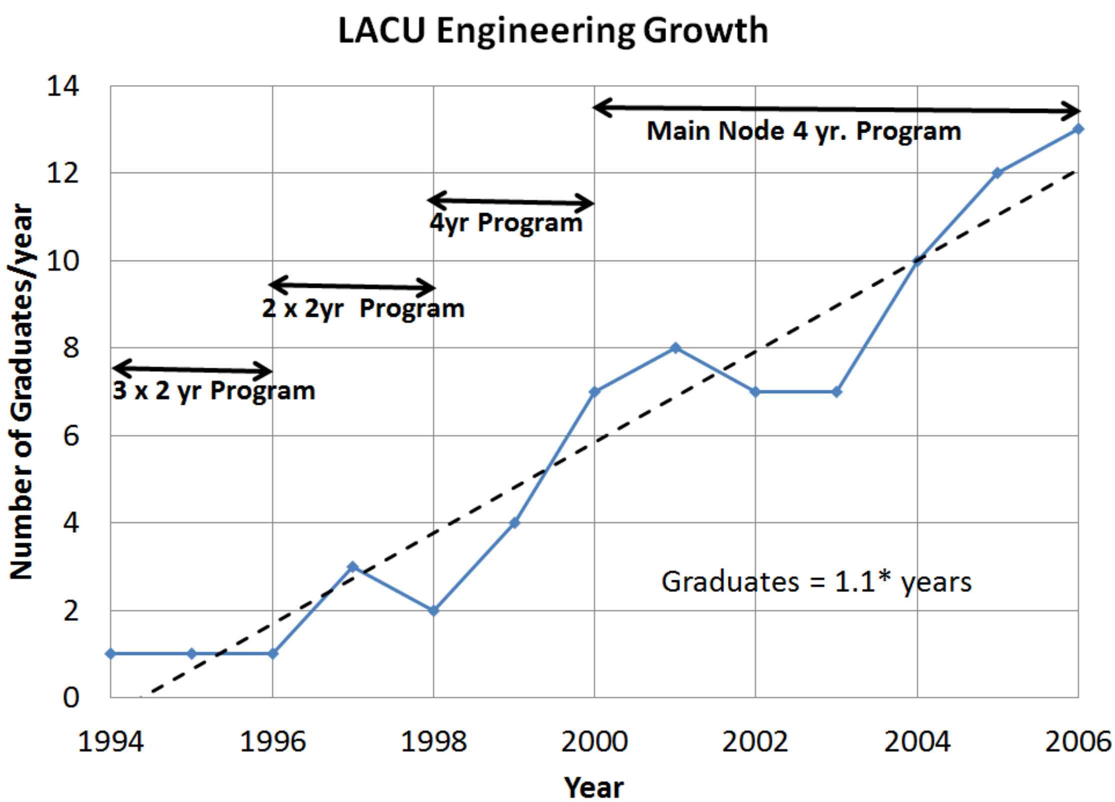

Figure 7. LACU Engineering Growth

ABET Review 2013: The recent 6 year ABET review of our department identified three engineering strengths as 1) the satellite design project (sophomore, junior and senior students), 2) our extensive summer practicums and internships for our students, and 3) our new science building (which was conceptually designed and modeled by our engineering students). The Summer Internships were all paid from external grants as students would usually work on "Big Idea" projects. Faculty could also be paid from the grants (about $10K/summer) since the LACU did not charge any Indirect Cost for AF University Nanosatellite Program student research grants. In many cases the mentoring and focus during the summer was transformational for the students. The grant would also pay for students to attend the Small Satellite conference in

Utah and other locations. This program to involve early freshman/sophomores and sophomores/juniors helped students jump start their learning and define their majors to pursue.

Department Review 2004 Similar strengths were identified by our 2004 Department review.

Alumni review questionnaire over the past 12 years gave the following preliminary results for students who were involved in our satellite design programs: sophomores (Principles class), juniors (Jr. Project class, 2hrs) and seniors (Capstone).

The grade scale is: 5 - Exceptionally Well (Grade = A), 4 - Very Well (Grade = B), 3 – Well (Grade = C), 2 - Not Very Well (Grade = D), 1 - Not at All (Grade = F), N – Not Sure/Does Not Apply

1) **Applying Theory**: How well did working on the TSAT and UNP-3 satellite program help you learn about applying theory to a real-world problem?
RESULT: 4.4 out of 5
2) **Systems Engineering:** How well did working on the TSAT satellite program help you learn about systems engineering? How did it help you learn how to work in a multidisciplinary environment, interface with the work of others, and fit your work into the bigger picture of the project?
RESULT: 4.8 out of 5

3) **Teamwork:** How well did working on the TSAT satellite program help you learn how to work in teams including 1) how to get along with/inspire others, 2) the power of the team for ideas, problem solving, division of effort, and 3) working with external companies/agencies?
RESULT: 4.7 out of 5

4) **Career Inspiration:** How well did working on the TEST satellite program develop your gifts and passion?
RESULT: 4.7 out of 5

5) **Preparation for the "Real –world" after Graduation:** How well did working on the TSAT satellite program give you "hands-on, real-world" experience that prepared you for work or graduate/professional school after graduation?
RESULT: 4.8 out of 5

Alumni Survey Examples: Several examples as quotes…..

Graduate A: *For the past 15 years, the Physics and Engineering department has integrated a rare blend of theoretical rigor and practical application. At Taylor, I learned "where there's a will, there's a way." I have found that this basic outlook on life is a prerequisite to becoming a successful entrepreneur, who must challenge the status quo and beat incumbents on a shoestring budget. In my days at Taylor (1997 - 2001), we were pushing the limits of undergraduate education in a variety of categories. From space probes under contract to NASA, to building a solar racing car on 5% of the budget of our competitors, to the nanosatellite program, where our design was built around non-radiation hard componentry, my time at Taylor was saturated with* *creative, entrepreneurial problem solving opportunity. Directly following graduation from SCU, I teamed up with Dr. Voss (Chair at the time) and student graduate (fellow 2001 Physics graduate) to create a new startup called NanoStar. Our collective goal was to commercialize the nanosatellite technology we built in the lab and deliver a store-and-forward communications system to the World. We pitched this concept to venture capitalists in six cities across the country and learned a great deal about how to design a robust startup in the process. These lessons undergird my current venture, MyFarms, which is going head-to-head with agricultural giant, Monsanto, to apply big data concepts to day-to-day farming practices and dramatically increase food production worldwide. My experience at SCU was truly transformational. I learned the core principles of managing science, technology and entrepreneurship; lessons that continue to serve me well each day."*

Graduate B, *"TSAT has played a tremendous role in my career decision and has been a major stepping stone in adjusting to my current job. I am currently doing ECU development in the automotive industry, and working on TSAT gave me the flexibility of learning more about the academic side and the practical side of embedded systems"*

Graduate C: *My senior project was good preparation for the "real-world." The experience of going through the entire design process of developing a scope, working hard to make sure the project is successful, and presenting the final product is similar to what I do now. I think that having the freedom to develop an idea and also to fail is important. I have some specific tasks that I must complete, but a lot of my job requires taking the goals of my department and developing "projects" to fulfill those high level goals. I do not have a "professor" or boss telling me everything I need to do. Allowing students to develop their own "project" as long as it meets the high level requirements of the engineering curriculum is a good way to grow and develop engineers. The science building project that I worked on was not my original project. We had started a different one, and realized it really was not a feasible project midway into fall semester. This was good experience, because sometimes you need to be able to swallow your pride and admit that your original idea was not as good as it initially appeared.*

Summary and Conclusions

Small Colleges and Universities (SCU) are an untapped resource for holistic Engineering Education, creative entrepreneurial "big ideas", and growth of national science, technology, engineering, and math (STEM) literacy in a competitive global market.

SCU engineering programs may efficiently adapt to a stronger paradigm in education that results in lower program cost, improved learning, improved social STEM awareness, and new growth of more SCU engineering programs. Implementation requires some program standardization, hybrid classes, and use of a mesh network communication protocol (articulation agreements). New 2-year SCU engineering programs (2 year Nodes) increase STEM awareness on their campus while becoming feeder schools for main 4 year Node schools. Five case studies were undertaken in the context of hybrid curriculum programs in a SCU consortium.

Just like a powerful wireless mesh network with a standardized protocol so a powerful SCU engineering mesh network could be established after review with a standardized articulation agreement and common assessment template. Currently we are working with Crown College in MN to start a 2yr ABET Engineering program with articulation agreements. Over the past Taylor Universiy had 2yr transfer students but credit transfer had to be worked out individually.

Several feasibility studies are currently underway with several SCU Liberal Arts schools. A network of SCU engineering programs working together can become a cost effective conduit for attracting many new students and more effectively meeting long term national needs of students and universities.

A baseline 2 year freshman and sophomore curriculum program is proposed based on case studies, on research, and on alumni questionnaires. Based on a decade of SCU Engineering Physics teaching experience it was also found efficacious to give closure to the 2 year program curriculum with a sophomore type "Cornerstone" class called "Principles of Engineering".

Acknowledgments

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References

[1] ABET Criterion 3. Student Outcomes (a-k). (1920, March 11). ABET Criterion 3. Student Outcomes (a-k). Retrieved January 1, 2014, from http://ecee.colorado.edu/~mathys/ecen2250/abet/criterion3.html

[2] Voss et. al. This Publication, Nanosatellites and HARP for Student Learning and Research, 122nd ASEE Annual Conference & Exposition, Seattle, Washington, June 14-27, 2015

[3] Voss, David L., K Alexander, M. Ford, C. Handy, S. Lucero, and A. Pietruszewski, Educational Programs: Investment with a Large Return, 26th Annual AIAA/USU, Conference on Small Satellites, Logan, Utah, SSC12-VII-1, Aug. 2012

[4] Welcome to the University Nanosat Program (UNP). Retrieved March 19, 2014, from http://prs.afrl.kirtland.af.mil/UNP/index.aspx

[5] Voss, Hank and Jeff Dailey, "TSAT Globalstar ELaNa-5 Extremely Low-Earth Orbit (ELEO) Satellite" Small Satellite Conference, Utah, August, 2014, paper SSC14-WK-6

[6] Sargent, T., Kiers, J., and Voss, H. (2014, March). ELEO-Sat Design Process for a Boom Deployment System with Monte Carlo Aerodynamics Simulation. Paper presented at ASEE Illinois-Indiana Section Conference. Terre Haute, IN: Rose-Hulman Institute of Technology.

[7] Straits, S., Mathioudakis, M., and Voss, H. (2014, March). 6-Unit Cubesat Design and Learning for Mechanical System, Solar Arrays, and Thermal Modeling. Paper presented at ASEE Illinois-Indiana Section Conference. Terre Haute, IN: Rose-Hulman Institute of Technology.

[8] Theien, T., Yoshino, K., Emison, J., Newhall, B., and Dailey, J. (2014, March). ELEO-Sat Instrument Suite. Paper presented at ASEE Illinois-Indiana Section Conference. Terre Haute, IN: Rose-Hulman Institute of Technology.12. United States Air Force Research Laboratory Space Vehicles Directorate (2013). *NANOSAT-8 USER'S GUIDE*. Albuquerque, NM: U.S. University Nanosat Program Office.

[9] Whitman, Lawrence, Toro-Ramos, Zulma, Skinner, Steven, Educating the Engineer of 2020: A Practical Implementation, Proceedings of the 2007 Midwest Section conference of the American Society for Engineering Education.

[10] Shealy, E., C. Brawner, C. Mobley, and . Layton, A descriptive Study of Engineering Transfer students at Four Institutions: Comparing Lateral and Vertical Transfer Pathways, 120th ASEE Annual Conference and Exposition, Jun 23-26, 2013, Paper ID #7198

[11] Salzman, Hal, Daniel Kuehn, and B. Lindsay Lowell, EPI Briefing paper, Economic Policy Institute, April 24, 2013., "Guestworkers in the High-Skill U.S. Labor Market", http://www.epi.org/publication/bp359-guestworkers-high-skill-labor-market-analysis/

[12] National Center for Education Statistics. (2009). *Digest of education statistics: Bachelor's, master's, and doctor's degrees conferred by degree-granting institutions, by field of study and year: Selected years, 1970-71 through 2007-08*. Retrieved from http://nces.ed.gov/programs/digest/d11/tables/dt11_289.asp

[13] David Langdon and George McKittrick, Office of Chief Economist, U.S. Department of Commerce, Economics and Statistics Administration, STEM: Good Jobs Now and for the Future,ESA Issue Brief, #03-11, www.esa.doc.gov, July, 2011

[14] B.L. Benderly, Boom or Bubble?, Prism-Magazine.org, November, 2013, p29-32

[15] Wm. A. Wulf is president of the National Academy of Engineering, and George M. C. Fisher is chairman of the NAE Council and retired chairman and CEO of the Eastman Kodak Company, http://www.issues.org/18.3/p_wulf.html , W.A. Wulf and G.M.C. Fisher, "A makeover for engineering education," Issues Sci. Technol., vol. 18, no. 3, Spring 2002.

[16] Waychal, Pradeep Kashinath, Sahasrabudhe, Anil Dattatraya, A Framework for Liberal Learning in an Engineering College, 120th ASEE Annual Conference & Exposition, June 2013, Paper #6029.

[17] Anderson-Rowland, M. R., Banks, D. L., Zerby, D. M., & Chain, E. A. (2005). Evaluating a collaborative program to increase the enrollment and retention of community college transfer students. Paper presented at the 35th ASEE/IEEE Frontiers in Engineering Conference, Indianapolis, IN.

[18] ABET Criteria for Accrediting Engineering Technology Programs, 2013-2014 Accreditation Cycle, www.abet.org.

Appendix 1: Advantages and Disadvantages of Engineering in SCU/Liberal Arts

Many Students, Parents, administrators and even faculty are somewhat uncertain of the tradeoffs with an engineering education at a SCU school. The following list helps to identify some of the considerations.

Some Advantages of a SCU Liberal Arts Engineering Education

- More well-rounded engineers:
    - Engineering jobs usually require 70% people skills (writing, communication, and social/team interaction).
    - Constraints on many designs now include environmental, stewardship, economic, cultural, psychological, and sociological — the substance of the liberal arts.
    - Many SCU engineer graduates recruited as Project Management…natural leaders.
    - More travel opportunities in small SCU with global engagement.
    - More service learning opportunities.

- Higher Quality Education:
    - Smaller class sizes with more direct contact and grading with teaching focus of professors. Less pressure on faculty to do large research programs and publish. Usually much smaller enrollments located near small town communities with environments conducive to learning.
    - More one-on-one research and internship possibilities with professors where there are few graduate students.
    - More creativity and critical thinking opportunities with broad curriculum. Teaches you how to learn, think, and adapt using knowledge strategies.
    - More opportunities and expression for Creative Research and Design (R&D) engineers.
    - Higher admission criteria and academic expectation than most state universities with lower admissions criteria and more grade inflation in introductory classes.
    - Integrated science learning and interaction with Physics, Chemistry, Engineering, Math, Biology, and Computer Science folks, usually all located within one building.

- More interactive student body
    - With engineering more SCU students understand STEM and get rid of stereotypes.
    - Students can move into many other career paths and more diverse student body.
    - More mixing of students in different majors within SCU.
    - Engineering/Innovation viewed positively by public/parents/outreach.

- Worldview and character building foundation
  - More philosophical interaction with students and faculty with different viewpoints. More understanding of what a person is, a job choice, and our role in society, ethics, and moral purpose.
  - Helps students integrate science, faith, philosophy, history, literature, and expression (wisdom and problem solving). Students as learners with vocation and not just learners of skills and degrees.
  - Students often broadly exposed to curricular and co-curricular experiences addressing ethics and personal responsibility.
  - The world becomes more understandable, coherent, and within context.

Some Disadvantages of a SCU/Liberal Arts Engineering Program

- Classroom education may also be weaker due to the number of class offerings, number of available ABET BS majors, number of department distinctive capacities, low upper class enrollments, lack of ample facilities and equipment, job opportunities and fairs, and documentation overhead.
- Relatively low engineering pay scales compared to industry so difficult to attract top faculty. Usually a business environment that cultivates equal salaries for all faculty majors.
- Many SCU faculty and administrators may view the applied science as less “pure” and do not appreciate the relevance of a holistic education that is connected to thoughtful applications and cultural advancement.
- Advertised Engineering “majors” can be run on a shoe string with weakly connected 3+2 programs, 2+2 programs, other transfer programs, 2 year Engineering Technology programs and non-accredited programs. These programs can hurt weaker engineering students who have little experience, no terminal degree, and also not viable for transfer to most ABET engineering schools.

Appendix 2: Competitive engineering requirements for department success

1. Department clear Vision and Adequate Facilities
2. Capable and diverse faculty and staff to cover many subjects and needs.
3. Multiple engineering tracks (concentrations) with hands-on practical experiences
4. Scholarships for students (Economically it is to the universities advantage to give scholarships to top recruits if the engineering classes are partially full so that no new faculty are required)
5. ABET accreditation and rigorous academic program (outcomes)
6. Admission Assistance: PR materials, engaging Web Pages, professional brochures
7. One or more engineering faculty with good industry and research experience
8. "Big Picture" projects with competition success helps inspire students and gives program recognition (Solar Car, NASA Research, HARP Balloon, Renewable Energy)
9. Student Research Program with summer internships for sophomores
10. Supporting Math, Physics, and Chemistry Programs
11. Good track record with alumni at top graduate schools and competitive job ready
12. Solid University reputation with attractive student programs

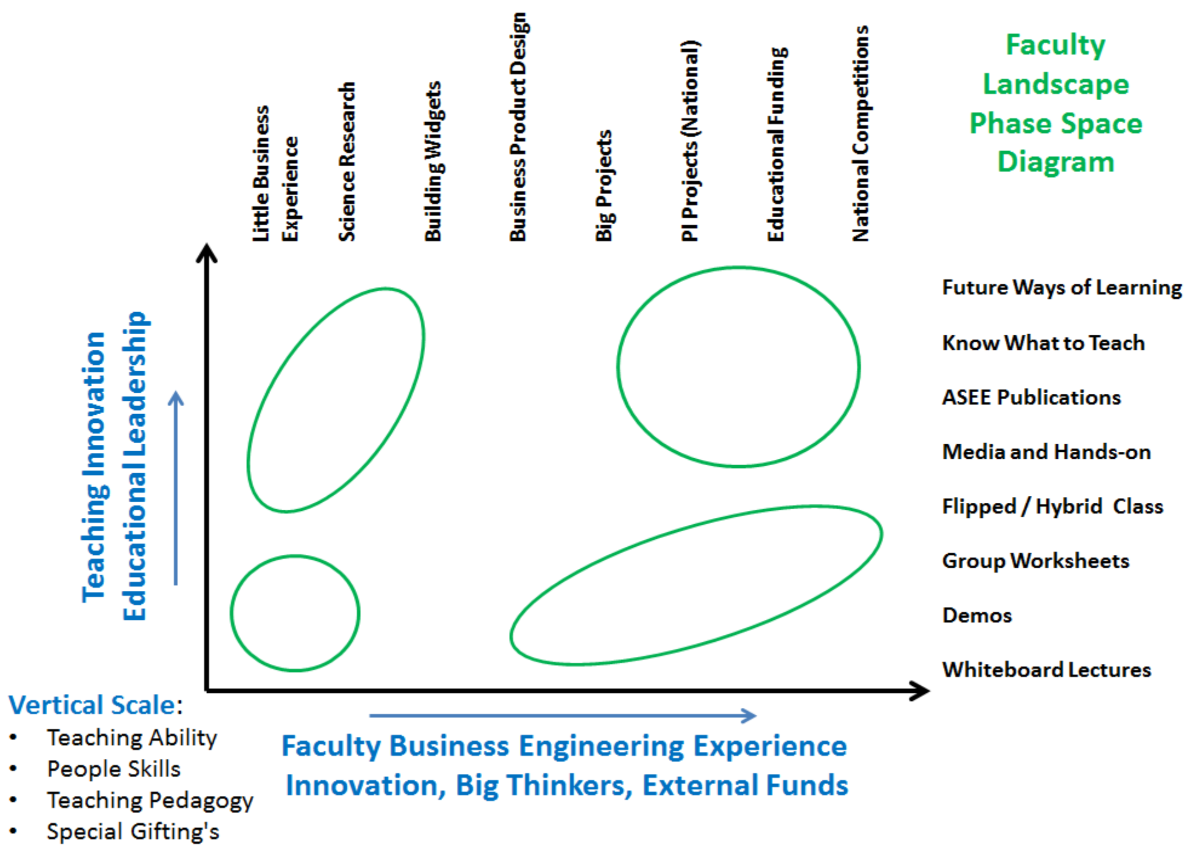

Figure A2: A healthy department team is one that is usually diverse, has individual freedom and respect, and contains faculty with unlike gifting's and experiences (2-D landscape). The 3-D vertical scale is not shown but is a given in terms of Teaching ability and people skills.

Appendix 3: Principles of Engineering Syllabus

Syllabus
ENP 252, *Principles of Engineering*
4 hours, Spring Semester 2011

Dr. Hank Voss
Supporting Professors: (Thermal Prof.)
Prof. Dailey (Lab and Project)
Teaching Assistance: AutoCad 10 and Inventor
Class meets: Monday (NS210), Wednesday and Friday at 3:00 PM (Ayres 120)
Lab meets: Thursday 8:00-9:50 AM, 1:00-2:50 PM in XXX 110 & Lab

ENP 252 – 4 hours PRINCIPLES OF ENGINEERING

This course introduces the student to the engineering profession and prepares the student for summer internships, upper division course work and upper division design projects. Topics include: design methodology, 3D modeling, technical drawings, hardware and software, oral and written communication, and engineering economics. The course also introduces Statics, Materials, Thermodynamics, Fluid Statics, Heat Transfer, and Finite Element Methods. Through this course, the student begins a path to becoming a professional engineer. This course includes a semester long design project that integrates design methodology, CAD, communication, and expertise in various engineering disciplines. It is required for CEN and ENP majors. *Prerequisites are: MAT 230, PHY 211 or permission of the instructor. Course is a SP course. Offered Spring semesters.* Lab Description: Labs are for design, assembly, testing, learning PC applications and optional problem solving time.

Texts and Lab Supplies: **Required:**

1) FE Review Manual, Second Edition, Michael Lindeburg, Professional Publications, Belmont, CA, 2006
2) Custom Text for Course, Principles of Engineering, ISBN 10: 0-39-089994-1, Published by McGraw – Hill - PRIMIS, Jan, 2008 (Will provide copies for purchase)
3) FE Supplied – Reference Handbook published by the National Council of Examines for Engineering and Surveying (http://www.ncees.org/exams/study_materials/fe_handbook/)
4) Freshman Physics Book, Physics for Scientist and Engineers, Giancoli, 4th edition, 2008
5) Free, Matlab, AutoCad 10 and Inventer/Rivet Software and Documentation

Optional: Engineer-In-Training Reference Manual and Solution Manual (SI units), 8th edition, by M.R. Lindeburg, Professional Publications, Inc., Belmont, CA 94002, 1992.

Primary Course Objectives

- Understand the fundamentals of engineering physics for future graduate studies and careers
- Exposure to engineering fields, improve laboratory procedures and use of technical equipment
- Obtain a "Big Picture" view of integrated science and technology by introductions to primary fields.
- Review math, science, and engineering so that all students have solid base for upper level classes
- Prepare for FE, PE and GRE Exams using practice problems and reference handbook
- Review basics for FE exam proficiency and system use in projects
- Introduce major engineering design process and implement in a major design project
- Develop understanding in engineering management, economics, and law
- Develop Stewardship skills (structures, energy, water, environment, , community needs, sustainability, etc.)
- Gain familiarity with problem solving skills and computer programming and applications
- Make Resume and acquire engineering skills to obtain summer internships and engage culture.
- Provide reference material, develop engineering notebooks, and increase knowhow by integrating disciplines
- Gain experience using 2-3D CAD, machine shop tools, Structures, fluids, thermodynamics and powerful software;
- Learn how to give a professional presentation SP Course

Projects Teams:, New High-Altitude Balloon Platform physics and instrumentation, Launch, INSGC
New type of Wind Energy Generator using a balloon-airfoil

Develop Software familiarity and skills: MatLab (programming/plotting/Differential Eq./Laplace, Simulink,) MatCAd, Microsoft Project, AutoCAD 10, LabView, PowerPoint features, Assembly code, OrCad, Visio, Wiki,

Possible Field Trip Include: Crandall Civil Engineering, Pierce, GM Plant, Machine Shop, Job Fair

Course Outcomes

By the end of this course, students should be able to:

1. Understand the unifying Principles that govern and connect interdisciplinary engineering fields: electrical, statics, dynamics, fluids, thermodynamics, economics, and mechanics.
2. Use 3D modeling software to model parts using: using AutoCad10, constructive solid geometry,
3. Capture design intent within a 3D model and explain why modeling according to design intent is important.
4. Perform assembly modeling using a top – down or bottom – up approach including creating assembly constraints and inter-part references.
5. Use all phases of a formal design methodology, concurrent engineering design, to complete a project with well defined requirements, solid analysis and effective implementation.
6. Setup and solve 2D and 3D statics problems including forces, torques, couples, distributed loads and equivalent systems.
7. Review Introduction to Electronics FE proficiency, transformers, motors, gates, processors, and IO
8. Use the concept of direction cosines to quickly and easily write down the components of vectors.
9. Reduce distributed loads to an equivalent system of a single force applied at a single point.
10. Describe how a tensile test is performed and five material properties obtainable from the tensile test.
11. State the definitions of stress, strain, sheer stress, sheer strain, elastic strain and plastic deformation.
12. Explain the meaning of cold work, fracture toughness, and creep.
13. Define key engineering thermodynamics terms such as: closed system, open system, boundary, property, state, process, intensive, extensive equilibrium, quasi – equilibrium, and internal energy.
14. Describe the features of a phase space diagram and find system properties using a phase space diagram.
15. Discuss the global environmental and societal issues associated with energy supply and usage.
16. Understand Sustainable Design with examples
17. Find energy transfers based on process knowledge of heat and work.
18. Apply the mass balance equation to open systems in solving engineering thermodynamics problems.
19. Explain and use the first law of thermodynamics for open and closed systems.
20. Simplify and use the open system first law for common systems such as nozzles, turbines, heat exchangers and pumps.
21. Conceptually explain engineering thermodynamics cycles such as power and refrigeration cycles.
22. Calculate the net force on a flat or curved surface from a surrounding fluid and find an equivalent system of a single force.
23. Determine if an immersed or floating body is stable.
24. Solve heat transfer problems involving conduction, convection or radiation.
25. Solve multimode heat transfer problems.
26. Use software to setup and solve heat transfer problems using finite element methods.
27. Develop detailed design requirements from an open ended design project.
28. Effectively make formal and informal oral presentations.
29. Work corporately in a team environment to generate ideas, perform research and complete analysis while working on a design project.
30. Use communication and interpersonal skills to be an effective team member.
31. Identify Biblical leadership styles.
32. Manufacture engineering parts and have knowledge of how the manufacturing process impacts engineering design.
33. Understand the basics if engineering economics
34. Learn practical software skills
35. Develop resume, job fairs, and apply for summer internships
36. Articulate how the practice of engineering can help others

Schedule of Class and Lab Activities

Week	Starting Date	Subject MWF	Lab	Prof	Readings Tests	FE Review, HW Topics Study
		PRELIMINARY				
1	Jan 31 Voss	Intro, FE, Resume, Jobs, Projects, Pretests, Electrical Review	Intro. to electrical IO Board 1	V D	Electrical handouts MatLab Handouts Giancoli Ch 21-26	XIV Ch 43-44 Ref. Handbook
2	Feb 7 Voss	Statics, Structure, Drawings	IO μ-Controller Board 2	V D	Staticsl Handouts MatCAD Handouts, Giancoli Ch 27-31	XIV Ch 45 I, II Units
3	Feb 14 Voss	Statics, Trusses, Drawings	AutoCAD 10 Drawings	V D	Review Quiz Statics MH 160-176	IV Statics VI Materials
4	Feb 21 Voss	Common Equations, Principles, and Math I	Inventor CAD Drawings	V	Holtzapple/Reece Foundations **TEST 1**	Holtzapple/Reece Foundations
5	Feb. 28 Takehara	Thermo, Properties, first law, power cycles, FE problems	Thermo 1 LAB	T	Giancoli CH 17 -18	VIII Thermodynamics
6	Mar 7 Tak	Thermo, Sustainable Design Heat Transfer	Balloon I Design Project, AutoCad	V	Heat Transfer MH 301-326	IX Heat Transfer
7	Mar 14 Tak	Thermo, gases, vapors, combustion FE Problems	Thermo 2 Lab	T	Giancoli CH 19	VIII Thermodynamics
	Mar 21	**SPRING BREAK**				
8	Mar 28 Tak Voss	Ortho, Notes, Mechanical design drawings	Balloon II Design Project, Launch	V	Giancoli, Fluid Statics Ch 13	VII Fluids Ch 22, 23
9	Apr 4 Tak	Thermo	Thermo 3 Lab	T	Giancoli Ch 20 **TEST 2**	VIII Thermodynamics
10	Apr. 11 Voss	Common Equations, Principles, and Math I	Balloon III Data Analysis	V	Holtzapple/Reece Foundations	Holtzapple/Reece Foundations
11	Apr. 18 Voss	Fluid properties, fluid statics, measurements, FE Problems	Machine Shop 1 Stress Strain	V D	Giancoli, Fluid Dynamics Ch 13	VII Fluids Ch 24
12	Apr. 25 Voss	Steel, Civil Engineering, Concrete,	Machine Shop 2, Welding, Projects	V	Document MH 124-143	VI Mechanics
13	May 2. 28 Voss	Engineering Economics Biology/Chemistry	Projects, Poster, Presentations	V	Economics MH 193-219	XVI Economics XI Biology
14	May 9 Voss	Presentations	Field Trip	V	**Quest**	Review
15	May 16 Voss	Final Tuesday 5/19, 3-5pm			**Final**	

Labs will be coordinated with the lecture. Professional Lab Reports are required for each lab. Lab requirements will be given in a separate handout. Also see Blackboard for latest updates.

Summary Notebook for Future Reference and Final

An integral part of this course will be the completion of a course notebook, containing:

1) Notes taken during class and from book
2) Handouts given out during class
3) Homework and Study Guides (completed by students for exam preparation)
4) Lab notebook

These notebooks need to be neat and organized and will be given a grade accordingly.

Homework

Homework will be given out each week and will be due at 5:00 pm in NS208 door envelope on the specified day. Most of the homework problems will be from the book. Assignments and solutions will be put on the blackboard.

Category	Percentage of Grade	Description
Final Exam	10%	Cumulative over entire course, FE Type Test
2 Tests - Quest	30 %	All test material will be directly linked to study guides
Homework	10%	Assignments checked for completion
Quizzes/Attend.	5%	Quest, Lowest quiz not used
Notebook	5%	Completeness and organization
Labs	18%	Labs and Lab reports
Project	17%	Design Process Steps, Design Review, Completion
Presentation	5%	Final documentation, design process, SP

Other syllabus university requirements and helps

Appendix 4: FE Other Disciplines Exam Summary and Assessment Rubric

Principles of Engineering Sophomore class is used to fill in many of the gaps in the FE exam material so students know a little in most of the subject areas to better understand engineering fields, internship and project literacy, and give context to the common laws and methods of problem solving. FE HP column gives the subject number of pages used in the FE handbook, # of ? on test column gives the number of questions on the FE test, Level prepared is a self-assessment of students at some point in their curriculum (Green=Good and Red = Weak), The next column is a student self-assessment on wanting to know the topic better, and the final column is used to trace which class this material is taught in.

Grade Scale: 4=A (Know Well), 3= C (Average) , 1=D (know little)

FE exam for other disciplines

Topic	FE HB # Pages	# of ? on test	Level Prepared	Know topic better?	Classes that have gone over topic
Mathematics and Advanced Engineering Mathematics	15	15	3.33		
Analytic geometry and trigonometry			4.00		
Calculus			4.00		Calculus I, Calculus II, Calculus III
Differential equations			3.67		Differential equations
Numerical methods			3.33		Calculus I, Calculus II, Calculus III
Linear algebra			1.67		Linear algebra
Probability and Statistics	17	7.5	1.50		
Measures of central tendencies and dispersions			1.67		
Probability distributions			1.33		
Estimation			2.00		
Expected value (weighted average) in decision making			1.67		
Sample distributions and sizes			1.00		
Goodness of fit			1.33		
Chemistry	6	9	3.40		
Periodic table			3.67		College Chemistry I
Oxidation and reduction			2.67		College Chemistry I
Acids and bases			3.00		College Chemistry I
Equations			3.67		College Chemistry I
Gas laws			4.00		College Chemistry I
Instrumentation and Data Acquisition	7	5	2.22		
Sensors			2.00		
Data acquisition			1.67		
Data processing			3.00		
Ethics and Professional Practice	2	4	2.33		
Codes of ethics			2.33		Introduction to Engineering Ethics
NCEES Model Law			2.33		Introduction to Engineering Ethics
Public protection issues			2.33		Introduction to Engineering Ethics
Safety, Health, and Environment	13	5	1.92		
Industrial hygiene			0.67		
Basic safety equipment			2.67		
Gas detection and monitoring			1.33		
Electrical safety			3.00		
Engineering Economics	7	10	0.80		
Time value of money			0.67		
Cost			0.67		
Economic analyses			1.33		
Uncertainty			0.67		
Project selection			0.67		
Statics	5	10	3.86		
Resultants of force systems and vector analysis			4.00		
Concurrent force systems			3.67		
Force couple systems			4.00		
Equilibrium of rigid bodies			4.33		
Frames and trusses			4.00		
Area properties			3.33		
Static friction			3.67		
Dynamics	8	9	2.75		

Dynamics	8	9	2.75		
Kinematics			3.67		
Linear motion			4.00		
Angular motion			3.00		
Mass moment of inertia			3.00		
Impulse and momentum (linear and angular)			2.67		
Work, energy, and power			2.67		
Dynamic friction			2.33		
Vibrations			0.67		
Strength of Materials	7	10	2.92		
Stress types			3.00		
Combined stresses			3.00		
torsion, or shear			3.00		
Shear and moment diagrams			4.00		
Analysis of beams, trusses, frames, and columns			2.67		
Deflection and deformations			2.67		
Elastic and plastic deformation			3.33		
Failure theory and analysis			1.67		
Materials Science	7	7.5	2.00		
Physical, mechanical, chemical, and electrical properties of ferrous metals			2.33		
Physical, mechanical, chemical, and electrical properties of nonferrous metals			2.33		
Physical, mechanical, chemical, and electrical properties of engineered materials			2.00		
Corrosion mechanisms and control			1.33		
Fluid Mechanics and Dynamics of Liquids	14	10	1.17		
Fluid properties			1.67		
Dimensionless numbers			2.00		
Laminar and turbulent flow			1.67		
Fluid statics			1.33		
Energy, impulse, and momentum equations			0.67		
Pipe flow and friction losses			1.33		
Open-channel flow			0.67		
Fluid transport systems			0.67		
Flow measurement			0.67		
Turbomachinery			1.00		
Electricity, Power, and Magnetism	20	9	3.81		
Electrical fundamentals			4.33		
Current and voltage laws			4.00		
DC circuits			4.00		
Equivalent circuits			3.33		
Capacitance and inductance			4.00		
AC circuits			3.00		
Measuring devices			4.00		
Heat, Mass, and Energy Transfer	23	11.5	2.39		
Energy, heat, and work					
Thermodynamic laws			3.00		
Thermodynamic equilibrium			3.00		
Thermodynamic properties			2.67		
Thermodynamic processes			3.00		
Mixtures of nonreactive gases			1.33		
Heat transfer			3.33		
Mass and energy balances			3.00		
Property and phase diagrams			2.67		
Phase equilibrium and phase change			2.33		
Combustion and combustion products			1.33		
Psychrometrics			0.67		

Appendix 5: Some Non-FE Exam Skills/Outcomes Assessment Rubric

Similar Matrix used to trace and track Non-FE exam abilities and assess student proficiency and interest. Class Trace (Last Column) is just partially filled out. Principles of Engineering Class is used to improve many weak (Red) areas for resume, summer jobs, and terminal Associates Degree at completion of two years.

		Comprehensive: DRAFT 15 January 2015		
		Some Non-FE abilities we want students to have		
1=low, 5=high				
Proficiency	**Interest**			**ratio: interest /proficiency Class Trace**
2.09	**3.94**	**Mechanical:**		**1.88**
1.67	4.33		Machine Shop Hands-on skills (Safety, Mill, Lathe, Laser cuter, Drill, tools ..)	Principles
2.67	3.67		3-D Printer Proficiency	ENP 104
1.00	4.33		CNC Machines programing (G-Code) and making items	
2.00	3.67		Order parts from McMaster Carr and others	Capstone
3.00	3.00		Measurement and tools	
2.67	3.67		How to make Professional Drawings (Drafting)	
2.67	4.00		Know Solid Works well	
1.00	4.67		Certificate in Solid Works Proficiency for resume	
2.33	3.67		Drawing Trees, ICD documents	Capstone
2.00	4.33		Work with machinist	
2.00	4.00		Model Building and wood shop	
2.48	**3.22**	**Electrical:**		**1.30**
1.67	3.00		Certified on all new Test Equipment	
1.33	2.67		PCB Mill Proficiency	
1.33	4.67		Electrician and Household Wiring Basics/safety	
3.67	2.67		Order parts, BOM, Digikey and others	
2.33	3.00		Know many parts IC and passive elements	
3.33	3.33		Know how to read a Data Sheet	
3.00	2.67		Know Electrical Software Packages	
2.67	4.33		DeBug skills	Capstone
3.00	2.67		PCB layout and manufacture	
2.39	**3.36**	**General:**		**1.41**
3.00	4.67		Build Real Projects: Personal Electronic Lab, others	Capstone
2.33	4.33		Project Management Skills	Capstone
3.00	3.33		ABET student Outcomes	All
1.00	4.00		System Engineering Certification, NASA, Resume	Capstone
2.67	3.00		Know Design Process Steps, Documentation, and Risk reduction	Capstone/All
1.67	3.33		Know some Industrial Engineering Topics	
1.00	2.00		Publications to Professional societies, ASEE, IEEE, ASME, AIAA, Small Sat, Others	Capstone
1.67	2.67		Student Membership in Professional Societies, Resume	
3.00	2.33		Poster Contest April	Capstone
3.00	4.33		Resumes and Summer Job Search	
2.33	4.33		Job and Graduate school Search	Capstone
4.00	2.00		notebook/logbook	Capstone/All
1.79	**3.09**	**Other Abilities**		**1.73**
3.33	3.33		Know Science and Worlview Topics related to Vocation	IAS 231
1.67	3.33		Know topics in Renewable Energy	
3.00	3.30		Work on "Big" Student Competition Research Projects, TSAT, ELEO, Euler, ..., Resume	Capstone
1.00	2.67		Know Topics in Aeronautics Engineering, Fund. Space Systems	ENP
1.00	1.67		Vacuum Systems	
2.00	2.33		HARP end to end flights of full systems	Capstone
2.33	3.33		Calibration of sensors	
1.33	3.67		Mechanical Labs (rocket, jets, RC planes, nozzle design,	
1.00	3.33		Shake and vibration labs	
1.33	3.33		Robotic Topics	
1.67	3.67		Engines/Power trains/ Generators	
2.31	**2.75**	**Software Abilities and Skills**		**1.19**
4.00	2.00		Office	
2.67	3.33		MatLab	
2.33	2.67		Mathematica	
1.00	3.33		LabView	
3.67	2.00		Eagle	
3.00	2.67		MultiSim	
2.00	1.67		OrCad	
2.67	2.33		Pspice	
2.67	3.00		Visio	
1.33	3.00		Microsoft Project	
1.33	3.67		C-Programing	
1.00	3.33		Assembly Code Programing	