GC 2012-5613: COMPARISON OF PRACTICAL TRAINING EXPERIENCES FOR ELECTRONICS ENGINEERS IN CHINA AND THE U.S.A.: CASE STUDY OF SOUTHEAST UNIVERSITY AND THE UNIVERSITY OF SAN DIEGO

Prof. Yongming Tang, Southeast University

Prof. Yongming Tang has get the bachler, master and Ph.D degree from School of Electronic Science and Engineering of Southeast University in Nanjing, China. He became a teacher from 1998. Now he is the deputy dean, who is working on the curriculum for undergraduate students. He also organizes two contests in Southeast University every year.

Dr. Susan M Lord, University of San Diego

Susan M. Lord received a B.S. from Cornell University and the M.S. and Ph.D. from Stanford University. She is currently Professor and Coordinator of Electrical Engineering at the University of San Diego. Her teaching and research interests include electronics, optoelectronics, materials science, first year engineering courses, feminist and liberative pedagogies, engineering student persistence, and student autonomy. Her research has been sponsored by the National Science Foundation (NSF). Dr. Lord is active in the engineering education community including serving as General Co-Chair of the 2006 Frontiers in Education (FIE) Conference, on the FIE Steering Committee, and as President of the IEEE Education Society for 2009-2010. She is an Associate Editor of the IEEE Transactions on Education. She and her coauthors were awarded the 2011 Wickenden Award for the best paper in the Journal of Engineering Education. In Spring 2012, Dr. Lord spent a sabbatical at Southeast University in Nanjing, China teaching and doing research.

Comparison of Practical Training Experiences for Electronics Engineers in China and the U.S.A.: Case Study of Southeast University and the University of San Diego

Abstract
Engineering education involves academic coursework as well as practical training. This training may take several forms including laboratories, design contests, design courses, and internships. Approaches to such activities vary within and among nations. In this work, we compare the approach to practical training of electronics engineers at Southeast University (SEU) in Nanjing, Jiangsu Province, China to that at the University of San Diego (USD) in San Diego, California, U.S.A. This work is the result of an international cooperation between faculty members at these institutions. Both institutions are committed to helping students develop critical hands-on skills. Laboratories play an important role in the required curriculum for both institutions. However, the logistics of these laboratories vary. For example, at USD, the laboratories are integrated into individual courses while at SEU, there is a separate Laboratory Center that offers laboratories for many Schools. This is a national center and serves as a demonstration facility for other educators across China. Both institutions offer students significant yearlong design experiences. Students work in small teams for both but there is considerable variation in the approaches. At USD, students are required to complete a capstone senior design as part of their required curriculum. At SEU, students must complete two credits of "Extracurricular Research" as part of a university "Ke Wai" requirement. Students may choose to participate in Design Contests, the Scientific Research Training Program (SRTP), do research with faculty, or attend professional lectures. The Design Contests and SRTP are the most popular and students typically do these projects as juniors. Strengths of the different approaches are considered.

Introduction

Engineering education involves academic coursework as well as practical training. This training may take several forms including laboratories, design contests, design courses, and internships. Approaches to such activities vary within and among nations. In this work, we compare the approach to practical training of electronics engineers at Southeast University (SEU) in Nanjing, Jiangsu Province, China to that at the University of San Diego (USD) in San Diego, California, U.S.A. This work is the result of an international cooperation between faculty members at each of these institutions. We begin with overviews of the institutions and programs. Then we consider how laboratory courses are handled in each program and then how design experiences are conducted. Finally, we summarize and offer some best practices.

Southeast University (SEU)

There are about 1000 universities and colleges in China, more than half of which offer majors in engineering. SEU, founded in 1902, is one of the national key universities administered directly under the Ministry of Education of China. It offers many highly ranked technical majors, such as Architecture, Civil Engineering, Communication Engineering, Bio-Medical Engineering, as well as Electronic Engineering.

At present, SEU has three main campuses in Nanjing and covers a total area of 427 hectares. The total number of faculty and staff is 6000, including 1300 full or associate professors, 450

doctoral supervisors, and 9 academicians of the Chinese Academy of Sciences and Academy of Engineering. The full-time student number is over 27000, including about 10000 graduate students.

Because of SEU's reputation, many excellent high school students want to attend. In fact, only the very best students have the chance to enroll SEU. The school is highly selective. For example, only the top 4000 out of about 500000 in Jiangsu province are eligible to apply. Every student registers in SEU with a specified major. They can apply to change their major during the summer holiday before their second year, but the number is limited. Most bachelor programs in engineering in China take 4 years. At SEU, 150 credits are required for graduation. More than 90% of students graduate on time at the end of their 4th year at SEU.

There are three semesters per year at SEU as shown in Table 1. Many practical training courses are arranged in the short semester, such as advanced C++ programming, fundamental Electric and Electronic practice, fundamental of Mechanical fabrication, printed circuit board computer aided design (CAD), introduction to scientific writing, fundamentals of innovation and patent application, etc.

Table 1. Time schedule for academic year at SEU

Semester Name	Short Semester (1st semester)	Autumn Semester (2nd semester)	Spring Semester (3rd semester)
Typical Dates	20 August ~ 18 Sept.	20 Sept. ~ 20 Jan.	20 Feb. ~ 22 June
Total Time	4 weeks for course	16 weeks for course and 2 weeks for exams	16 weeks for course and 2 weeks for exams

At SEU, several laboratory centers, such as the electric and electronic laboratory center, the mechanical laboratory center, the physics laboratory center, were established before the year 2000. They are managed by the university and do not belong to one specified school. These separate Laboratory Centers offer fundamental laboratories for many Schools. With integrated input from the university to these centers, their experiment condition and maintenance are good. Most of them are also national demonstration laboratory centers where they serve as resources for other educators in China.

In addition to the specified curriculum, since 2003, all SEU students must complete two credits of "Extracurricular Research" as part of a university "Ke Wai" requirement. Students may choose to participate in Design Contests, the Scientific Research Training Program (SRTP), do research with faculty, or attend professional lectures. It has grown to be 69 design contests offered in SEU in 2011. SRTP and Design Contests will be described later in this paper. Each semester, SEU invites famous experts from universities, research institutions or companies to give lectures on campus describing recent technology developments. The students who attend must write a report on the lecture to receive credit.

With some instructions on SRTP by faculty members, more than 60% of SRTP projects now pass the final check, with about 15% regarded as excellent. Most of the contests inside SEU have no supervisors. Only less than 20% of applicants in design contests can get awards, which result

in credits. On average, students can get about 1~2 credits for successfully completing each SRTP and about 0.5~1.5 credits for each contest and 0.3~0.5 credits for each lecture report.

SEU School of Electronic Sciences and Engineering

The SEU School of Electronic Science and Engineering was founded in 1961as the Electronic Engineering Department. Now it consists of five professional research centers including the National AISC Design Engineering Center, MEMS Key Lab of Chinese Ministry of Education, Display Technology Engineering Center, etc. There are about 90 faculty members with 32 professors and 27 associate professors. There are about 550 undergraduate students and about 650 graduate students in this School. The major of Electronic Science and Engineering is regarded as one of the best majors at SEU and was ranked No.6 among all Chinese universities in 2007. It is a popular major with the enrollment of first year students in this major higher than the average for SEU. Also, each year there are about 15-20 students from other Schools who join this School after their first year at SEU by passing the required examinations. Typical class sizes are 36 and each year about 180 students graduate with their bachelor's degree in this major.

The curriculum for the bachelor of science (BS) degree in Electronic Science and Engineering contains five parts as summarized in Table 2. Courses in the first three categories are required. In the Professional Courses category, students choose twenty credits from among many elective offerings. In the fifth category, the Practical Courses are mostly offered by the School but the University Requirements apply to all students at SEU. Students choose from many options for satisfying these University Requirements. The Extracurricular Research is described later in this paper.

Table 2. Overview of SEU Curriculum for BS in Electronic Science and Engineering

	Category	**Main Courses**
1	General Fundamental Courses	Math, Physics, Foreign Language, Philosophy, Programming Language, and other general courses.
2	Discipline Fundamental Courses	Electric Circuit Design, Logic Circuit Design, Analog Circuit Design, Signals and Linear System, Computer Structure and its Interfaces, Electromagnetic Fields
3	Major Principal Courses	Solid-state Physics, Semiconductor Physics, Modern Optics, Physical Photo-electronics, Introduction to VLSI, Electronic Devices, etc.
4	Professional Courses	Introduction to Optic-network, Nano-material and Devices, Optic-fiber Communication, Vacuum Technology, Display Technology, Introduction to IC fabrication, Introduction to MEMS, Embedded System Design, Video Processing Fundamental, Analog Integrated Circuit, Digital Integrated Circuit, Thin-film Technology, etc.
5	Practical Courses	Advanced C++ programming, Printed Circuit Board CAD, Electronic System Design, Introduction to Scientific Writing, Research and Engineering Practice, etc.
	University Requirements	Extracurricular Research, Cultural Education Practice, etc.

University of San Diego (USD)
USD is a private, Roman Catholic school in San Diego, CA. It was founded in 1949 and is ranked by U.S. News and World Report as #97 among National Universities in the U.S. There is a College of Arts and Sciences, and Schools of Law, Nursing, Education, Peace Studies and Business. The overall enrollment is about 8000 students with about 5000 undergraduates. There are 402 full time faculty and 443 part time faculty. USD has one campus that covers a total area of 180 acres.

There are two main semesters each year at USD, which are shown in Table 3. There is a summer semester when students can choose to take classes but this is not commonly done. Given the high cost of USD, more students who want to take summer classes take them at less expensive community colleges. As is typical in the U.S., there are some holidays throughout the semesters including a short fall break, Thanksgiving break, and a week-long spring break in the Spring. An additional holiday is also given for Easter.

Table 3. Time schedule for academic year at USD

Semester Name	Fall Semester	Spring Semester
Typical Dates	5 September ~ 20 December	20 January ~ 20 May
Total Time	14 weeks for course and 2 weeks for exams	14 weeks for course and 2 weeks for exams

USD EE Program
The USD Department of Engineering is housed with the School of Business and includes programs in Electrical, Mechanical, and Industrial and Systems Engineering. There are 15 faculty in the department. The department graduates about 40 engineers per year and has no graduate program. It is ranked #27 by U.S. News and World Report among Undergraduate Engineering programs without doctorates. All three programs are ABET accredited.

Undergraduate students are not permitted to enter USD with a declared major. However, upon entering they can indicate an interest in engineering and begin taking engineering courses. The curriculum for the first two years is the same for all engineering programs so that students can take basic courses in all three disciplines and make an informed choice on their major by the end of the sophomore year.

The Electrical Engineering (EE) program at USD began in the 1980s and was first accredited by ABET in 1990. The EE program has six faculty members and graduates about 15 students each year. The standard curriculum includes 147 units spread over nine semesters (4.5 years). Each student receives a unique BS/BA degree in electrical engineering. The engineering students take the same liberal arts requirements as all other students on campus. In most U.S. universities, engineering students take fewer liberal arts courses and thus have standard patterns of 4 years. At USD, about half of the students graduate in 4.5 years, one-quarter in four years (if they came in with advanced placement credit and took summer courses) and the other one-quarter in five years (including students in the Navy Reserve Officer Training Core (NROTC) who have additional coursework requirements). The unique BS/BA reflects the USD Engineering Department's commitment to have students experience "extensive technical education and the

USD emphasis on a broad liberal education."[1] The students in EE are about 80% men and 20% women and most choose to go to industry after graduation.

An overview of the USD EE curriculum is shown in Table 4. Note that the Core Curriculum Requirements are set by the university overall. The EE program specifically requires economics and public speaking as social science courses. All EE students receive a minor in mathematics. Students can also choose to minor in other disciplines with computer science being the most popular.

Table 4. Overview of USD Curriculum for BS/BA in Electrical Engineering

	Category	Main Courses
1	Mathematics and Basic Science (33-39 units)	Math, Physics, Chemistry, Life Science
2	Engineering Core (19-28 units)	Introduction to Engineering Design (2 courses), Circuits, Computer programming, Materials Science, Probability and Statistics, Statics, Thermodynamics
3	Electrical/Electronics Engineering (47 units)	Analog Electronics (2 courses), Digital Electronics (2 courses), Signals and Systems, Electrical Power, Applied Electromagnetics, Control Systems, Communication Principles and Circuits, Senior Design (2 courses), EE Electives (2 courses)
4	Core Curriculum (39 units)	Public Speaking, Economics, Foreign Language, Philosophy (2 courses), Engineering Ethics, Economics, Religion (3 courses), Humanities, English, Literature, Diversity

Laboratories

Laboratories play an important role in the required curriculum for both institutions. However, the logistics of these laboratories vary.

SEU: Laboratory Center

At SEU, there is a separate Electric and Electronic Laboratory Center that offers related laboratory courses for many Schools including the School of Electronic Science and Engineering. This is a national center and serves as a demonstration facility for other educators across China. It contains more than 5000 m^2 of facilities including standard EE equipment such as oscilloscopes, DC power supplies, multimeters, function generators, etc.

In fact, all the laboratories for the discipline fundamental courses in this School are provided by that laboratory center. There is one laboratory course for each corresponding discipline fundamental course. The instructors for the lecture and laboratory courses are different. Usually the teachers for the lecture course are from the school, and the teachers for the lab course are from the laboratory center. Most of the separate laboratory courses are one-credit and have eight to sixteen experiments. Students work individually in the laboratories.

There are two ways to carry out these laboratories. One is with a scheduled time and lab room. Another is that the experiment time can be reserved over the university network. Students can go

to the lab center during their reserved time with their university ID cards. The experiment location is automatically arranged by the network. Most of the experimental results can also be recorded automatically. Now most lab courses use both of these ways. The first few labs are done with the scheduled time and room with an instructor. After that, the later labs are done by the students at a time that is suitable for them. There is always an instructor available. For most of these lab courses, students are asked to do the experiment 3 hours once per week. They should learn the experiment in advance and finish it independently.

Because there are different teachers for the lecture course and the lab course, some scheduling have occurred. The lecture and lab instructors are encouraged to discuss often and the lab course usually starts in week 6 of the 16-week semester, when the students have already prepared enough basic knowledge for experiments.

The laboratories for the major principal courses and the professional courses are organized by the School itself. All of these laboratories are integrated into the courses. Two teaching-specified labs have been constructed in this School, the photo-electronics lab and the embedded systems design lab. Most of the other laboratories are carried out in the research lab of the course instructor. The experiments or design work is usually carried out with a group of 2~3 students.

Currently, more design experiments are encouraged since design was considered to be an area that needed improvement. Another goal at SEU is to encourage more teachers to gain experience in industry so that can provide better hands-on engineering instruction for the students.

The School also provides funding to support professors to improve their professional courses' laboratories or to make special experiment platforms. The School also has established and maintains an undergraduate creative lab, which is an important place for students to do their practical training out of class.

USD: Integrated into courses

At USD, the laboratories are integrated into individual courses. There are two introductory courses with labs in the first year for all engineering students. In the second year, there is one required EE course in Circuits and it has a lab. In the sophomore year, there are five required EE courses and four of them include a lab. In the senior year there are four required EE courses and three of them have a lab. In addition, the two-semester senior design sequence is focused on hands-on experiences. All of these laboratories are taught by faculty. There are no graduate students. These labs are offered every week for the entire semester. Students typically work in teams of two and receive one course credit hour for the lab so that a course with a lab becomes a four-unit course while courses with lecture only are three units. Ideally, the lecture and lab are taught by the same instructor. However, scheduling and faculty loads do not always allow this. However, there is only one group of faculty who teach all of the courses, unlike the lecture and laboratory faculty at SEU. Typically, these labs are expected to be completed in the scheduled three hours per week. Some labs include projects, which would extend over several weeks and necessitate the students working outside of class to complete them. Many instructors have students rotate lab partners so that they get a chance to work with different people and insure that all students develop a range of laboratory skills and not become dependent on each other.

There are three EE laboratories with standard equipment: oscilloscope, multimeter, DC power supply, function generator (AC) etc. A personal computer is provided at each station and includes technical software such as Electronics Workbench Multisim simulation software, Mathcad, Matlab, etc. as well as Microsoft Office for word processing and spreadsheets. The equipment is interfaced to the computer to allow for screen and data capture.

Strengths of each program
Lab Center
Dedicated faculty who only teach lab can develop expertise in this area and do more specific laboratory development. Pooling resources can provide for excellent facilities that are well maintained since there are staff hired for this purpose.

Challenges for this approach include mismatch between the lecture and lab particularly when the instructors are not familiar with the other courses.

Integrated Approach
When the integrated approach works well, students can clearly see the connections between the content they learn in the lecture and the activities they do in the lab. This is beneficial for their learning. If the same instructor teaches lecture and lab, he/she can facilitate those connections. Ongoing improvements in the course can impact both lecture and lab.

Challenges for the integrated approach include difficulty in scheduling many sections and coordinating instructors. Also some faculty may not be equally comfortable or skilled at teaching both lecture and lab.

Design Experiences
Both institutions offer students a significant yearlong design experiences. Students work in small teams for both but there is considerable variation in the approaches.

SEU: SRTP and Design Contests
Students in the School of Electronic Science and Engineering are very active in the Extracurricular Research activities going beyond the required 2 units. More than 90% of the students participate in SRTP and more than 60% participate in design contests. In 2011, the collected data shows that the average number of credits for practical activities outside of class for students in this School is greater than 4. The distribution of how they achieve these credits is shown in Figure 1. About 1/3 of the credits are from SRTP, another 1/3 from contests, the others are from lecture reports, independent research project, etc. Some excellent student designs from SRTP and contests have been encouraged to become conference presentations, journal publications and patent applications.

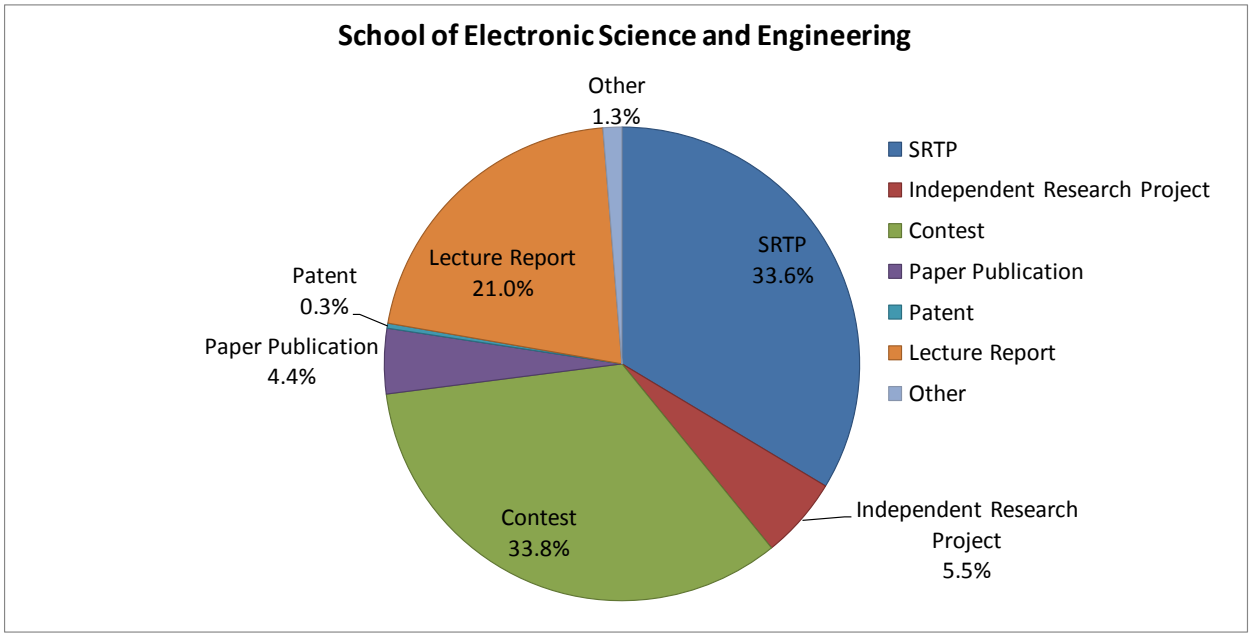

Figure 1. Practical credits distribution for the School of Electronic Science and Engineering

In most SRTP and design contests, students themselves are asked to propose ideas with detailed targets and a research approach. Now more proposals from industry or national scientific research projects are introduced to the students before the SRTP applications are due. If the students' SRTP applications are successful, they can start their research with funding from 600 RMB to 20000 RMB each from the university or their school. If their application is unsuccessful, they do not receive funding but they can still do the project as an independent research project and receive Extracurricular Research credit if they do well. If the students' contest applications are successful, they can start the contest design with a provided design platform. Usually, a student group for SRTP consists of 3~5 persons and that for a contest consists of 3 persons. Students typically do these projects as juniors and there are also some sophomores involved. Students typically work on these projects for about a year.

Reports are required for design contests and SRTP projects. Most Design Contests also require a physical demonstration while SRTP projects require a presentation for a faculty panel with about half of the projects having a prototype. Design contests only count towards graduation if a student is awarded first, second or third prize. SRTP projects are graded and the amount of credit depends on how well the project does in overall competition with more credit at the national level.

This School organizes the programmable logic device (PLD) design contest and embedded systems design contest at SEU every year. Figure 2 shows some pictures from this event. A student team is shown demonstrating their project on the left and on the right, the award-winning teams present their work as posters before the award ceremony.

Figure 2. Demonstration (left) and exhibition (right) in the PLD design contest at SEU

Current ideas to further improve the design experience at SEU are (1) rules to prevent some students from participating in too many SRTPs or contests that negatively impact their basic course study, (2) more instructions on more marketable design, and (3) more instructions on formal technical documents writing to summarize the design.

USD: Capstone Design

In the U.S., capstone design courses fill a critically important role in the curriculum bridging school and the workplace. They are essential for meeting ABET accreditation requirements and have been a topic of research for many years.[2, 3, 4] At USD, students are required to complete a two-semester senior design as part of their required curriculum. Ideas come from students, industry, faculty or the university. Students must produce a physical prototype to meet specifications. Examples of student projects can be found at http://www.sandiego.edu/engineering/current/seniorprojects/ Students must raise the funds needed to complete their projects. Many student groups obtain funding from the USD student government, Associated Students, which has a competitive research grant process. Other groups have received funding from industry or other offices within the university such as the USD Office of Sustainability.

In these courses, there is a considerable amount of writing. Students must do several drafts and evaluation of each other's written work to fulfill a university writing requirement. They prepare written and oral presentations at the proposal, preliminary design review, critical design review, and final design review stages. These are reviewed by peers, faculty, and industry. Students also evaluate their peers using the Comprehensive Assessment of Team Member Effectiveness (CATME).[5] The instructor gives each student an individual grade based on all of this input. Not all students on the team receive the same grade.

Usually, these projects involve only EE students although there have been some joint Mechanical Engineering (ME)-EE projects. These multidisciplinary projects are encouraged and can result in high quality projects, as students are able to use different technical skills. However, the logistics of these projects are more challenging for faculty and students.

These courses focus on many ABET accreditation outcomes which are challenging to incorporate in other courses such as lifelong learning, design, teamwork, and contemporary issues. In 2010-2011, the projects at USD had a theme of sustainability to insure that this

important but often overlooked outcome is explored by students.[6] Incorporating sustainability fits well with the vision of the University of San Diego (USD), a Roman Catholic institution, to educate "globally competent, ethical leaders working and serving in our complex and changing world".[7]

Strengths of each program

SEU

Students who are successful at SRTP or Design Contests learn to work on their own, without extensive guidance from faculty. This helps them develop as autonomous lifelong learners.[8, 9] Students learn about how to work with team. In SRTP projects, students may work together for an entire year. Highly successful teams can leverage these activities to produce journal publications and/or patents. Students can work on several of these projects over the course of their time at SEU.

USD

Every student is required to participate in this yearlong design experience that covers the entire design sequence from proposal through final design review. Effective oral and written communication are emphasized. Students learn more about how to work with team for an extended period of time, two semesters. Industry representatives are involved in reviewing presentations and reports and serve as mentors for some projects. Students bring together the knowledge gained during the engineering curriculum in this capstone experience in their senior year. To be successful, students must take ownership of their project and go beyond what is taught. This helps them develop as autonomous lifelong learners.

Summary

The cases of the Electronic Sciences and Engineering School at Southeast University in China and the Electrical Engineering program at the University of San Diego in the U.S.A. have been considered. These are two very different programs in terms of institutional context, size, and curricula. Both are committed to providing practical training experiences for their students. Each program's approach has its strengths. These can provide ideas of best practices that can be learned from these different institutions in different cultural contexts for other engineering educators across the world.

Acknowledgements

S. M. Lord would like to thank all those at USD and SEU who made her sabbatical time at SEU in Spring 2012 possible.

References

[1] Unique features of USD's Engineering Programs available at http://www.sandiego.edu/engineering/ Last Accessed 14 May 2012.

[2] McKenzie, L. J., M. S. Trevisan, D. C. Davis, and S. W. Beyerlein, "Capstone Design Courses and Assessment: A National Study," *Proceedings of the 2004 ASEE Annual Conference*, Salt Lake City, UT, June 2004.

[3] Dutson, A. J., R. H. Todd, S. P. Magleby, and C. D. Sorensen, "A Review of Literature on Teaching Engineering Design Through Project-Oriented Capstone Courses," *Journal of Engineering Education*, vol. 86, no. 1, 1997, pp. 17-28.

[4] Todd, R. H., S. P. Magleby, C. D. Sorenson, B. R. Swan, and D. K. Anthony, "A Survey of Capstone Engineering Courses in North America," *Journal of Engineering Education*, vol. 84, no. 2, 1995, pp. 165-174.

[5] Ohland, M. W., H. R. Pomeranz, & H. W. Feinstein, "The comprehensive assessment of team member effectiveness: A new peer evaluation instrument," *Proceedings of the 2007 ASEE Conference*, Chicago, IL, June 2006.

[6] Lord, S. M. and C. N. Pateros, "Sustainability and Senior Design at the University of San Diego," *Proceedings of the 2011 Frontiers in Education Conference*, Rapid City, South Dakota, October 2011.

[7] Vision "The University of San Diego is a nationally preeminent Catholic university known for educating students who are globally competent, ethical leaders working and serving in our complex and changing world." available at http://www.sandiego.edu/about/mission_and_vision.php Last Accessed 14 May 2012.

[8] Ryan, R. M. and E. L. Deci, "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being," *American Psychologist*, vol. 55, no. 1, pp. 68-78, 2000.

[9] Deci, E. L., *Why we do what we do: the dynamics of personal autonomy*, New York: Putnam's Sons, 1995.