AC 2011-2664: INDUSTRY-BASED PROJECTS AND PREPARING ENGINEERS FOR THE 21ST CENTURY WORKFORCE

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Karen Wosczyna-Birch, a national award winning Professor of Chemistry, is the statewide director for Connecticut's College of Technology, which includes all 12 Connecticut community colleges, six universities and partner high schools including the technical high school system. She is also the executive director of the Regional Center for Next Generation Manufacturing, a National Science Funded Advanced Technology Center, where she provides leadership for the advancement of manufacturing and related engineering and technologies. Karen also has expertise in providing professional development that includes strategies for the engagement and persistence of under represented populations in STEM disciplines. She has received awards from several organizations including the American Association for University Women (AAUW) for her work in addressing the need to increase females in engineering and technology fields as well as for her work in educating students with the skills required for the 21st century workforce.

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Industry Based Projects and Preparing Engineers for the 21st Century Workforce

Introduction

At the October 2005 National Science Foundation Advanced Technology Education (NSF-ATE) Annual Meeting, Dr. Renee S. Lerche, an executive at The Ford Motor Company and a national authority on global leadership and workforce development, said that, *"employers need workers with deep experience with scientific inquiry, design and problem solving solutions."* Students must be able to apply what they learn to real world problems that are relevant and meaningful. In particular, research has documented that contextual learning, hands-on or problem based learning that engages learners, is significantly more effective than traditional lecturing, especially for women and minority populations[1]. The National Science Foundation (NSF) Board presented an extensive report during their 2007 meeting that addressed the key challenges necessary to change and transform engineering and technology education. Basic engineering skills and experience provided by engineers in emerging countries at a significantly lower cost due to lower wages, put U.S. companies at a significant competitive disadvantage. To tackle this growing problem, U.S. engineering and technology education should focus on improving interrelationships including not only traditional engineering and technology, but also human and environmental factors. The main challenge is to educate engineers with strong entrepreneurial, leadership and innovative skills within a social and business context[2].

Problem Based Learning (PBL) is an instructional approach that challenges students to "learn how to learn" through collaborative real world problem solving. PBL is based on the constructivist model of learning, whose major tenets are: ***(1)*** learning and understanding are directly related to the environment or context in which learning occurs, ***(2)*** cognitive conflict or "puzzlement" is the stimulus for learning and determines the organization and nature of what is learned, and ***(3)*** social learning environments stimulate alternative views and generate additional information against which the viability of comprehension can be tested[3]. Research demonstrates that when compared to traditional lecture-based instruction, PBL improves student understanding and retention of ideas, critical thinking, interpersonal and problem-solving skills, as well as the ability to adapt their learning to new situations and skills deemed critical to lifelong learning[3,4]. PBL teaches students the process of solving real-world, open-ended problems with multiple solutions.

Figure 1 - Constructive Learning Cycle

The Life Support and Sustainable Living Program (LSSL) is a National Science Foundation Advanced Technology Education (NSF-ATE) funded program that has been successful in helping to prepare Connecticut engineers and technologists with both technology and professional skills that are required to meet today's 21st Century workforce demands. LSSL Program project activities continue to address the recruitment and retention of underrepresented populations by implementing recruitment strategies that focus on the societal aspects of the LSSL Program projects. Many of the Program's projects deal directly with improving life on this planet. In addition, the LSSL Program continues to implement recruitment and retention strategies identified in the National Institute for Women in Trades, Technology and Sciences (IWITTS), an NSF funded project, which addressed gender equity and the recruitment and

retention of underrepresented populations in non-traditional fields. The structure of the LSSL Program has impacted not only students enrolled in the Program but also educators and industry partnerships through innovative education techniques, particularly the integration of professional/soft skills with PBL.

LSSL Program project teams have been functioning effectively, since 2007, producing corporate level project development since 2007. Lou Manzione, Dean of CETA at the University of Hartford stated *"As a former Executive Director at Bell Labs, I can attest that the student participants in the LSSL Program are producing work that I would expect to see from seasoned industry professionals. The professional skills learned add an entirely new dimension to the skill set that our graduates take into the workplace."*

Interdisciplinary, cross-institutional and self-directed teams have resulted in significant synergy between university and community college students as a result of a blend of respected disciplines including engineering and technological skill sets. What differentiates the LSSL Program from other PBL initiatives is that it prepares students to not only learn critical thinking, entrepreneurial and relevant technical skills, but to also enter the workforce with professional skills including teamwork (including virtual teamwork), leadership, project planning, understanding behavioral diversity, communication skills and social networking experiences. In addition, academic partnerships with industry, medical hospitals and government entities like NASA, the Department of Homeland Security and the U.S. Coast Guard using real world applications, have been proven to engage diverse populations, in particular women and minorities. Because of the reputation developed by the LSSL Program, start-up entrepreneurs have solicited the LSSL Program to have student participants assist in the product/solution development for their companies.

The LSSL Program teams are inter-institutional as well as interdisciplinary and capitalize on the synergy between the theoretical knowledge of university faculty and students, and the requisite hands-on technical skills of community college students and faculty. An important outcome of the LSSL Program is that the university students teach their skills to the community college students and visa-versa. In addition, community college students are mentored by their university student peers, increasing their success in the pursuit of a B.S. degree. In fact, 99% of the community college participants have successfully matriculated into various university engineering related programs.

The LSSL Program focuses on mechanical engineering technology with applications in Aerospace, Aeronautics and Biomechanics, using real-world industry-driven projects. Projects include the development of a portable life support system, geostationary habitat heat rejection system, lunar habitat life support systems, water cooled condensers for power plants, combined cycle power plant, greenhouse gas emissions from natural gas sweetening, dental surgery device, environmental friendly navigation system, various space suit and space capsule initiatives, sustainable/smart traffic signal control system, high efficiency diesel engine, a device that will enable print material to associate with rich media and web-based contents, proprietary wheelchair and alternative energy initiatives.

Fall Semester: Problem-Case-Based Learning Recruiting and Projects

The Executive and Assistant Directors meet with potential industry partners throughout the year to solicit projects with life support and sustainable living objectives, which provide opportunities for students in problem solving, innovation and creativity as well as the ability to work in a team environment and interface with industry leaders.

Student recruitment for the LSSL Program begins in October and continues through the second week of December. Program Directors make presentations at various community colleges and universities to encourage involvement among potential participants for the LSSL Program's Winter Intersession.

As a result, LSSL Program participants are able to use humanistic, real-world industry-driven problem scenarios linked to course content, problem solving strategies, as well as assessment and evaluation strategies, online resources such as Moodle, video conferencing and group-ware such as Web-Ex.

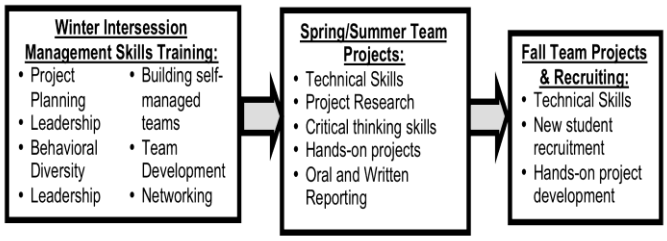

Figure 2: LSSL Program Student Objectives

Spring/Summer Intersession Projects

At the beginning of the spring semester, the student teams start working on their PBL industry projects. A major outcome of this proposal is the ability to engage a diverse population of students including women, minority populations and veterans. This strengthens the synergy that continues to impact students and educators participating in the LSSL Program. At the end of the spring semester, each team must submit a final report that not only outlines the progress of the project but also provides an outline for new groups to continue to work on the initiative. Faculty developed PBL Modules, based on LSSL Program projects, will eventually be disseminated to high school teachers and community college faculty for integration into classroom curriculum. In addition, these modules will be integrated into comprehensive outreach activities targeting high priority high school districts.

The LSSL Program, in partnership with industry and research institutions, have and will create a series of multimedia-based PBL case studies and instructional resource materials, covering a range of applications in mechanical engineering technology. The multimedia case studies focus on actual real-world problems encountered by partner companies, such as NASA, and research institutions, as well as the process by which those problems were solved. Unlike traditional case studies, where students just are passive observers, the PBL case studies actively engage the students in the problem-solving process through interdisciplinary collaborative teams.

Methodology

The LSSL Program recruits students from Connecticut community colleges and universities for the purpose of conducting research initiated by select Connecticut and U.S. Government organizations. These organizations provide access to science, engineering and business experts who work as mentors for the students. The projects focus on real world research projects that address life support and sustainable living challenges facing America and the rest of the world today.

During the 15-week program the students exercise their technical and engineering skills as well as learning essential professional skills including how to function in self-managed teams as well as project planning and management. The student teams submit monthly progress and a comprehensive report at the conclusion of the program.

The 2011 LSSL Program, which began on January 3, 2011 allowed students to select from 12 projects. Industry representatives were asked to present their ideas and needs to all LSSL Program student participants. Teams were organized based on their interest and capabilities and ranged from 3 to 8 members per team. Tables 1 and 1a show the projects along with the technical sponsor.

Table 1. 2011 LSSL Program Projects with Mentoring Organization

Project Name	Mentoring Organization
Dental Surgery Device	ISIS Technologies
High Efficiency Diesel Engine	LiquidPiston, Inc.
Heat Rejection Sys-Geostationary Habitat	NASA
Lunar Habitat	NASA
Environmental Friendly Navigation System	U.S. Department of Energy
Plastic into Oil	University of Hartford
Portable Life Support System for Mars	NASA
Sustainable/Smart Traffic Control Systems	CT Dept of Transportation
Water Cooled Condenser	U.S. Department of Energy
Solo Transfer Wheelchair	Structured Solutions II, LLC
Wireless Dermascope	Eye Ear IT, LLC
"Magic Flashlight"	Eye Ear IT, LLC

Table 1a. 2010 LSSL Program Projects with Mentoring Organization

Project Name	Mentoring Organization
Bowel Sounds in Premature Infants	CT Children's Medical Center
Greenhouse Gas Capture	U.S. Department of Energy
Ground Source Heat Pump	University of Hartford
Hydrogen Fuel Station Infrastructure	CT Dept of Transportation
Ion Flow	United Technologies
Lunar Habitat	NASA
Water Flow and Heat Transfer (Space Suit)	NASA
Solo Transfer Wheelchair	Structured Solutions II, LLC
Portable Life Support System	NASA
Sustainable Traffic Control Systems	CT Dept of Public Works
Wind Power for Afghanistan	Engineers Without Borders

As part of ongoing research investigations, many project teams make field trips to industrial sites in order to gather data. There were some notable trips made in 2010 that allowed participants to fully understand how their research and/or products that they are developing would be utilized.

Solo Transfer Wheelchair – The goal of this project was to design and fabricate a proof of concept patient to bed wheel chair. This team interviewed wheelchair experts at Gaylord and Danbury Hospitals along with faculty at Quinnipiac University. This project will result in the commercial production of a wheel chair some time in 2011 and several patents by some of the students are expected.

Hydrogen Fuel Station Infrastructure – This team visited Proton Energy Systems, Wallingford, CT. They got to view Proton's home hydrogen fueling station utilizing their water electrolysis technology which eliminates the large-scale storage and long-distance transportation pieces of the supply chain by directly fueling the vehicle where the hydrogen is being generated.

Sustainable Traffic Control Systems – This team spent several hours at the Department of Public Works Traffic Center. The Center contained multiple cameras and computers where students could see and control the lights at all the intersections in Hartford, CT. These computers provided access to all of the timing information for the lights. From one push of a button students could change the color of the lights or summon the pedestrian crossing lights to come up. Valuable insight in support of the project was realized.

Wind Power for Afghanistan – Resources, demand and options for energy supply were evaluated. This team visited the Boston Science Museum in order to gain a better understanding on the state of wind power technologies today. Various turbines were investigated to determine best fit based on projected demands.

Results Life Support and Sustainable Living Program (LSSL) student participants evaluated the "Course", the "Instructor" and the "Student Effort" (Figure 3). The questions and participating responses are documented along with the corresponding student scores. Responses for all of the student evaluation questions were all "strongly in favor" of the LSSL Program. For this report, the Likert scale was used to assess the response to evaluation questions. The student responses were ranked from scores of 1.0 – 5.0 ranging from "strongly disagrees" to "strongly agrees", respectively. Table one describes the range of the interval, student response option and the value of the interval.

Table 2: Likert Scale "Interval", "Option" and "Value of Interval" for student evaluation responses.

Interval	Option	Value of Interval
1.00-1.80	Strongly Disagree	Strongly Against
1.81-2.60	Disagree	
2.61-3.40	Undecided	Not Sure
3.41-4.20	Agree	Strongly in Favor
4.21-5.00	Strongly Agree	

The highest rated response for the surveys were for the following statements "*the course provided useful information and/or skills*", " *The instrucutor were enthusatic about the subject*

they taught," and "I *would recommend this course to other students*" for the course, instructor and student evaluation respectively.

The following tables provide the summative evaluation for the LSSL Programs held in 2008, 2009 and 2010.

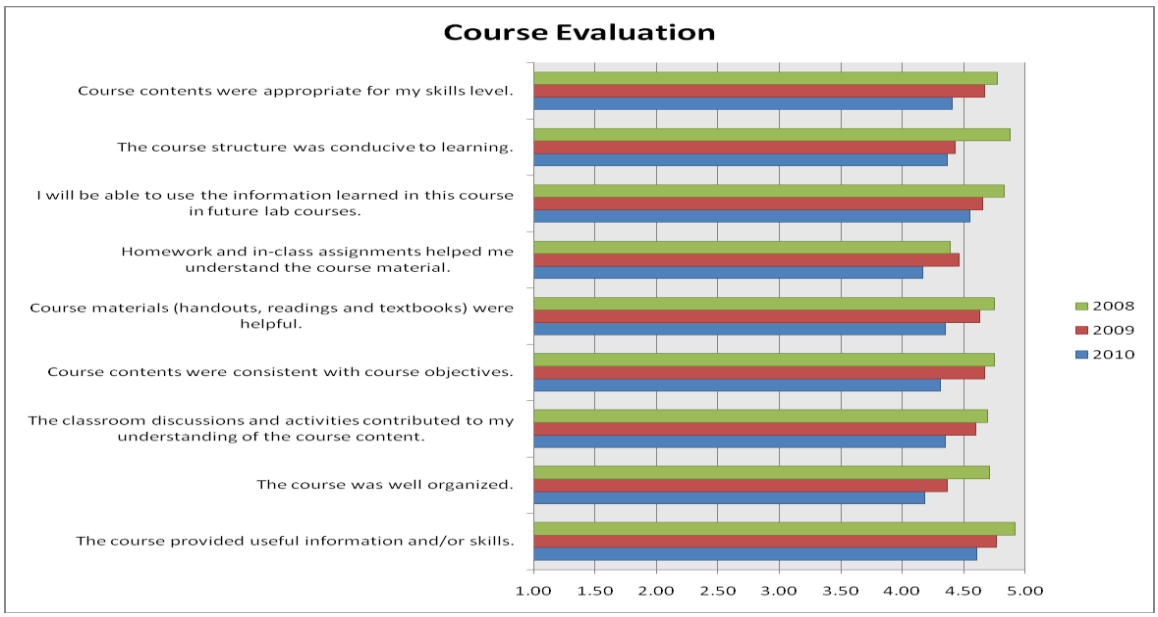

Figure 3: Course evaluation of students participating in the LSSL program from 2008-2010

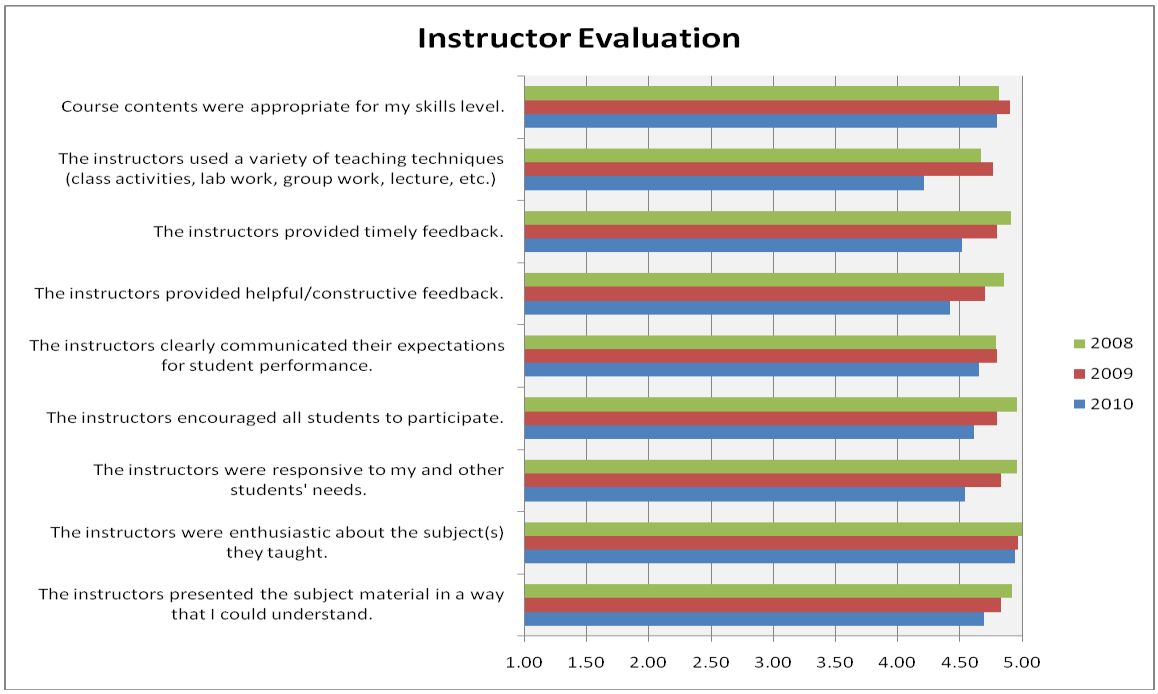

Figure 4: Evaluation of the Instructor 2008-2010

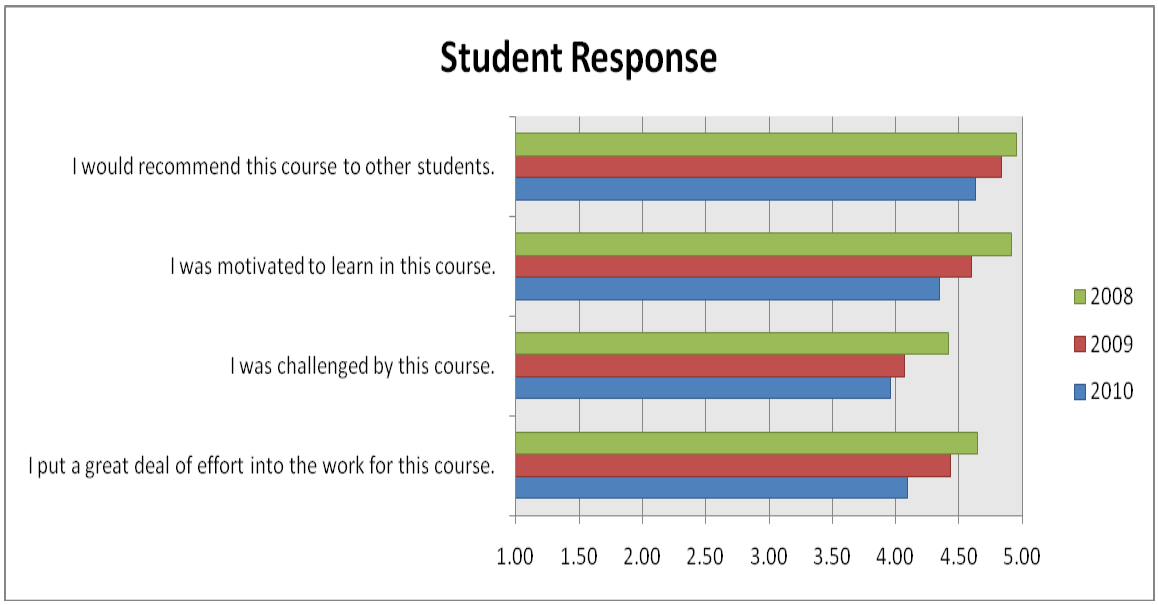

Figure 5: Evaluation of student response 2008-2010

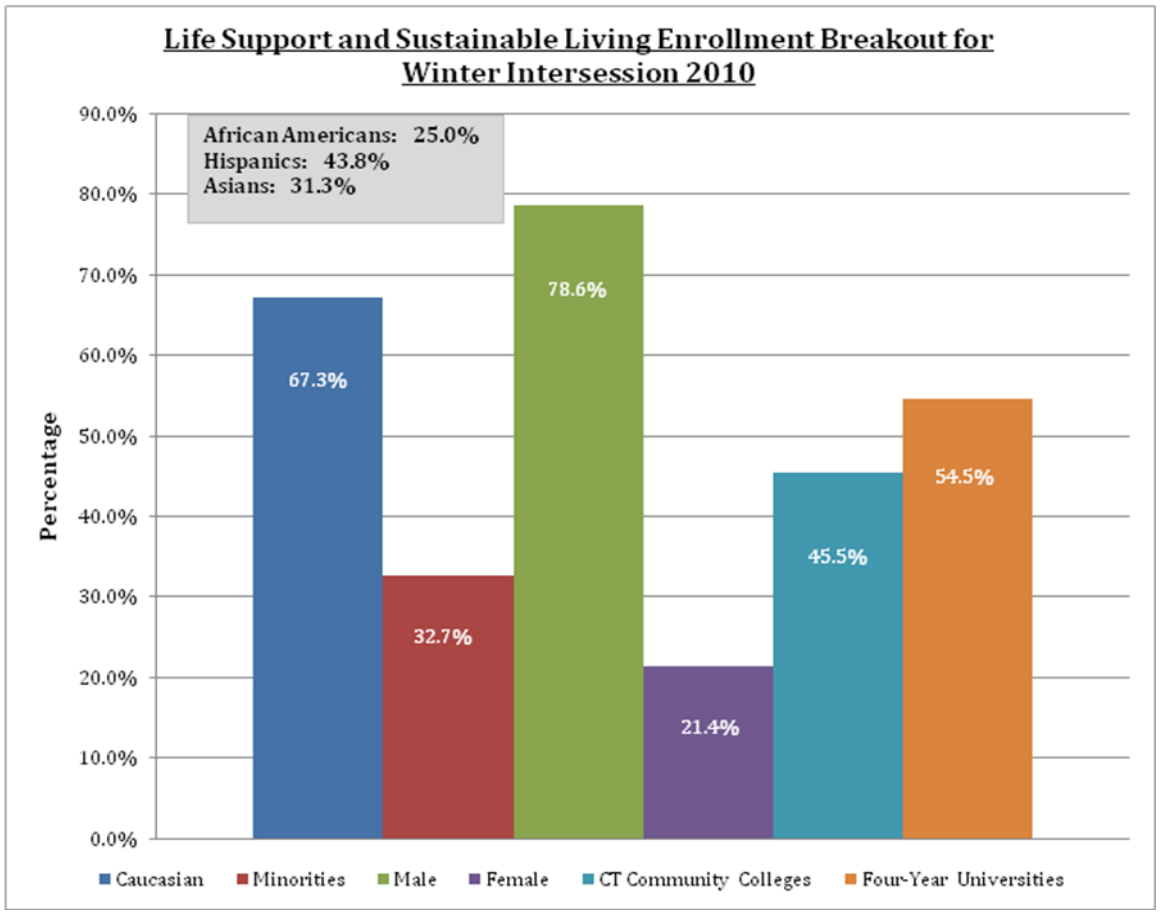

Figure 6: Enrollment for winter intersession 2010 (25% African American, 44 Hispanic, 33% Asian)

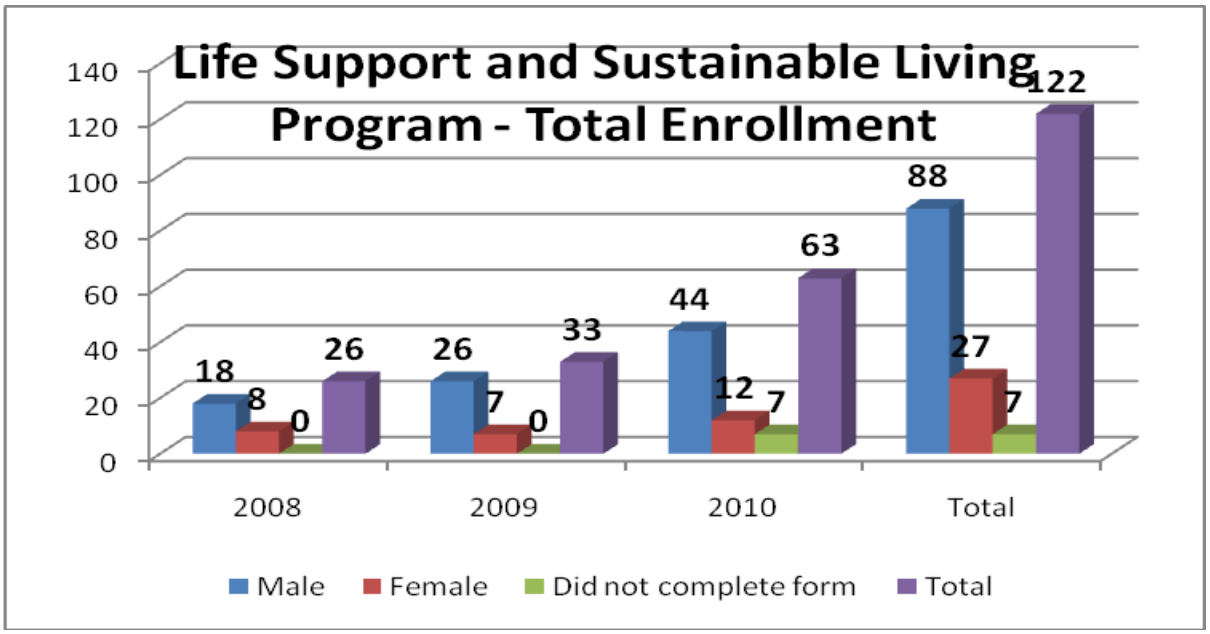

Figure 7: Total LSSL Program Enrollment 2008 through 2010

To date, the LSSL Program has accomplished the following:

- The LSSL Program has grown from 18 students to the current level of 63 student participants.
- A comprehensive and multi-color **marketing and recruitment package** with inserts for each project was developed to target recruiting female and underrepresented populations.
- An LSSL Program **website** was developed to disseminate program and project information as well as to enhance recruitment.
- As a recruitment and retention strategy, as well as steps to institutionalize the curricula and sustain the program, two of the lead community college partners, awarded **three (3) academic college credits** for students who completed the program.
- Students presented professional presentations on their projects to key stakeholders including NSF and NASA representatives, industry partners, as well as all senior personnel from all participating community colleges and universities, resulting in in-kind and direct funds from industry, medical centers and NASA to continue to support the projects.
- Two student participants have published technical papers in engineering/technology journals.
- **Two PBL learning modules with video clips**, *Support of Homeland Security with Helicopter-Based Pod System* and the *Apnea Monitor for Premature Infants*, were developed as case studies and disseminated to community college faculty and high school teachers**.**
- Eight (8) students are named in a **pending patent** relating to the development of a special needs wheelchair for severely disabled patients.
- **Three (3) professional papers** on the LSSL Program have been accepted for publication. All three (3) papers have been presented at various venues and at various times.
    1) "Problem based learning initiative in collaboration with the CT College of Technology's Center for Life Support and Sustainable Living, American Society for Mechanical Engineers International Mechanical Engineering Congress and Exposition, (2008). IMECE2008-66229

2) "Integrating Professional Skills into the 21st Century Engineering and Technical Curriculum," American Society for Mechanical Engineers International Mechanical Engineering Congress and Exposition, (2008). IMECE2008-68811
3) Robotics on Water. *The NSTA Summer Journal 2010, pp. 49 – pp. 52, (July* 2010).

- Three (3) **week-long (5 day) teachers' workshops** were held at the United Stated Coast Guard Academy in New London, CT. Teachers were trained in methodologies and pedagogies developed as part of the LSSL Program. The *Apnea Monitor for Premature Infants* PBL Module was piloted as part of the workshop. The results of the program evaluations by the participants were outstanding. Newspaper articles, radio and television interviews have been produced featuring the program.
- Teachers from the summer workshops agreed to pilot test the Apnea Module at their institutions and evaluate its effectiveness on student learning and share their experiences with peers through the LSSL list-servs. They also agreed to pilot additional modules as they became available.

The LSSL Program has developed a strong collaborative relationship with the United States Coast Guard Academy who have co-sponsored and hosted the summer workshops for the past two (2) years with a commitment to host the teachers' program for two (2) more years. To date, over 75 high school teachers and community college faculty have been trained in the Program's best practices. Participating teachers have come from throughout the United States and Puerto Rico.

Faculty and students have been actively engaged in projects as well disseminating the results to peers, educators and their industry advisors. The achievements of the LSSL Program are exemplary and being recognized by the external mentors as a new model for educating our 21st Century workforce. In his plenary presentation for the LSSL Program workshop held at Tunxis Community College in July 2008, Dr. Eisenfeld, Chief Pediatrician, Connecticut Children's Medical Center and a lead industry collaborator for the LSSL Program pilot project stated:

> ***"The collaboration of community college and university students and faculty on the development of an apnea monitor for premature infants has created a synergy that I have not observed in education. The student teams are enthusiastic and professional...as a result of our partnerships; we now have several prototypes that are being patented … and several professional articles."***

Student interviews and testimonials corroborate Dr. Eisenfeld observation that the LSSL Program has had a transformative effect on students and faculty.

Conclusion

The LSSL Program has been successfully implemented, helping to prepare engineers and technologists with both technology and professional skills that are required to meet today's workforce demands. In addition, the proposed activities continue to address the recruitment and retention of underrepresented populations by specifically targeting females and minorities at 50% of the enrollment in the LSSL Program. The structure of the LSSL Program has impacted not only students enrolled in the program but also educators and industry partnerships through innovative education techniques.

[1] Perrenet, J.C., Bouhuijs, P.A.J., & Smits, J.G.M.M, "The Suitability of Problem-based Learning for Engineering Education: Theory and Practice", Teaching in Higher Education, 5 (3), 345-358, 2000.

[2] Johnson, J. The Case Files. http://www.thecasefiles.org/index.htm. Nashville State Community College. Due NSF# 0703167.

[3] Marstons, W. The Emotions of Normal People. International Library of Psychology. ISBN No. 0415210763. 1999.

[4] Collins, A., & Hastings, J., "Teaching teachers practice what you teach", Science and Children, 27, pp. 38-39, 1990.