

UNIVERSITY OF HAWAI‘I SYSTEM REPORT



REPORT TO THE 2010 LEGISLATURE

Report on a Comprehensive Approach to the
Teaching and Training of Engineering
at University of Hawai‘i Campuses Statewide

SR 105 SD1 (2009)

December 2009

University of Hawai'i
Report to the 2010 Legislature
In Response to SR105, SD 1

This report is in response to Senate Resolution 105, Senate Draft 1, of the Twenty-fifth Legislature in 2009, requesting that the University of Hawai'i System develop a comprehensive approach to the teaching and training of engineering at university campuses statewide, and to submit findings and recommendations to the Legislature before the Regular Session of 2010.

This report consists of two parts – one, a summary of efforts to examine the future of engineering education comprehensively across the University of Hawai'i System; and two, a report of our findings and preliminary recommendations. Discussions among the key stakeholders continue.

Background Summary

The University of Hawai'i strategic plan goals are articulated with the higher education and workforce needs of the state in the University of Hawai'i (UH) System *Strategic Outcomes and Performance Measures, 2008-2015*. One of these measures is to increase degrees in science, technology, engineering, and math (STEM) fields. The University met its 2009 goal of 1,732 STEM degrees by producing 1,733; however, it continues to evaluate current needs and develop strategies to more successfully produce the engineering graduates that Hawai'i needs while using resources effectively.

Since fall 2008, a number of broad based discussions have focused on engineering education. An Engineering Fall Summit, convened by the Dean of the University of Hawai'i at Mānoa (UHM) College of Engineering was held at the East West Center Conference Center on September 10, 2008, with delegates invited from all ten UH campuses, the UH System, and other organizations in the state and business communities.

Participants at the fall summit agreed to support a systemic effort across the entire UH statewide system, and identified, in rank order: 1) a need to develop online and distance learning capabilities that might support access for students on all islands to engineering and its prerequisite courses; 2) the necessity of developing a plan for engineering, engineering technology, and technology education across the entire UH system that is appropriately articulated among campuses in order to maximize efficient and effective use of limited resources while addressing statewide needs; and 3) a commitment to improve student retention, thus providing a stronger pipeline (AA and AS degrees) to the UHM College of Engineering and increasing the number of engineering graduates (BS, MS, and PhD).

The UH System Vice President for Academic Planning and Policy convened a group from the seven community colleges and the UHM College of Engineering (COE) on September 24, 2009, to review transfer data and to develop curricular, student support, and outreach strategies to increase the number of community college students who successfully transfer to the College of Engineering. Campuses identified critical bottlenecks for students transferring (e.g., calculus) to the Mānoa engineering program. Current efforts are aimed toward strengthening a pre-engineering community college curriculum, moving students through calculus more quickly and successfully, and working with high schools to promote math preparation and to recruit students interested in pre-engineering studies.

On December 1, 2009, deans from the UHM COE and University of Hawai'i at Hilo (UHH) College of Agriculture, Forestry, and Natural Resources Management, a faculty member from the UHH College of Pharmacy who was appointed as lead to explore engineering for UHH, and the UHH Vice Chancellor for Academic Affairs met with the UH System Vice President for Academic Planning and Policy to discuss engineering education at UH. UH Hilo's preliminary proposal was discussed, with subsequent discussion about partnering, sharing courses, and joint efforts. The State Legislature made appropriations to UHH for engineering planning (FY 2010) and program implementation (FY 2011) for a Bachelor of Science degree in applied engineering.

In addition to these activities aimed specifically at engineering education, the University, working with the DOE and P-20, initiated efforts in 2008 to focus on students' preparation in mathematics. Weak math skills have been identified repeatedly as a serious impediment for Hawai'i's students in both K-12 and higher education, particularly for students who plan to earn degrees in STEM fields. Engineering students in bachelor's degree programs are required to complete four semesters of calculus and, depending on the department, additional math courses in linear algebra or differential equations. Thus, incoming engineering students must have strong prior math preparation in order to enroll in required math courses and complete baccalaureate degree requirements.

Under the leadership of the UH System, the Hawai'i Department of Education (DOE), and Hawai'i P-20 Partnerships, three Math Summits (October 10, 2008; February 21, 2009; and October 3, 2009) were held during the 2008-09 academic year. The Math Summits were aimed to improve the math pipeline to career and college readiness for students, to align math courses between the DOE and UH and among the UH campuses so that students are able to transition more smoothly, and to prepare more qualified math teachers and instructors. DOE math teachers, UH faculty, and administrators reached agreements on innovations and specific action strategies that are currently being planned for implementation.

Findings

1) Engineering academic and workforce needs in the state of Hawai'i

The U.S. Department of Labor's Standard Occupational Classification (SOC) lists 17 engineering occupations, seven engineering technician occupations, and one engineering manager category. In addition, there are categories for software computer engineers (applications) and software computer engineers (systems). One occupation, geoscientists, includes an engineering geologist category as one type of geoscientist. The data below are from the EMSI *Complete Employment – 2nd Quarter 2009 v. 2* report for the state of Hawai'i and counties. Educational requirements are from the *Occupational Outlook Handbook 2008-09*.

Engineers

EMSI data for the 17 engineering occupations in the state of Hawai'i project 176 annual jobs to fill by 2015, with a range from 0 (marine engineers/naval architects) to 71 (civil engineers). The civil engineer classification is the only category with more than 50 annual jobs to fill by 2015. Engineering occupations require a bachelor's degree in engineering for most entry-level jobs.

When data is broken down by counties, the City and County of Honolulu has a projected 145 annual jobs to fill by 2015, including 58 for civil engineers.

For the County of Hawai'i, there are 11 estimated annual jobs to fill by 2015: civil engineers (5); computer hardware engineers (1); electrical engineers (2); electronics engineers, except computer (1); nuclear engineers (1); and all other engineers (1).

For the County of Maui, there are 11 estimated annual jobs to fill by 2015: civil engineers (5); computer hardware engineers (1); electrical engineers (2); electronics engineers, except computer (1); nuclear engineers (1); and all other engineers (1).

For the County of Kaua'i, there are five estimated annual jobs to fill by 2015: civil engineers (2); computer hardware engineers (1); electrical engineers (1); and electronics engineers, except computer (1).

Engineering Technicians

EMSI data for the engineering technician occupations in the state of Hawai'i project a total of 43 annual jobs to fill by 2015 for the state of Hawai'i, including civil engineering technicians (5); electrical and electronic engineering technicians (12); electro-mechanical technicians (3); environmental engineering technicians (2); industrial engineering technicians (9); mechanical engineering technicians (1); and engineering technicians, except drafters, all others (11). Most engineering technicians enter the job with an associate's degree.

When data is broken down by counties, the City and County of Honolulu is projected to have a total of 36 annual engineering technician jobs to fill by 2015. The County of Hawai'i's projection is 2 annual jobs to fill by 2015; the County of Maui's is 2; and the County of Kaua'i's is 1.

Engineering Managers

Statewide, there are an estimated 17 annual jobs to fill by 2015, including the City and County of Honolulu (12); County of Hawai'i (1); County of Maui (1); and County of Kaua'i (1). Most engineering managers have a degree plus work experience.

Other Engineering Occupations

Computer software engineers (applications or systems) are another classification. Statewide, there are 42 estimated annual jobs to fill by 2015 for computer software engineers (applications) and 19 estimated annual jobs to fill by 2015 for computer software engineers (systems software). Most of these jobs (37 software applications and 16 systems software) are projected in the City and County of Honolulu. These jobs require bachelor's degrees.

The Geoscientist occupations include engineering geologists. Nine annual jobs to fill by 2015 are projected statewide for all geoscientists, but data is not broken down to show how many of these might be in the engineering geologist category. A master's degree is required for entry level jobs.

2) Existing engineering education & facilities on neighbor islands

The University of Hawai'i at Mānoa offers the following degree programs in engineering:

- BS/MS/PhD in Civil and Environmental Engineering
- BS/MS/PhD in Mechanical Engineering
- BS/MS/PhD in Electrical Engineering
- BS/MS in Biological Engineering
- MS/PhD in Ocean and Resources Engineering

Enrollments in the fall semesters from 2003 to 2007 ranged from 947 to 1,070 with an average of 1,017 for each fall semester. Earned BS in engineering and bioengineering degrees from 2003-04 to 2007-08 totaled 566 with an average of 113/year. Earned MS degrees in engineering for the same period totaled 206 with an average of 41/year.

Maui CC offers:

- An Associate in Science (AS) degree that provides training in:
 - Electronic Engineering Technology, which includes electro-optics instrumentation, adaptive optics for astronomical applications

- detectors, amplifiers, power supplies, computer hardware, and robotics; or
- Computer Engineering Technology, which includes Windows and Unix system administration, routers, hubs, switches, and High Performance Computing (HPC) Technology, which focuses on installation, maintenance, and programming of HPC cluster computers.

Enrollments for fall semesters from 2003 to 2007 ranged from 45 to 62 with an average of 55. AS earned from 2003-04 to 2006-07 totaled 21 with an average of 5/year.

The College of Engineering at UH Mānoa is currently operating at a student faculty ratio of about 17:1. Typical large mainland State Schools operate engineering colleges at significantly larger student faculty ratios (albeit with larger support staff). In order to increase the number of qualified students, COE Mānoa is significantly involved in K-12 outreach programs through ACT 111, including robotics programs and competitions.

To summarize, estimates based solely on EMSI annual demand projections and average UH engineering graduates per year seem to suggest that to fill annual demand for engineers by 2015 will require 124 engineers a year with BS degrees in addition to those currently produced by UHM, assuming that there is perfect fit of supply and demand. More detailed analysis, however, is needed to understand the specific types of engineering education needed, numbers needed, and whether or not the need is best met by developing new programs, expanding current capacity, or developing partnerships that meet both niche or emerging fields as well as traditional fields.

3) Cost of engineering education

One way to look at potential costs of engineering programs is to examine the average cost of educating a full time equivalent (FTE) student at the UH Mānoa COE. Average cost per FTE includes direct costs (instruction), indirect costs (student services, scholarships, and fellowships), and prorated costs for academic support, institutional support, and operations and maintenance.

In fiscal year 2008-09, the average cost per FTE for upper division engineering undergraduates was \$22,658; and for graduate level engineering students, \$57,171. By comparison, the average cost per FTE of all upper division students was \$19,151 and for graduate students, \$34,726.

The cost of graduating a full-time undergraduate College of Engineering student who attended UH Mānoa for four years from FY 2005-06 to FY 2008-09 was \$67,722. On average, 111 Bachelor of Science degrees are awarded annually

from the College of Engineering (excluding degrees in biological engineering). Therefore UH Mānoa's total cost to graduate its undergraduate College of Engineering students during that period was roughly \$7.5 million.

Another way to look at cost is to examine what was expended by a given college or school per student semester hour generated. Expenditures include all general funds plus fringe benefits and net tuition and fee special funds expended during the year, including prior fiscal year encumbrance liquidations, and excludes Summer School and Continuing Education expenditures, and encumbrances. Expenditures per Student Semester Hours (SSH) include fall plus spring semester credit student semester hours.

In fiscal year 2008-09, average expenditures per SSH in the College of Engineering was \$801. Expenditures per SSH in lower division engineering was \$429; upper division, \$596; and for graduate level, \$2,183.

Compared to other programs, engineering has relatively high expenditures per SSH. Among UH Mānoa schools and colleges, expenditures (including lower division, upper division, and graduate level) per SSH ranged from \$85 (Military Science) to \$1,237 (School of Medicine). The College of Engineering had the fourth highest expenditure per SSH among 15 Mānoa schools and colleges, after the School of Ocean and Earth Science and Technology (\$1,084), the School of Pacific and Asian Studies (\$1,202), and the School of Medicine (\$1,237).

It should be noted that the FTE costs and expenditures above do not include start up costs such as new faculty and staff positions, library expansion, and facilities required for engineering education. Budget estimates prepared by UHH for the two engineering degree programs that they are recommending project \$2 to \$5 million for 25 students. Of this, a range of \$1 to \$4 million is estimated for build-up of laboratory spaces and equipment for an engineering program. In addition, approximately \$1 million are recurring costs related to faculty and support staff positions, library services, and expenses related to preparing pre-engineering students through a summer bridge program.

As noted above, the UHM College of Engineering is actively seeking to increase the number of qualified students eligible for enrollment. The infrastructure support per student is typically high and economies of scale play heavily. The student capacity of the COE could be increased as much as 50% with additional support in terms of staff, infrastructure, and laboratory equipment. This support has been significantly reduced over the last year by a reduction in budget of 12% imposed on the College of Engineering.

4) Articulation & transfer among campuses

Between 2005-06 to 2008-09, there were a total of 240 transfer students admitted to the UHM College of Engineering. One hundred twenty-five were from the UH Community Colleges (CCs); 51 from Leeward CC, 50 from Kapi'olani CC, 8 from Maui CC, 7 from Kaua'i CC, 4 each from Honolulu and Windward CCs, and 1 from Hawai'i CC. Twenty-five transferred from UH Hilo, 5 from Hawai'i Pacific University, and 85 from non-Hawai'i institutions.

Articulation of pre-engineering courses (i.e., math, physics, chemistry, English 100, Speech 251, and a lower division economics course) is seamless between UHM and the UHCCs. Kapi'olani and Leeward CCs also offer lower division engineering courses which are equivalent to similar courses required of students in the UHM COE.

A meeting of the UHCCs and UHM COE was held on September 23, 2009 with a focus on identifying strategies to increase the number of CC transfers to engineering programs at UHM. As a result, Kapi'olani CC has proposed a grant from the National Science Foundation TCUP/PEEC program to support the development and sustainability of a multi campus collaborative to produce more Native Hawaiian baccalaureate-degree engineers "for a global economy and growing interest in invention and production of green technologies and sustainable energy production." Another meeting between the UHCCs and UHM COE is planned for January 2010 to continue the discussion regarding improving CC transfer to UHM COE.

5) Academic considerations

In 2009, two new degree programs in engineering and engineering technology were approved by the University of Hawai'i Board of Regents (BOR), and tentative plans are being formulated for a multi-campus Pre-Engineering Education Collaborative (PEEC) to build on existing program strengths at community colleges.

On May 29, 2009, the UH BOR approved the Bachelor of Applied Science in Engineering Technology degree at Maui Community College. The program will commence in fall 2010. It addresses local and regional needs for electronics engineering technicians with specialized skills in optics and remote sensing and as computer engineering technicians with specialized skills in information and computer technologies.

On November 19, 2009, the UH BOR approved the Bachelor of Science (BS) degree in Computer Engineering at the UHM College of Engineering, effective fall 2010. This is a joint program between the UHM College of Engineering and the UHM Department of Information and Computer Science. The program will

train a workforce that can design, analyze, and integrate hardware and software of computers. It is the only computer engineering program in the state of Hawai'i. By focusing on computer hardware and architecture, it differs from the broader BA and BS degrees offered by the Department of Information and Computer Sciences at UHM, and replaces the Electrical Engineering computer track program at the College of Engineering. The BS in Computer Engineering was totally based on current capability and courses, requiring no additional funding.

In addition to bachelor's level programs, community colleges' pre-engineering pathways are being strengthened to increase the transfer success of students and to support the pipeline of Native Hawaiians seeking STEM degrees.

One example of a planning effort that is learning from past successes is the Kapi'olani Community College (KapCC) proposal to build on a program to increase the enrollment and retention of Native Hawaiian students at the college, and to increase the number of Native Hawaiian students successfully transferring to and graduating from a 4-year institution with a STEM degree. Initially funded by a fall 2004 Tribal College and Universities Program (TCUP) planning grant, followed by a \$1.25 million, 5-year initiation grant, the College has met or exceeded the goals and benchmarks established in the original TCUP grant by using a number of best practices in STEM education.

KapCC's Associate of Science in Natural Science (ASNS) degree pathway provides students a clear academic goal and a fully articulated curriculum leading to successful transfer to engineering and other baccalaureate degree programs within the UH system. Currently, there are 56 students in the Physical Science pathway. Ultimately, pre-engineering students will arrive at the UH Mānoa College of Engineering as sophomores or juniors.

Currently KapCC and the UHM COE are proposing partnerships with other campuses to apply successful practices to improve student achievement and transfer. Toward this end, KapCC will offer its pre-engineering courses online beginning in spring 2010.

6) Current University of Hawai'i at Hilo (UHH) proposals

The State Legislature appropriated \$200,000 for FY 2010 and \$300,000 for FY 2011 for UH Hilo for required costs to support an advisory committee (FY 2010) and program implementation (FY 2011) of a Bachelor of Science degree in applied engineering. In a previous year, the legislature had appropriated funds for two faculty positions.

UHH has developed a preliminary proposal suggesting the development of two applied engineering degree programs: a BS in Agricultural and Biological Engineering and a BS in Systems Engineering. UHH's proposed implementation

schedule is to complete an authorization to plan by the end of fall 2010 and to inaugurate its first class of students in fall 2012.

In initial discussions in December 2009 with UHH, UHM COE, and the UH System, approaches to working collaboratively were discussed, for example, aligning the first two years' curriculum requirements in engineering. There was also discussion about whether the proposed degrees meet the emerging workforce needs of the state (for example, support for the implementation of the Thirty Meter Telescope or the increased attention to renewable energy, sustainable agriculture, and plant based drugs), most effective use of resources, and the need to avoid duplication among UH programs.

7) Proposed implementation schedule

To summarize the descriptions above, three confirmed engineering related initiatives are scheduled to start in the next two semesters that positively impact engineering education on the neighbor islands as well as Oahu:

- Spring 2010: Kapi'olani Community College will provide pre-engineering courses for transfer to the UH Mānoa College of Engineering via distance learning.
- Fall 2010: The UH Mānoa BS degree program in Computer Engineering starts.
- Fall 2010: The Maui Community College BAS degree program in Engineering Technology starts.

Preliminary Recommendations

- Given the current fiscal environment, we recommend that the UH System continue to collaborate with campuses to support the successful transition of students from community colleges to four year programs. Continued efforts should be made to evaluate the feasibility of putting additional courses online so that programs, like those at Kapi'olani Community College, present students with options in course taking and scheduling and support their academic needs.
- We recommend that cross system planning among the four-year campuses continue in order to systemically address the workforce needs of the state while ensuring that redundancies in programs among campuses are minimized.

- Engineering degree programs are costly to establish and to maintain. The marginal student costs of building capacity in an existing program are considerably lower than those of a new program start up. Improved articulation and transfer efforts, collaboration with the DOE and community colleges on all islands, and capacity building at UHM are cost-efficient ways to increase the number of engineering graduates. The costs of new program establishment at UHH will be weighed against the Big Island/State need for the proposed programs (Agricultural and Biological Engineering and Systems Engineering) and the potential number of students eligible to enroll.

References

Economic Modeling Specialist, Inc. (EMSI). *Complete Employment – 2nd Quarter 2009 v. 2*

University of Hawai'i Budget Office. October 2009. *Expenditure Studies: University of Hawai'i, Fiscal Year 2008-09*. <http://www.hawaii.edu/budget/expend.html>

United States Department of Labor, Bureau of Labor Statistics. *Occupational Outlook Handbook, 2008-09 Edition*. <http://www.bls.gov/oco/home.htm>

University of Hawai'i Institutional Research Office, Enrollment reports. <http://www.hawaii.edu/iro/maps.php?category=Enrollment>

University of Hawai'i Institutional Research Office, Degrees and Certificated Earned Reports. <http://www.hawaii.edu/iro/maps.php?title=Degrees+and+Certificates+Earned>

University of Hawai'i System, Office of the Vice President for Academic Planning and Policy. (May 2008). *University of Hawai'i System Strategic Outcomes and Performance Measures, 2008-2015*. <http://www.hawaii.edu/ovppp/uhplan/SOPM.pdf>

University of Hawai'i System, Office of the Vice President for Academic Planning and Policy. *Serving the State of Hawai'i: University of Hawai'i System Performance Measures, 2008*. (Dashboard Reporting) <http://www.hawaii.edu/ovppp/uhplan/PM08.pdf>