



COLLEGE OF AGRICULTURE & LIFE SCIENCES
COLLEGE OF ENGINEERING

**Agricultural &
Biosystems Engineering**

**ABET
Self-Study Report
for
Biosystems Engineering
Bachelor of Science Degree**

**The University of Arizona
Tucson, AZ**

June 28, 2016

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BACKGROUND INFORMATION

A. Contact Information

The pre-visit contact person for the Biosystems Engineering program is:

Dr. Kitt Farrell-Poe, Department Head, Specialist, and Professor
Department of Agricultural and Biosystems Engineering Department
The University of Arizona
403 Shantz Building No. 38; 1177 East 4th Street, P.O. Box 210038
Tucson, Arizona 85721-0038

Phone: 520-626-9120, Fax: 520-621-3963, email: kittfp@email.arizona.edu

B. Program History

This section includes a discussion on the history of the Biosystems Engineering program including the year implemented, the date of the last general review, and a summary of the major program changes that occurred since the last general review.

The Biosystems Engineering program at the University of Arizona has a rich history dating back over one hundred years. Like similar departments at most Land Grant universities, the Agricultural and Biosystems Engineering department is jointly administered by the College of Agriculture and Life Sciences and the College of Engineering. The budget is administered by the College of Agriculture and Life Sciences and is divided into the three components of instruction, research, and extension.

The roots of the Biosystems Engineering program start with the agricultural engineering program which was initiated with the appointment of a Meteorologist and Irrigation Engineer in 1891 although the name "Agricultural Engineering" was not applied to the department until 1923. The program remained almost exclusively in the water resources and irrigation areas until an engineer specializing in farm machinery was added in 1946. The major was called "Rural Engineering" from 1914 to 1920 and "Irrigation Engineering" until 1927 when it became "Agricultural Engineering." The program predominantly constituted an agricultural mechanization, rather than an engineering, curriculum until 1957.

Between the 1950's and the 1980's the department underwent a number of reorganizations and changes in leadership. In 1991, Dr. Donald Slack assumed the headship and led a re-evaluation of the program to apply available resources to better meet the needs of the statewide clientele. Several faculty-run strategic planning sessions refined the research and instructional programs to a more clearly defined bi-modal focus on "water resources" and "biological engineering." Dr. Mark Riley served as Department Head until October 2012 when he resigned to assume the position of Head

of the Department of Biological Systems Engineering at the University of Nebraska. Dr. Slack was appointed as Interim Head in October 2012 and continued in that position until February 2014. Dr. Kathryn “Kitt” Farrell-Poe was appointed Head in February 2014 and continues to serve as department head. Between 2009 and present time, the department kept its program focus in the water area, however also increase focus also in the biological, bioenergy, bioinformatics and controlled environment agriculture area.

In the fall of 2004, we underwent a regular cycle ABET Accreditation Review and, for the first time since establishment of the Engineering program, received an NGR (next general review) outcome. This meant that the Biosystems Engineering program had been accredited for a full six year period until 2010. The reviewer raised only one concern, that our undergraduate students did not have adequate space and equipment to undertake class projects, study together and develop reports, etc. To address this concern, the department established a small student computer room with adequate number of computers, printer and study table. This room has been used extensively by both undergraduate and graduate students and has been well received by all of them.

In 2009, the Agricultural Systems Management (ASM) Program in Yuma was moved to an option in the Agricultural Technology Program within the Department of Agricultural Education. Dr. Stephen Poe, who had been in charge of the ASM program, was moved to the Tucson Campus where he assumed teaching and extension roles. Dr. Kitt Farrell-Poe, who was the State Water Quality Coordinator for Extension, also moved to campus at that time, maintaining her extension and academic program appointments.

In 2009, the Department of Biomedical Engineering was established in the College of Engineering. This resulted in a significant drop in enrollment in the B.S. Biosystems Engineering (BE) program as one of the major tracks of the program had been Biomedical Engineering. Enrollment in the BE program dropped from 92 in fall 2009 to 39 in fall 2012. Subsequently, the enrollment has moved back up to nearly 45 in fall 2015.

The Biosystems Engineering BS program underwent a comprehensive accreditation review by ABET, Inc. in fall 2010 and was re-accredited for a full six-year period.

C. Options

The Biosystems Engineering (BE) degree has no formal options but does have focus areas based on individual student interests. Students may choose a primary focus area in Biological Engineering or Water Resources Engineering (or a combination) by concentrating their technical and design electives on these topics. Within the Biological Engineering focus area, students may chose a pre-health track which allows them to satisfy all common medical school requirements and also meet BE degree requirements. This is achieved by taking 8 units of organic chemistry as part of the required technical electives. Lists of suggested courses are provided for the student to choose in consultation with their departmental faculty adviser.

D. Program Delivery Modes

The Biosystems Engineering program is offered in day mode, with instructions based on lectures and laboratory sections in classes. Several online courses are also offered in the program.

E. Program Locations

Include all locations where the program or a portion of the program is regularly offered (this would also include dual degrees, international partnerships, etc.).

F. Public Disclosure

The Program Education Objectives (PEOs) and Student Outcomes (SOs) are made available for public access on the following ABE Department Web Pages:

<http://www.cals.arizona.edu/abe/content/program-educational-objectives-and-outcomes>

<http://www.cals.arizona.edu/abe/content/abe-mission>.

The Biosystems Engineering program is accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org>. Annual student enrollment and graduation data is made accessible to the public on <http://engineering.arizona.edu/undergrad/ABET>

G. Deficiencies, Weaknesses, or Concerns from Previous Evaluation(s) and the Actions Taken to Address Them

The previous ABET analysis of the program in Agricultural and Biosystems Engineering, performed in the Fall 2010 general visit was to “Accredit to Fall 2016.” However, the reviewer raised one weakness (on *program educational objectives*) which was resolved after the visit, and four concerns (on *program outcomes, faculty, facilities, and support*) were indicated which remained unresolved by the time of the previous visit and ABET Final Statement. The Department has continued working on assessments of educational objectives and outcomes and continuous improvements, and have taken actions and initiatives to address the concerns and improve continuously since the last 2010 ABET review.

The weakness on *program educational objective* was resolved after the 2010 review by extending the assessment of program educational objectives with a presentation of survey data from employers of graduates in addition to alumni survey and FE exam results which were only used in the PEO assessment. Since the previous review, we continued to assess PEO using results of alumni surveys and FE exam results. Furthermore, the educational objectives have been reviewed annually at the ABE Alumni/Industrial Advisory Council meetings each fall, generally in November. The most recent such meeting was on October 23, 2015, where a review of the Program Educational Objectives was an agenda item and the results of this discussion were captured in the minutes of that meeting.

The concern on *program outcomes* was raised due to using only FE exam results and a single ABE course to evaluate understanding of professional and ethical responsibility. The concern remained unresolved in the 2010 Final Statement. We have continued periodically using FE exam results since last review, as it provides means of evaluating *Ethics and Professional Practice* as one of the exam subject matter. Furthermore, we also added ABE 452 course in addition to ABE 496a to assess student's "*understanding of professional and ethical responsibility*." The results of assessing "*Ethics and Professional Practice*" are provided in multiple tables and figures in Criterion 4 Continuous Improvement section of this report.

The concern on *facilities* was raised due to need for facilities for modern engineering practices requiring updated and modernization of equipment. The concern remained as unresolved in the Final Report in the previous review. To address this concern since the previous review, the ABE Department has taken several steps. Right after the review, we have initiated a student project to generate on campus biodiesel from local waste materials. This project was supported by a local company, Greecycle, the University of Arizona Green Fund, the ABE Department, and the College of Ag and Life Sciences (CALS) and include \$90,000 of new equipment to interface with a local company's activities on campus. All students in the Biosystems Engineering major gained experience in relevant activities including biofuel production and quality control. Technical support has also been provided. In 2011, we have establishes an alternative energy integrated controlled environment greenhouse system facility with funds though University of Arizona Green Fund project and with industry in-kind donations. This project help us to acquire several new sensors, instrumentation and autonomous data acquisition systems, and PV system performance testing instrumentation. In 2011-2012 period, the CALS pledged \$20,000 to upgrade our teaching facilities. Some of this funding was used to upgrade computer, audio/video hardware, projector in our main teaching classroom, while some of the funds were used to purchase new sensors and data acquisition systems and to establish small biosystems testbeds for hands on student learning. We have been in the process of establishing a new indoor vertical farm based hydroponics food production teaching, research and outreach facility at our Controlled Environment Agriculture Center (CEAC) with advanced sensors and instrumentation and equipment. Our DOE funded research projects helped establishing and improving algae research facility which is also used for student instructions, internships, independent studies and also for student projects in several classes. Almost all of our research labs has been periodically upgrading computers, software, sensors and instrumentation since the last review. Our biosensors lab, advanced sensing and control lab for CEA, remote sensing lab, and labs at MAC and YAC has been constantly upgrading and acquiring new equipment which are used for instruction and research. With two faculty hires in the bioinformatics area since last review, we have substantially enhanced our computational capabilities with required equipment, software, and access to big data analytics and computing platforms.

The third concern on *faculty* was raised due to the observation by the reviewer that two of our more experienced faculty, both of whom teach in the critical water resources area, were likely the nearest to retirement. The concern remained as unresolved in the Final Statement of the previous ABET review. The two faculty members in the water area did not retire and continue to serve as faculty members. Another two faculty in the biological focus area left the department for positions in other institutions. However, we have hired two faculty members in the

bioinformatics area and another faculty joins the department in remote sensing area in July. We are also in the process of hiring another assistant/associate Bioinformatics Engineer faculty.

Final concern was due to lack of technical staff *support* to maintaining and scheduling equipment use. The concern remain unresolved in the Final Statement report of the previous ABET review. We have an engineer (Mr. Neal Barto) who helps install, maintain, and manage laboratory equipment at CEAC, and work with students in the lab and research setting. Our fabrication shop supervisor (Mr. Charlie DeFer) helps installing and maintaining lab equipment as well. We have full time IT staff (Mr. Brian Little) who helps with needs of installation, maintenance, and upgrading of departments computing software and hardware, and he is also involved in student design projects helping with programing and equipment used by the students. In addition, graduate students and postdoctoral researchers in research labs also helps with calibrations, maintaining and scheduling equipment use.

GENERAL CRITERIA

CRITERION 1. STUDENTS

A. Student Admissions

In this sub-section, we summarize the admission requirements and procedures for non-transfer freshman; these students matriculate almost exclusively in the Fall semester. Admission of transfer students is described in *Section C. Transfer Students and Transfer Courses*.

First-time freshmen who apply to the College of Engineering must submit their high school transcripts, their standardized test scores (SAT or ACT), and an online application to the University of Arizona (UA). Beginning with the Fall 2006 freshmen cohort, the Office of Academic Affairs (OAA) in the College of Engineering has been responsible for making all final admissions decisions.

A.1. Admissions Requirements of the University

To gain admission to the University, applicants must meet the following Arizona Board of Regents (ABOR) requirements for high school competency courses:

- English: 4 HS units (e.g., composition, literature)
- Mathematics: 4 HS units (e.g., algebra, geometry)
- Laboratory science: 3 HS units (e.g., biology, chemistry)
- Social science: 2 HS units (e.g., American history)
- Foreign language: 2 HS units (of the *same* foreign language)
- Fine arts: 1 HS unit (e.g., art, dance, music, drama)

Please note: in the list above, ‘HS unit’ denotes one academic year of high school course work.

A.2. Current Requirements and Processes for Admission to the College of Engineering

To gain admission to the College of Engineering, students must satisfy an additional set of requirements, which exceed those for admission to the University. The OAA has worked closely with the UA Office of Admissions to set up a two-tiered review process for all students seeking admission to Engineering. The extant process ensures a substantive review of each applicant. The following describes the details of the two-tiered admit structure now in place.

Tier I. Tier I describes the ‘auto-admit’ standard. About 60% of admitted students (see criteria below) meet the auto-admit standard. College of Engineering staff do not review the files of auto-admit students, prior to their admission to the College; these students, who clearly have strong records of high-school achievement, are straightforwardly admitted to the College by the UA Office of Admissions through an automated process. This first tier for admissions was established

to keep the number of files directly reviewed by the OAA at a manageable level. For both Residents and Non-residents, the auto-admit standard is:

- a. no course work deficiencies (ABOR complete) or one deficiency in Fine Arts (ABOR Incomplete, only deficiency in fine arts); and
- b. 1260 SAT (critical reading + math) or 28 ACT; and
- c. 620 SAT Math sub-score or 27 ACT Math sub-score
- d. Academic Index¹ (AI) of 200 or above

Tier II. OAA personnel directly handle the decisions on all applicants who fall below the auto-admit standard. To conduct a comprehensive review, the College gathers as much information on these applicants as possible, before making a decision to admit or deny. The following list includes the academic and non-academic criteria reviewed by Engineering:

- Academic Index
- Test Scores (math and composite scores for SAT and/or ACT)
- Academic GPA (student's GPA in all academic coursework)
- Grade trend
- Class rank
- Rigor or strength of high school curriculum (AP, IB, Honors, etc.)
- Engagement in leadership and co-curricular activities
- Personal essay

Applications handled at Tier II are reviewed by two OAA appointed personnel. If the two reviewers are in agreement, the decision on the applicant (admitted to engineering or denied admission to engineering) is entered into the University admissions database. The dossier of a student denied admission to engineering is referred back to the Office of Admissions, so that the student can be considered for admission to other colleges in the University. If the two AAO reviewers are not in agreement, a third reviewer acts as the 'tie-breaker.'

The current admissions criteria and processes are very similar to those that were in place at the time of our last ABET accreditation review (2010-11 cycle). For AY 2010–11, the auto-admit (Tier I) entrance requirements were:

- a. no course work deficiencies (ABOR complete) or one deficiency in Fine Arts (ABOR Incomplete, only deficiency in fine arts); and
- b. 1250 SAT (critical reading + math) or 26 ACT or 3.60 Academic GPA or top 15% applicant class rank; and
- c. Academic Index (AI) of 200 or above (SAT or ACT scores exist)

¹In 1997, The UA Office of Admissions began use of a metric, the Academic Index (AI), to assess applicants to the University. The AI was designed to reflect the strength of the curriculum taken by the applicant in their HS career. The AI also serves as a predictor of success (freshman-year GPA) at The UA. The AI formula accounts for: high school GPA; SAT/ACT scores; AP/IB classes; Honors/Accelerated classes; and college-level courses taken while in high school.

Minor adjustments to the auto-admit criteria reflect measures taken to identify students who would benefit from a more thorough review of their applications. In 2013, GPA and Class Rank were dropped from the auto-admit algorithm to allow for a better assessment of students who, despite having a strong GPA or high school class rank, report low SAT or ACT scores. Additionally, the SAT comprehensive score was bumped up to 1260 and the ACT comprehensive score was increased to 28. In 2014, for the AY 2015-16 freshmen cohort, ACT and SAT math sub-scores were added to the auto-admit algorithm.

Headcount, diversity and quality indices for engineering non-transfer freshman, Fall 2010 through Fall 2015 cohorts, are shown in Table 1-A.1.

A.3. Requirements and Processes for Admission to an Engineering Degree Program

Beginning with the AY 2010-11 cohort, non-transfer freshman admitted to the College of Engineering have been initially admitted to a category denoted ENGR-NMS, which stands for 'Engineering–No Major Selected.' That is, new freshmen students are, at first, admitted to the College of Engineering, but not necessarily into an engineering major.

Prior to matriculation, a subset of the ENGR-NMS freshmen is given the discretion to select and move into an engineering degree program—in short, newly-admitted engineering students with stronger HS backgrounds and records of achievement are offered the chance to choose their engineering major (in recent years, most have chosen to stay as ENGR-NMS). The other ENGR-NMS freshmen are obliged to remain as ENGR-NMS until they have satisfactorily completed at least 12 units of university-level work in math, science, and/or engineering courses. In effect, the ENGR-NMS pool is the major source of incoming students to the Biosystems Engineering program, and is where much of our recruitment efforts go. See Table D-3 in Appendix D to see the ramifications of the College's evolving matriculation procedures on our Program's enrollment.

The basis on which newly-admitted freshmen are given the discretion to move out of, or are obliged to matriculate in, the ENGR-NMS classification is summarized immediately below.

- For AY 2010-11 through AY 2012-13: newly-admitted ENGR-NMS freshmen were reviewed on the basis of SAT, ACT, HS GPA, AI, etc. and approximately half of the students were subsequently extended the option to move into a major prior to matriculation.
- For AY 2013-14 to the present: newly-admitted ENGR-NMS freshmen are offered the option to move into an engineering major, prior to matriculation, if the student is also admitted to the university's honors program (known as Honors College).

In the main, Honors College admits have AP, IB and/or dual-enrollment credit and are taking some sophomore-level courses in their first semester at the University. For context, headcount, diversity and quality indices for engineering freshman admitted to Honors College, Fall 2010 through Fall 2015, are displayed in Table 1-A.2.

Headcounts for newly-admitted engineering freshmen, differentiated by those matriculating directly into an engineering degree program and those matriculating as ENGR-NMS, are shown

in Table 1-A.3 for Fall 2010 through Fall 2015. Note that, for the last three freshmen cohorts, well over 80% of the new engineering freshmen matriculate as ENGR-NMS. Moreover, at least half of the students who had the option to matriculate directly into an engineering major decided to remain in the ENGR-NMS classification. Shown in Table 1-A.4 are the disaggregated headcounts of non-transfer freshmen who decide to matriculate directly into an engineering major, as a function of the engineering degree programs, for Fall 2010 through Fall 2015.

Table 1-A.1. New freshmen profile, College of Engineering, Fall 2010 through Fall 2015.

	Fall '10	Fall '11	Fall '12	Fall '13	Fall '14	Fall '15
Headcount, ENGR Frosh	473	556	627	610	601	621
Residents, Percent	74.2%	71.6%	65.1%	68.9%	63.7%	66.8%
Non-Residents, Percent	25.8%	28.4%	34.9%	31.1%	36.3%	33.2%
Full – Time, Percent	98.5%	98.6%	99.2%	99.0%	99.3%	99.7%
Attempted Credits/Semester, Mean	15.42	15.47	15.54	15.41	15.52	15.63
HS GPA (unweighted), Mean	3.67	3.70	3.72	3.68	3.70	3.72
ACT, Mean	26.7	27.0	27.6	27.6	27.6	27.8
SAT, Mean	1234	1237	1251	1249	1239	1246
Academic Index, Mean	225.0	234.0	230.7	229.0	230.9	223.5
UA GPA @ End of 1st year, Mean	2.95	2.96	3.01	3.04	3.04	—
Percent with UA GPA < 2.00	12.2%	12.6%	10.5%	9.3%	11.6%	—
Female Percent	22.6%	27.3%	28.1%	24.8%	28.8%	29.8%
African American, Percent	1.5%	2.0%	1.0%	1.3%	2.0%	1.3%
American Indian, Percent	0.4%	0.5%	0.6%	0.5%	0.5%	0.5%
Asian American, Percent	6.4%	7.5%	7.3%	8.1%	6.2%	6.0%
Pacific Islander, Percent	0.2%	0.0%	0.3%	0.0%	0.0%	0.0%
Hispanic, Percent	20.2%	21.9%	21.9%	19.2%	20.6%	22.3%
White, Percent	61.5%	57.2%	55.3%	56.9%	57.0%	53.6%
Two or More Races, Percent	2.8%	4.6%	3.2%	4.1%	6.2%	4.9%
Nonresident Alien, Percent	7.0%	6.4%	10.3%	9.8%	7.5%	11.4%
Total Minority, Percent	31.5%	36.4%	34.4%	33.3%	35.5%	35.0%

Table 1-A.2. New freshmen profile, College of Engineering students in Honors College, Fall 2010 through Fall 2015.

	Fall '10	Fall '11	Fall '12	Fall '13	Fall '14	Fall '15
Headcount, ENGR Frosh in Honors	177	235	252	202	207	236
Percent ENGR Frosh in Honors	37.4%	42.3%	40.2%	33.1%	34.4%	38.0%
Residents, Percent	72.3%	74.0%	68.3%	74.3%	68.1%	80.5%
Non-Residents, Percent	27.7%	26.0%	31.7%	25.7%	31.9%	19.5%
Full – Time, Percent	100.0%	100.0%	100.0%	99.0%	100.0%	99.6%
Attempted Credits/Semester, Mean	16.01	15.99	16.00	15.75	15.87	15.93
HS GPA (unweighted), Mean	3.87	3.84	3.85	3.84	3.83	3.85
ACT, Mean	28.8	29.0	29.9	30.0	30.0	29.7
SAT, Mean	1332	1316	1329	1341	1333	1312
Academic Index, Mean	260.7	260.7	255.2	256.2	256.0	244.4
UA GPA @ End of 1st Year, Mean	3.32	3.31	3.36	3.43	3.42	—
Percent with UA GPA < 2.00	3.4%	4.3%	4.4%	2.5%	2.4%	—
Female, Percent	29.4%	35.7%	36.9%	34.7%	40.1%	41.5%
African American, Percent	0.6%	2.2%	2.0%	2.0%	0.5%	2.2%
American Indian, Percent	0.0%	0.0%	0.0%	0.5%	0.5%	0.4%
Asian American, Percent	10.2%	10.0%	6.5%	10.9%	8.8%	8.6%
Pacific Islander, Percent	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%
Hispanic, Percent	19.3%	23.0%	25.8%	25.4%	23.4%	27.6%
White, Percent	65.9%	56.5%	59.7%	58.7%	60.0%	55.6%
Two or More Races, Percent	1.7%	7.4%	3.2%	2.0%	5.4%	4.3%
Nonresident Alien, Percent	1.7%	0.9%	2.8%	0.5%	1.5%	1.3%
Total Minority, Percent	32.4%	42.6%	37.5%	40.8%	38.5%	43.1%

Table 1-A.3. Selected headcount for newly-admitted engineering freshmen, including those matriculating directly into an engineering degree program and those remaining in ENGR-NMS, Fall 2010 through Fall 2015.

	Fall '10	Fall '11	Fall '12	Fall '13	Fall '14	Fall '15
Headcount, ENGR Frosh	473	556	627	610	601	621
Headcount, ENGR Frosh Matriculating Directly into a Degree Program	160	168	137	59	102	53
Percent ENGR Frosh Matriculating Directly into a Degree Program	33.8%	30.2%	21.9%	9.7%	17.0%	8.5%
Headcount, ENGR Frosh in ENGR-NMS	313	388	490	551	499	568
Headcount, ENGR Frosh in Honors	177	235	252	202	207	236
Percent ENGR Frosh in Honors	37.4%	42.3%	40.2%	33.1%	34.4%	38.0%

ENGR-NMS students may apply for admission to an engineering degree program when they have completed 12 or more units of math, science or engineering course work at the UA; this course work must be applicable to the degree requirements for the student's intended major (degree program). Each engineering degree program has a minimum GPA, known as the minimum admission GPA, which the student must meet or exceed to gain admission to the degree program. The minimum admission GPA is set by the faculty of a degree program; the minima for the respective degree programs are as follows:

Degree Program	Minimum Admission GPA	Degree Program	Minimum Admission GPA
Aerospace Engineering	2.500	Engineering Management	2.000
Biomedical Engineering	2.750	Industrial Engineering	2.000
Biosystems Engineering	2.000	Materials Science & Engineering	2.000
Chemical Engineering	2.300	Mechanical Engineering	2.500
Civil Engineering	2.250	Mining Engineering	2.000
Electrical & Computer Engineering	2.500	Systems Engineering	2.000
		Optical Sciences & Engineering	2.500

Please note that a student's admission GPA is not equivalent to the student's cumulative GPA. The admission GPA is the grade point average for the math, science and engineering courses taken as

part of the student's degree program and excludes General Education course work, except for ENGL 102 (first-year composition, second semester), ENGL 108 (English composition for ESL students, second semester) or ENGL 109H (advanced first-year composition for Honors College students).

Table 1-A.4. Headcounts for Non-Transfer Freshmen matriculating directly into an engineering degree program, Fall 2010 through Fall 2015.

Degree Program	Fall '10	Fall '11	Fall '12	Fall '13	Fall '14	Fall '15
Aerospace Engineering	31	24	17	11	7	8
Mechanical Engineering	34	22	25	9	17	5
Biomedical Engineering	46	39	26	18	32	18
Chemical Engineering	21	18	25	5	14	7
Civil Engineering	9	14	7	3	1	1
Computer Engineering†	1	—	—	—	—	—
Electrical & Computer Engineer	32	27	13	4	17	12
Electrical Engineering†	2	—	—	—	—	—
Biosystems Engineering	3	2	4	1	0	0
Optical Sciences & Engineering	9	10	9	3	5	0
Materials Science & Engr	4	4	3		2	0
Mining Engineering	3	7	5	1	4	1
Engineering Management	5	1	0	0	0	0
Industrial Engineering	1	1	1	1	2	1
Systems Engineering	3	3	2	3	1	0
ENGR-NMS	313	388	490	551	499	568

†Computer Engineering and Electrical Engineering were ABET-accredited degree programs that were discontinued after the formation of a new degree program, Electrical & Computer Engineering, which the EAC Executive Committee voted to accredit through September 30, 2017.

The application process to enter an engineering degree program is straightforward and now makes use of an interactive online form, which mirrors the hardcopy application in use for much of the last six years. ENGR-NMS students self-report the grade earned in required courses, and the form calculates the number of units earned and the student's admission GPA based on the student's

input. Students know the result of the admission GPA analysis, as soon they complete the application. Students have the option to electronically submit the completed application—even if they do not meet the admissions requirements for the proposed degree program—or they may elect to close the interactive form and submit at a later date.

The information on a submitted application is compared with the student's academic history and any discrepancies are resolved. The application, course history and calculations are reviewed by two Academic Advisors in the OAA. If the advisors cannot reach a consensus, the College's Advising Coordinator reviews and makes the final admissions decision. The student and the academic advisor for the declared degree program are notified of a favorable admissions decision by email, the student is moved into the degree program, and the student is directed to confer with the academic advisor. A mandatory advising hold flag is placed on the student's UAccess (registration) account and remains in place until the academic advisor for the degree program contacts the OAA to verify the advisor has conferred with the student. Students who do not meet the admission requirements for their proposed degree program are also notified of a (negative) decision by email.

ENGR-NMS students may remain in that designation through the end of their sophomore year, or once they have completed 60 units at the University. At that stage, university policy applies: *Students must declare a major in a degree program prior to earning 60 units or before attaining junior standing. Incoming transfer students with a minimum of 60 transferable units have one semester at the University before they need to declare a major in a degree program.*

Headcounts for continuing students who successfully moved from ENGR-NMS, into an engineering degree program, are shown in Table 1-A.5 for each of the last three academic years (AY 2013-14 through AY 2015-16).

A.4. ABE Department

Once the College of Engineering (CoE) matriculates the student, the Agricultural and Biosystems Engineering (ABE) department Academic Program Coordinator receives an email notice from CoE that a student has applied to our major – they must meet CoE and ABE qualifications first before this step occurs. Then the student meets with the Academic Program Coordinator and she reviews their course history and/or transfer credits, and approves the application and removes the advising “hold” on the student's record. She then assists the student in creating a general four-year plan of work. She determines their area(s) of interests, and encourages them to meet with faculty in their areas of interest at least once a semester. Currently, there are no measures in place to ensure that students visit with their faculty advisor.

Table 1-A.5. Headcounts of students moving from ENGR-NMS into an engineering degree program for AY 2013-14 through AY 2015-16.

Degree Program	AY 2013-14		AY 2014-15		AY 2015-16	
	Fall '13	Spring '14	Fall '14	Spring '15	Fall '15	Spring '16
Aerospace Engineering	15	2	13	17	19	7
Biosystems Engineering	6	2	2	1	11	7
Biomedical Engineering	18	6	21	10	13	24
Chemical Engineering	16	13	16	9	26	26
Civil Engineering	8	11	11	10	5	13
Electrical & Computer Engineering	21	15	30	24	57	39
Engineering Management	5	3	11	5	19	9
Industrial Engineering	6	4	11	6	10	2
Mechanical Engineering	28	14	32	29	62	32
Mining Engineering	8	7	4	5	4	2
Materials Science & Engineering	12	8	14	1	10	2
Optical Sciences & Engineering	4	5	14	2	13	9
Systems Engineering	9	3	13	2	11	4
Total	156	93	192	121	260	178 [†]

[†]Includes two students moving into Environmental Engineering, a degree program launched in AY 2015-16.

B. Evaluating Student Performance

B.1. College of Engineering

Student performance is evaluated against University, College, and degree-program requirements, most of which involve the student's grades and transcript. Progress is monitored directly through an on-line degree auditing and advising system, as well as through established milestones and benchmarks that students must reach if they wish to advance in the curriculum of their chosen degree program.

Grading System

Students are graded on a 4.0 system with (regular) grades *A*, *B*, *C*, *D*, and *E*. A letter grade of *A* equals 4 quality points per credit hour. The grade-point-average (GPA) is the arithmetic mean of the grade points earned for all credits taken at the University of Arizona for University Credit or by Special Examination for Grade, where regular grades are awarded. Ordinarily cumulative GPAs

are calculated using only the courses at the career level of the student. For example, the undergraduate GPA is based on undergraduate courses only.

Only regular grades (*A, B, C, D, E*) are included in the calculation of GPA. In some instances, an alternative grade scale—viz. *S, P, C, D, E* or *S, P, F*—is available for what are known as University-wide House Numbered Courses, such as independent-study courses, internship courses and selected colloquia and seminars. The grades of *S* (Superior), *P* (Pass), and *F* (fail) are not part of the GPA computation, as indicated in the summary below.

Grade:	In GPA:	Description:	
A	yes	excellent	(regular grade)
B	yes	good	(regular grade)
C	yes	satisfactory	(regular grade)
D	yes	poor	(regular grade)
E	yes	failure	(regular grade)
S	no	superior	(alternative grade)
P	no	passing	(alternative grade)
F	no	failure	(pass/fail option)

Academic Requirements and Academic Advisement Report

Students are encouraged to remain in contact with their academic advisor(s) as they progress through their degree programs at the University (see *Section D. Advising and Career Guidance*). Student progress is monitored by advisors and members of the faculty through use of an on-line advising system—a computerized degree audit/advising support system designed to help students achieve their academic goals efficiently. Two reports are the key components of the system:

1. The Academic Requirements Report (ARR), which displays, for any given degree program at the University, a complete statement of the requirements and approved courses. These reports are available online in the University of Arizona General Catalogue.
2. The Academic Advisement Report (AAR), known more simply as the Advisement Report (AR), which summarizes for a student, the student's progress toward degree completion by evaluating the student's academic record against the ARR, the requirements of the student's specific degree program. Students can access their personal AR through UAccess Student, an online portal to their dossier.

The AR provides the following essential academic information:

- academic requirements completed and the grades earned
- academic requirements in progress
- academic requirements remaining
- additional course work that has not been applied toward the fulfillment of degree requirements
- GPA and Major GPA (and for some degree programs, Advanced Standing GPA)

The AR explicitly tracks course and requirement completion and thus enables students and advisors to spend less time in record-keeping and more time planning how to achieve academic and career objectives. The AR helps students make informed academic choices, by providing accurate and comprehensive information regarding student achievement relative to the standards and requirements for their chosen or prospective degree program.

Advanced Standing

In the College of Engineering, eligibility to enroll in 300- or 400-level (junior and senior level) courses is called *Advanced Standing*. The Advanced Standing benchmarks provide a standard to evaluate a student mid-way through their course of study. Meeting the advanced standing requirements helps to ensure that students have: taken the pre-requisite and foundational courses for advanced study in engineering; are prepared to take rigorous junior and senior level classes; and are on track for timely graduation.

To apply for Advanced Standing, a student must meet with an academic advisor, or program faculty member, in their major and submit an Advanced Standing application form. Application forms are available through the departmental offices and the OAA.

To qualify for Advanced Standing, students must meet the following criteria:

Completion of Required Courses: A student must successfully complete lower division (100- and 200-level) courses stipulated by the degree program as essential for Advanced Standing. At least 12 units of the stipulated course work must have been completed at the University. In some cases, advanced standing may be granted if not all of the stipulated lower division coursework has been completed—that is, if the deficiencies are minor. When Advanced Standing is awarded with course work deficiencies, those deficiencies must be corrected by the end of the first year in which Advanced Standing was granted.

Advanced Standing Grade Point Average: The Advanced Standing GPA is based on grades earned in the lower-division courses that a program stipulates as essential for Advanced Standing. The specific set of lower-division courses includes foundational mathematics, English composition, science and engineering courses; each degree program establishes that program's Advanced Standing GPA, which must be equaled or exceeded by the student to gain Advanced Standing in the degree program. In addition, the student's cumulative GPA must be 2.000, or higher, to advance. The current minimum Advanced Standing GPAs are listed below, by degree program:

Degree Program	Advanced Standing GPA	Degree Program	Advanced Standing GPA
Aerospace Engineering	2.500	Engineering Management	2.000
Biomedical Engineering	2.750	Industrial Engineering	2.000
Biosystems Engineering	2.000	Materials Science & Engineering	2.000
Chemical Engineering	2.300	Mechanical Engineering	2.500
Civil Engineering	2.250	Mining Engineering	2.000
Electrical & Computer Engineering	2.500	Systems Engineering	2.000
		Optical Sciences & Engineering	2.500

Allowing (limited) enrollment in 300- and 400-level courses, while a student completes (minor) lower-division course work deficiencies, enables a student to retain full-time enrollment status and maintain progress to degree. Students may only proceed in this fashion if: (a) they have no more than two stipulated lower-division courses to complete; (b) are on track to meet the Advanced Standing GPA for the degree program; and (c) consent to an academic agreement, which specifies when (in which semester) any course work deficiency will be addressed. If the requirements for Advanced Standing are not completed as agreed upon, Advanced Standing is revoked, and the student is not permitted to subsequently register for 300- and 400-level engineering courses until deficiencies are fixed.

Transfer students who have not done 12 units of the stipulated lower division course work at the University, but who have completed the requisite lower division course work, are granted Advanced Standing on a provisional basis. Once such a transfer student has completed 12 units of degree required course work at the University, they must have attained a GPA (in that course work) which meets or exceeds the Advanced Standing GPA for their degree program. Transfer students who do not meet this GPA requirement after their first 12 units of degree required course work must either: (a) change degree programs or (b) take remedial action by engaging in lower-division, program-specific course work at the University.

Degree Check

Degree check is a formal process to evaluate student performance as the student nears graduation; degree check is designed to establish that a student is indeed on a path to meet the requirements for graduation. In the semester prior to the semester in which the student expects to graduate, the student initiates the degree-check process at the College level. Students pick up a degree-check instructional handout in the OAA (Room 200 of the Engineering Building) and then complete an exit survey for graduating seniors. After completing the exit survey, students print a confirmation page and submit it to the OAA. Upon receipt of the confirmation page by the staff in the OAA, the student is given an application to degree candidacy. Upon submission of the completed application,

the student is given a final degree check form (commonly referred to as the “pink sheet”) and an informational handout of Frequently Asked Questions.

The pink sheet is completed by the degree program advisor or designated program faculty member (in consultation with the student) and returned to the OAA for a second review. A senior program coordinator in the OAA reviews the pink sheet. After the pink sheet is approved, the student’s paperwork is forwarded to Graduation Services for final processing (a description of the role played by Graduation Services can be found in *Section F. Graduation Requirements*).

Regarding completion of the pink sheet, students are instructed to make an appointment with their academic advisor or the appropriate program faculty member; completion of the pink sheet is designed to establish that the student is on track to graduate in the expected timeframe. Students are instructed to review and print their AR (Advisement Report). Based on an audit of the AR, the academic advisor can unambiguously assess the student’s academic record with respect to all degree requirements and pending coursework. Any necessary adjustments to the AR, or to the student’s remaining plan of study, are made during the pink-sheet AR audit. If, for students with transfer credit, the advisor finds that the transfer work is not properly accounted for on the AR, the advisor instructs the student to request an official transcript to be sent to the University Registrar. Note that, when an adjustment is made to a student’s AR, the advisor ensures that all ABET criteria are still fulfilled after the adjustment.

B.2. ABE Department

Multiple redundant processes are in place to track student progress through the required curriculum and in performance in each course. Completion of the required curriculum and program activities (presented in more depth below) ensure that students meet Biosystems Engineering program outcomes. These program outcomes have been demonstrated to be successful in meeting our program objectives.

As the student progresses through their academic program, there are three to four primary procedures in place to ensure that the student is making appropriate progress and attaining the required course grades for success:

1. SAPR (Student Academic Progress Report), an online record keeping database for which both student and advisor have access, this system was replaced with the online UAccess in 2012 and renamed to SAAR (Student Academic Advising Report);
2. UAccess/Analytics Student Center, the academic course review conducted each semester by College and Department to determine performance (GPA of 2.0 or greater). Students that are not meeting those requirements are considered “at-risk students” and an intervention is conducted (the Academic Program Coordinator contacts all at-risk students to set up meetings with her and the ABE faculty);
3. Advanced Standing application process, required before students take 300-level (junior standing courses); and
4. Senior Degree Check, required a semester prior to graduation.

1) Advising and Student Academic Advising Report (SAAR)

Students are encouraged to remain in contact with the ABE Academic Program Coordinator and faculty advisor as they progress through their degree programs at the University. Student progress is monitored by the Academic Program Coordinator and faculty advisors through use of the university data systems UAccess or UAnalytics which replaced the online record-keeping system SAPR (Student Academic Progress Report) that existed at the time of the last ABET review.

The Student Academic Advising Report provides the following essential academic information:

- Academic requirements completed and the grades earned
- Academic requirements in progress
- Academic requirements remaining
- Additional course work that has not been applied toward the fulfillment of degree requirements
- GPA and Major GPA

The requirements for each engineering degree are described in the SAAR so that at any time students can see how the courses they have completed apply to degree requirements and what is remaining. Based on the SAAR, an automatic degree audit checks to see that all course requirements are met prior to graduation. Any adjustments are made under the direction of either the student's faculty advisor or the ABE Academic Program Coordinator who verifies that when an adjustment is made all program criteria are still fulfilled.

2) UAccess/Analytics Student Center

Both the College of Engineering and the ABE Department monitor student grades on a semester basis and in the event that a student is not making adequate progress (either with low grades or not completing the appropriate courses), the ABE department and the student's faculty advisor develop an action plan to correct the problem. Using the UAccess or Analytics Student Center, an academic course review is conducted each semester by both CoE and ABE to determine performance (GPA of 2.0 or greater). Students that are not meeting those requirements are considered "at-risk students" and an intervention is conducted whereby the ABE Academic Program Coordinator contacts all at-risk students to set up meetings with her and the ABE faculty.

3) Advanced Standing

In order to enroll in Upper Division (300-400 level) courses in the College of Engineering, students must be granted Advanced Standing. The Advanced Standing benchmarks provide a standard to evaluate a student mid-way through their course of study. Meeting the advanced standing requirements helps to ensure that students have taken the pre-requisite and foundational courses for advanced study in engineering, are prepared to take rigorous junior and senior level classes, and are on track for graduation. Advanced standing is assessed typically when a student is in the fourth semester of residence.

To apply for Advanced Standing, Biosystems Engineering majors must meet with the ABE Academic Program Coordinator and complete the Advanced Standing application form (example Appendix K). All Biosystems Engineering major Advanced Standing applications need to receive approval from the ABE Academic Program Coordinator and the ABE Department Head as well as receive final approval from the Dean of the College of Engineering Academic Affairs.

To qualify for permanent advanced standing, Biosystems Engineering majors must meet the following criteria:

1. Biosystems Engineering Major Grade Point Average of 2.0 (or higher).
2. Complete all of the following lower-division courses required for the degree: English I & II (ENGL101 & ENGL102 or ENGL109H), Chemistry I & II (CHEM 151 & CHEM152), Physics I & II (PHYS141 & PHYS142), Calculus I (MATH122A/B or MATH125), Calculus II (MATH 129), Engineering Math (MATH223, & MATH254), Biology (MCB181 or PLS240 and ECOL182, or MIC205A or PSIO201), Lower Division Core ABE courses (ABE201, ABE205, ABE284), and the Engineering Core (ENGR 102 and CE214). Appendix K has the Advanced Standing application form used by the ABE Academic Program Coordinator to assess student's qualifications for advanced standing.
3. Advanced standing requires successful completion of at least 12 units completed at the University of Arizona and no admission deficiencies. NOTE: Under special circumstances, students may be deficient in one or two classes. However, deficiencies must be corrected by the end of the first year in which the advanced standing was granted.

Advanced Standing may be revoked if the student's University of Arizona grade-point average or the major grade-point average falls below 2.00.

4) Senior Degree Check - Degree Certification Procedures

The final degree audit is a required process for ensuring degree requirements have been met before graduation. Requests to complete degree requirements must be submitted the semester prior to the expected graduation date – in the fall semester for spring graduation or in the spring semester for summer or fall graduation. The College of Engineering majors must declare their final degree term and apply for candidacy for the final degree in the Engineering Academic Advising Office (AAO) through the UAccess Student Center and complete the CoE online Exit Survey sent from the Assistant Director of Office of Intuitional Research & Planning Support. The student will bring the receipt showing the completion of the Exit Survey to Room 200 of the Engineering Building, and are given an instruction sheet and a Senior Degree Check Adjustment Form (commonly referred to as the “pink sheet”). To ensure that the student has met degree requirements, the ABE Department requires majors to meet with both their Faculty Advisor and the ABE Academic Program Coordinator. The Faculty advisor reviews the student SAAR (Student Academic Advisement Report) with the student to make sure that the student has met the course requirements, approve course adjustments, and confirm the student's final course plan. The ABE Academic Coordinator will review the SAAR with the student, assist student with enrolling in their final ABE course work, process approved and/or needed course adjustments to the SAAR, and complete and sign the Senior Degree Check Adjustment Form. The ABE Academic Program Coordinator will forward the completed form and SAAR to the CoE Dean's office for his final approval. As a general practice, the Academic Program Coordinator is encouraged to keep a student's SAAR up-to-date by making adjustments whenever a course is substituted for approved courses. The ABE Faculty Advisors are also encouraged to notify the ABE Academic Program Coordinator of the any issues they find on the SAAR right away.

A final audit of student records is done by CoE to ensure that the student has completed all requirements for their degree. Any questions that arise are directed to the college Dean's Office

and the major advisor. This process ensures and documents that students either meet or will meet all of the graduation requirements in what they plan to be their final semester. The University requires a GPA of at least 2.0 for graduation. In addition, the College of Engineering requires that graduates have GPA in the major of 2.0. The Biosystems Engineering majors are required to complete 128 units with a cumulative GPA of at least 2.00. CoE also requires that 42 units of upper-division units are required to be completed at the University of Arizona. The general degree requirements are listed in Appendix E3.

In addition to the semester reviews with the Academic Program Coordinator and meetings with faculty advisors, evaluations are performed typically when a student is in their fourth semester of a normal program (an evaluation of eligibility for advanced standing) and the Senior Degree Check performed in the seventh semester of a normal program. The CoE sends out an exit survey at the time of the senior degree check. The ABE Department randomly performs exit interviews on seniors shortly before their graduation.

With few exceptions, no modes other than traditional on-campus instruction are employed in the College of Engineering programs. However, the ABE department is providing more classes via online every year. Currently, the following courses are taught via online/hybrid with open labs: ABE 205 (Engineering Analytic Computer Skills), ABE 221 (Computer Aided Design), and ABE 459 (an elective course, Onsite Wastewater Treatment).

The ABE Department has a process in place to ensure that students meet the prerequisite courses. We have placed blocks in UAccess Student to disallow students from enrolling in lower-division courses who have not met the prerequisite requirements. For example, ABE 284 requires MATH 129 or higher and PHYS 141 or higher before they can enroll in that class. If a student does not have one of these courses, the system will block them from enrolling. We have also placed in UAccess Student blocks on all of the ABE upper-division courses. This requirement disallows all students that do not have an advanced standing in engineering from enrolling in ABE 300- and 400-level courses.

C. Transfer Students and Transfer Courses

In this sub-section, we summarize the requirements and process for accepting transfer students and transfer credit, including state-wide articulation agreements. Inasmuch as admission to the College of Engineering is selective, we also describe the process by which a continuing student at the University transfers from a non-engineering degree program into an engineering degree program.

C.1. College of Engineering

Transfer Requirements

Though all transfer students matriculate directly into an engineering degree program, the admission process is handled by the OAA working collaboratively with the University's Office of Admissions and the Department that houses the engineering degree program. The nominal admission requirements for students transferring into College of Engineering degree programs from other universities and/or community colleges are:

- 2.500 cumulative GPA for all previous college-level work
- At least 12 transferrable units²
- Completion of Calculus I with a grade of *C* or higher
- Acceptable grades in transferrable math, science and engineering courses

Transfer Process

The transfer process begins when The UA Office of Admissions provides OAA staff a detailed Excel[®] spreadsheet containing the following student information:

- Student ID number
- Student Name
- Requested term for admission
- Transfer GPA
- Number of transfer units
- Requested major
- Previous institutions
- Special student group (e.g., STU 210, Domestic student with International transcripts)

The spreadsheet also contains the following fields for the College of Engineering evaluators:

- Notes
- Evaluator #1 decision
- Date of decision
- Evaluator #2 decision
- Date of decision
- In the event of a split decision, the same fields for evaluator # 3
- File date
- Add to system of record date

Using the information in the spreadsheet and copies of official transcripts, the first evaluator checks for compliance with the nominal admission requirements.

Exceptions to these criteria can be made under certain circumstances. For example, some students begin their academic careers before they are ready to take on the challenges of college-level coursework and this initially results in a poor academic record. If a student has gone on to rehabilitate their record—meaning that they have completed required coursework with high marks—in the semesters immediately prior to their transfer application to The UA, their successful academic progress is taken into consideration and an exception to the required GPA is allowed. Conversely, if Calculus I has been passed with a *C* and there are no higher-level math classes with final grades of *A* or *B*, the student must prove academic viability by earning grades of *A* or *B* in required science or engineering courses. If a solid academic record has not been achieved in math, science, and engineering courses, the student can be denied admission to the College/degree program, even if the GPA and Calculus I grades meet the nominal requirements stated above.

²By University policy, applicants with less than 12 transferrable units are considered for admission by The UA Office of Admissions and the College of Engineering as new students, not transfer students.

At least two OAA evaluators must review each transfer application and reach an agreement on the admissions decision (admitted vs. denied). Once a decision has been made, the information is added to the system of record, currently UAccess, and The UA Office of Admissions sends an acceptance letter to the student with detailed information for completing the student's transition into the University and desired degree program.

Transfer students are directed to access the on-line Next Steps Center (nextsteps.arizona.edu), initiating the transition process into the University and the College. Newly-admitted students are instructed to create a unique Student UA Net ID and University of Arizona email address. Then, using their UA NetID and password, students can log on to their Next Steps on-line tour.

The Next Steps tour covers the main steps in transitioning into the University, and then specifically into the relevant College of Engineering degree program. During the tour, new-transfer admits are instructed to click on the Transfer Student Academic Preview link that will take them to a series of informational tabs. The Advising tab provides instructions for initiating the Transfer Orientation process and, therein, students are asked to send an email including their name, student ID number and major (degree program) to the OAA advising email account. The account is monitored by several advisors in the OAA to ensure a timely response. The emails are reviewed for the appropriate information and any omissions on the part of the student are corrected. The email is forwarded to the academic advisor assigned to these duties in the OAA.

The OAA advisor reviews all transferable coursework and determines which transfer courses can be used to fulfill The UA's General Education requirements. The OAA advisor sends the student a Welcome Email with information regarding their general education transfer credit analysis. This preliminary review prevents duplication of courses already taken and subsequently helps the academic advisor for the degree program, as they guide the transfer student with regard to appropriate selections for degree-specific course work.

Owing to an extensive array of previously-articulated transfer course agreements, in-state transfer coursework in English, Math, Physics, Biology, Chemistry, and most Engineering will be automatically placed into the appropriate section of a student's University of Arizona Advisement Report. Email correspondence sent to transfer students with credit from outside the State's system of higher education includes contact information for the departments listed above (English, Math) so the student can request evaluation of applicable coursework.

All transfer students are sent the name and contact information of the academic advisor for their degree program, along with instructions to meet with the advisor for the completion of the transfer process. Service indicators are applied to all student accounts by the Next Steps Office. Once the degree program's advisor notifies the OAA that the compulsory advising component has been satisfied, these service indicators or 'holds' are removed by the OAA academic advisors. The student is then free to register for classes at The UA. Headcounts for the Fall 2010 through Fall 2015 cohorts of newly-matriculated transfer students are shown in Table 1-C.1 for the various engineering degree programs.

Table 1-C.1. Headcounts for New Transfer students matriculating directly into an engineering degree program, Fall 2010 through Fall 2015.

Degree Program	Fall '10	Fall '11	Fall '12	Fall '13	Fall '14	Fall '15
Aerospace Engineering	10	8	14	3	4	9
Mechanical Engineering	19	21	12	16	24	24
Biomedical Engineering	2	6	2	9	7	6
Chemical Engineering	12	5	11	16	12	13
Civil Engineering	5	5	10	8	11	8
Electrical & Computer Engineer	15	14	17	25	22	35
Biosystems Engineering	2	2	0	3	1	1
Optical Sciences & Engineering	4	5	8	5	2	3
Materials Science & Engineering	0	4	5	2	1	2
Mining Engineering	5	1	5	7	5	5
Engineering Management	1	2	2	0	2	3
Industrial Engineering	2	2	2	2	0	1
Systems Engineering	7	7	7	4	4	5
Total	84	82	95	100	95	115

Transfer Credit and Articulation Agreements

An engineering articulation task force (steeringcommittee.aztransfer.com) consisting of representatives from each state-supported engineering program in Arizona (UA, Arizona State University, Northern Arizona University, and all community colleges) meets annually to review and update transfer agreements. State-wide articulation of the freshman (and other lower-division) engineering courses ensures that students taking the appropriate course at any one school will receive proper credit, and preparation for subsequent coursework, at all the other schools. The collective work of this articulation task force, and that of similar task forces on other subject areas, has yielded the Arizona Higher Education Course Equivalency Guide (CEG), which is available on-line (aztransmac2.asu.edu/cgi-bin/WebObjects/CEG) and lists all courses taught in community colleges and their transfer equivalencies at the three Arizona state universities. The CEG documents articulated agreements for all in-state transfer work in essentially all subject areas.

Many of the engineering transfer students come from Pima Community College (PCC) and, so, the articulation and transfer process is strengthened by having a member of the PCC engineering faculty serve on The UA's College of Engineering Undergraduate Studies Committee.

All courses transferred in the absence of an established articulation agreement (e.g., upper-division course work from a four-year institution) are evaluated by a faculty advisor. In most instances, the students are asked to provide the course syllabus and name of the textbook used in the course as part of the transfer evaluation process. Out-of-State transcripts typically originate from less than one-quarter of the transfers.

Transferring into an Engineering Degree Program from Other UA Degree Programs

A student enrolled at The UA, but not in the College of Engineering, may subsequently apply to transfer into an engineering degree program (and the College of Engineering) after completing Calculus I, with a grade of *C* or better, and 12 or more units of coursework within the curriculum for their intended engineering major, excluding Tier 1 and Tier 2 General Education courses. An abridged menu of UA courses that a prospective engineering student may take to establish admissibility is given in Table 1-C.2.

Table 1-C.2. Abridged listing of lower-division math, science, engineering or English courses that may be taken to establish admissibility for college of engineering degree programs.

UA Course	Subject	Number of units
MATH 122A and B or 125	Calculus I	5 or 3
MATH 129	Calculus II	3
CHEM 151	General Chemistry I	4
CHEM 152 ^a	General Chemistry II	4
MSE 110 ^a	Solid State Chemistry	4
MCB 181 ^a	Introductory Biology I	3 to 4
PHYS 141	Introductory Mechanics	4
ENGR 102A	Introduction to Engineering Lecture Series	1
ENGR 102B	Introduction to Engineering Design	2
ECE 175 ^a	Computer Programming for Eng'g Applications	3
ENGL 102, 108 or 109H	First-Year English Composition	3

^aTo count toward admissibility, these courses must be required by the intended engineering major of the prospective transfer student.

To transfer into an engineering degree program, a student must achieve a GPA, in their engineering curriculum, that meets the Advanced Standing GPA of their proposed degree program, viz.

Degree Program	Advanced Standing GPA	Degree Program	Advanced Standing GPA
Aerospace Engineering	2.500	Engineering Management	2.000
Biomedical Engineering	2.750	Industrial Engineering	2.000
Biosystems Engineering	2.000	Materials Science & Engineering	2.000
Chemical Engineering	2.300	Mechanical Engineering	2.500
Civil Engineering	2.250	Mining Engineering	2.000
Electrical & Computer Engineering	2.500	Systems Engineering	2.000
		Optical Sciences & Engineering	2.500

When a student has completed the requisite coursework to transfer into an engineering degree program, they may file a ‘Request for Change of College/Degree Program’ form and a ‘GPA Check Sheet’ with the OAA. Once their record has been verified by OAA staff, the forms are returned to the student, who is directed to meet with an academic advisor in their (new) engineering degree program. The student is instructed to obtain the advisor’s signature on the Request-for-Change form and then return the form to the OAA for processing, which formally completes the transfer of the student into the engineering degree program.

Headcounts for students transferring into engineering degree programs, from other (non-engineering) degree programs in the University, are shown in Table 1-C.3 for AY 2013-14 through AY 2015-16. About 160 to 170 students have followed this pathway into engineering degree programs each of the last three years.

C.2. ABE Department

Once students are matriculated into CoE and have declared a major, they are required to meet with the ABE Academic Program Coordinator for mandatory advising and orientation. She reviews their course history and/or transfer credits and approves the application and removes the advising “hold” on the student’s record. She then assists the student in creating a general four-year plan of work. She determines their area(s) of interests, and encourages them to meet with faculty in their areas of interest at least once a semester. Currently, there are no measures in place to ensure that students visit with their faculty advisor.

Table 1-C.3. Headcounts of students moving from a non-engineering degree program at the University of Arizona into an engineering degree program for AY 2013-14 through AY 2015-16.

Degree Program	AY 2013-14		AY 2014-15		AY 2015-16	
	Fall '13	Spring '14	Fall '14	Spring '15	Fall '15	Spring '16
Aerospace Engineering	5	0	6	6	8	4
Biosystems Engineering	4	3	4	1	5	6
Biomedical Engineering	12	3	6	3	5	2
Chemical Engineering	7	14	20	6	26	7
Civil Engineering	3	5	10	6	10	4
Electrical & Computer Engineering	23	6	14	16	20	5
Engineering Management	5	6	3	4	7	3
Industrial Engineering	5	7	5	2	3	3
Mechanical Engineering	9	7	11	11	18	16
Mining Engineering	3	9	1	2	5	2
Materials Science & Engineering	5	2	6	1	2	1
Optical Sciences & Engineering	5	1	2	2	6	0
Systems Engineering	7	7	7	9	3	2
Total	92	70	95	69	118	56 [†]

[†]Includes one student moving into Environmental Engineering, a program launched in AY 2015-16.

D. Advising and Career Guidance

D.1. College of Engineering

Advising begins as students prepare for new-student or transfer-student orientation and continues throughout a student's tenure. Students are encouraged to see an advisor at least every semester, especially in advance of their priority registration period.³

At least three milestones require that an engineering student meet with an academic advisor or program faculty member, viz.

³ The priority registration period is a five-week interval at the beginning of the registration period for the next semester's courses. During the priority registration period, each cohort of continuing students (e.g. juniors) is assigned a week for which that cohort has priority access to the course registration system. During a given cohort's priority access period, other cohorts of students are unable to register or adjust their course schedules. A lengthy, open registration period follows priority registration.

1. A student must meet with an advisor prior to registration for their first set of classes at the University. This happens during orientation (described below).
2. A student must meet with an advisor at the time they apply for Advanced Standing (see *Section B. Evaluating Student Performance*). This occurs toward the end of the sophomore year (middle of the 4th semester) or, for transfer students who enroll as upperclassmen, after approximately 12-units of engineering coursework at the University.
3. A student must meet with an academic advisor or faculty member at degree check (see *Section B. Evaluating Student Performance*), which should take place the semester before the student plans to graduate.

A student who matriculates as ENGR-NMS, or who transfers into the College of Engineering from some other college in the University, is also required to meet with an academic advisor for their intended degree program—the meeting with the advisor is part of the process by which the student is admitted to an engineering degree program; these processes were described in *Sections A* and *C*, respectively.

In the balance of *Section D*, we summarize: New Student Orientation, including placement exams; advising of ENGR-NMS students by academic advisors in the OAA; and advising of students in the degree program, which occurs primarily within the Department, involves departmental staff/advisors and program faculty, and includes career guidance. Transfer student orientation and advising processes specific to transfer students are described in *Section C. Transfer Students and Transfer Courses*. Advanced Standing and Degree Check, milestones that require students to engage with the advisor(s)/faculty of their degree program, have been previously described in *Section B*.

New Student (Freshman) Orientation

Orientation is designed to assist newly-admitted students and their families by providing interaction with new and current UA students, UA faculty, UA academic advisors and other UA staff. A typical on-campus orientation session involves 30 to 50 new engineering students. The University/College partner to offer approximately 12 to 15 on-campus orientation sessions each summer. The orientation sessions for most students are a working day in length; orientation sessions for students in Honors College last two days, with Honors College staff handling the content and format of the second day—the first day follows the format of the one-day sessions.

OAA staff also participate in off-campus orientation sessions offered in New York, Chicago, Denver and Seattle, which families of some out-of-state students prefer in lieu of a summer trip to Tucson. The off-campus sessions deviate from the format described below, as they typically involve at most a handful of engineering students and, so, information is conveyed and counsel given in small groups.

The one-day (or first-day) orientation program offers new students an opportunity to learn about important aspects of campus life and obtain a class schedule for their first semester so they can enjoy a smooth transition into the University. Emphasis is placed on preparing for academic success by providing the following:

- placement in Math and English (and in some cases a second language)
- description of the engineering curricula, with emphasis on the first year
- meetings with academic advisors
- registration for courses, with the counsel and guidance of advisors
- information on resources available to engineering students (e.g. tutoring, advising)
- advice on the advantages of career-engagement during one's tenure as a student
- a description of the student chapters of engineering societies and other clubs
- information sessions on: financial aid; housing and meal plans—residence-hall living, off-campus living; strategies for success—time management and study skills; career planning; campus recreation, how to become involved on campus, how and when to pay the bills, and parking & transportation

During a 75-minute morning session, matriculates are introduced to the College of Engineering through a presentation given by OAA staff, including the OAA academic advisors and current engineering students. Many of the topics itemized above are covered during the morning session. In the afternoon, new students meet with the OAA advisors for training on how to use the University's system to register for courses, which is a feature within UAccess Student.

Immediately following that training session, students are escorted to a computer lab, where they can access their course schedule and make adjustments to their registration, as needed. On the day of an orientation session, only the new students participating in that session have access to the University's registration system; all other student populations are blocked from logging in. This allows the neophyte student to become familiar with the course selection/registration process without system traffic from other students. Counsel and advice are available from the OAA academic advisors and the academic advisors for the various degree programs in the College of Engineering, who are present at the computer lab. The team of advisors assists with course selection and help to troubleshoot registration issues. This also presents an opportunity for the new students to meet (nearly) all of the academic advising staff (OAA + degree programs) in the College. Students are also given the opportunity to meet with outside resources including the Math, English and Second language placement teams, Honors College, and more.

Placement is a key component to the orientation process, as placement is strongly coupled to permission to register for certain courses. Engineering students are subject to placement testing/assessment in Math, English and, in some cases, a Second Language.

Math Placement Exam

The University requires the ALEKS Math Placement Exam to assess a student's prerequisite knowledge for placement into a University mathematics course at or below the level of Calculus I (MATH 122a,b or MATH 125). Results of the ALEKS exam also affect placement in courses on other topics relevant to first-year engineering students, such as physics, chemistry, biology and introductory engineering courses. Students are asked to take the ALEKS exam on-line, prior to their scheduled orientation date. The exam has no proctor unless the student is re-taking the exam to improve their math placement (a student can take the test three times).

The ALEKS assessment covers a broad range of algebra or pre-calculus material. The ALEKS system is fully automated and the ALEKS assessment is adaptive. The first questions asked are

drawn from across the curriculum, and may be too easy or too hard. As the assessment proceeds, the student's answers are used to give the system an idea of the student's knowledge, and it will gradually focus the questioning in an individually appropriate way. By the end of the assessment, the student should find the questions generally challenging but reasonable for their individual level of knowledge.

The length of the assessment covers 20 to 35 questions. The number of questions will vary, depending on the action of the adaptive mechanism just described. It is likely that students will be asked questions on material they have not yet learned. On such questions it is appropriate for students to answer 'I don't know,' which is interpreted by ALEKS to mean that the student does not know the topic, and this will be reflected in the assessment results.

There are several desirable features of the online ALEKS exam. First, the student is apprised of their math placement before they arrive at Orientation. Second, the ALEKS software has a learning mode and students can practice problems online before taking the placement exam. Third, if a student scores poorly, they can take advantage of the learning mode and subsequently re-take the exam to improve their placement.

The following students take the ALEKS Math Placement Exam:

- All incoming freshman (including international students) or students participating in New Student Orientation
- Transfer, international, non-degree-seeking, re-admitted, or current students who have never taken a college level math course, or who have not completed one in the last three semesters, and plan on taking a mathematics course at or below the level of Calculus I.

The ALEKS placement score is valid for one year. If a student does not complete a UA math course within a year of taking the test, the student must re-test and try to meet the placement requirement for a particular course.

Engineering students take a version of the ALEKS exam called the Prep for Calculus ALEKS Placement Exam. Results of the exam may place students into Calculus I (MATH 122a,b or MATH 125), Preparation for Calculus (MATH 120R) or College Algebra/Trigonometry (MATH 112/111). During testing periods, placement test scores are uploaded daily into the UA system at 5:00 a.m. and 7:00 p.m. In addition:

- All students can check their scores through a password-protected, online portal.
- Incoming freshman and transfer students can verify scores in the Next Steps Center before their orientation or registration date. After registration or orientation, scores are available in UAccess Student, under Academic History Report (Unofficial Transcript).
- International students can verify test scores in UAccess Student, under Academic History Report (Unofficial Transcript) when they arrive for orientation.
- Current students can verify test scores in UAccess Student under Academic History Report (Unofficial Transcript) within 48 hours of testing.

Prospective engineering students who do not establish an ALEKS score sufficient to place into MATH 120R (or higher) may try for a higher placement by re-testing. Re-testing is done through the UA Testing Office on the UA campus; as noted, re-tests are proctored. Students are advised of several strategies to improve their ALEKS score, viz.

- Try ALEKS Learning Mode and re-test.
- Review on their own and re-test.
- Take a summer review math course and re-test.

Note that students can place into Calculus II or higher, based on AP Math or IB credit. (See *Section E. Work in Lieu of Courses.*)

English/Writing Placement

First-year English composition courses are primarily concerned with writing at the University level and must be taken to satisfy University General Education requirements (see *Section F. Graduation Requirements*). The English Department's Writing Program has an established empirical algorithm that provides placement on the basis of data from matriculates' high school records and standardized test scores. The Department considers the following information in determining placement in English:

- UA admissions GPA (which includes those courses required for admission)
- GPA in high school English courses (freshman through junior year)
- The number of AP English and/or Honors English classes taken through the HS junior year
- SAT verbal and/or ACT English scores

Over the past decade, English Department surveys of students and teachers in the Writing Program indicate that the empirical writing-placement procedure works well. However, roughly 15% of students still feel they would have benefited from a different placement. In instances where students feel they have not been properly placed, a student may ask to have their placement reviewed, which means that members of the Writing Program staff will read samples of the student's writing and re-examine their high school record.

Students who score sufficiently well on either of the Advanced Placement Examinations for English (scores of 4 or 5) or on the higher-level (HL) International Baccalaureate examination (scores of 5, 6, or 7), can choose to take ENGL 109H, a one-semester advanced English composition course that satisfies the first-year writing requirement for students who earn a final mark of *C* or higher in the course. Students who receive advanced placement credit based on the English Language/Composition AP exam can, alternatively, choose to apply the credit toward ENGL 101 and thereafter take ENGL 102 to complete first-year composition. The English Literature/Composition AP exam can offer the same option, or can be applied toward other General Education requirements (Tier I Traditions and Culture or Tier II Humanities). Non-native speakers of English must submit additional writing materials before AP or higher-level IB credit can be applied toward advanced placement in ENGL 109H.

All international students are required to take a Writing Placement exam. International students receive specific exam information during International Orientation, a special orientation session

tailored to international students, at which time they have an opportunity to speak to a Writing Program advisor.

For a variety of reasons, a small percentage of students cannot be placed on the basis of their high school records. In some cases this is because their records of classes are incomplete; in other cases, a student may not have taken either the SAT or ACT.⁴ Such students are notified by the UA Orientation Office that they have ‘No Placement’ in English. To serve such students, the English Department oversees a writing placement exam. This test is offered at each Orientation session, as well as during the first week of classes in the Fall semester. In most cases, the tests can be scored in time for students to register for first-year English composition courses within twenty-four hours. The exam includes a timed essay (45-minute limit) and a short multiple-choice test (this takes about 30 minutes). The essay test involves composing an essay in response to a short reading — and is scored independently by at least two experienced teachers from the Writing Program. All materials are provided at the test site, which is announced to students through the Orientation Office.

Second Language Placement

Second language proficiency is not a requirement for students in the College of Engineering. However, the University has entrance and graduation second language proficiency requirements for a majority of their degree programs. Engineering students who wish to complete a minor or a (second) major in another college must meet the language proficiency requirement of that college.

Entrance language placement exams are administered to assess a student’s second language proficiency and to establish whether a student needs to take additional language classes to meet language graduation requirements. Language placement exams are typically taken at New Student Orientation.

French, German, Latin and Spanish language placement exams are given at the College of Humanities Instructional Computing labs in Modern Languages 511. The exams are computer-based and consist of multiple choice questions on reading and grammar. An exam lasts about 20 minutes. The proficiency score places the student into a course that best fits their language skills. Students can take a language placement exam for each language they have studied. Students are advised that their strongest language may be the one to choose to meet their graduation requirements.

Students who have studied Hebrew, Italian, Chinese, Japanese, Portuguese, Greek, Russian, Arabic, Persian, Turkish, Navajo, Tohono O’odam, or American Sign Language, are typically not able to take a language placement exam during orientation. Placement exams for these languages are normally administered by the relevant department(s) at the beginning of the semester.

Students need not take a language placement exam if they have earned college credit by exam through Advanced Placement, College Level Examination, or International Baccalaureate programs.

⁴For admission in AY 2010-11 and thereafter, applicants seeking entrance to the College of Engineering are required to take the SAT or ACT. The SAT and ACT were strongly recommended for applicants in AY 2009-10 and prior.

Advising of ENGR-NMS Students

Students who matriculate under the designation ENGR-NMS are overseen by academic advisors in the OAA at the College level, until such time as they move into an engineering degree program or, alternatively, out of the College. The requirements and process for admission of an ENGR-NMS student into an engineering degree program were described in *Section A. Student Admissions*.

Please refer back to Table 1-A.4 to see headcounts for new freshmen matriculating as ENGR-NMS, as well as headcounts for those matriculating directly into an engineering degree program. Table 1-A.5 shows headcount data for continuing engineering students migrating from ENGR-NMS into an engineering degree program, for each of the engineering degree programs, in recent academic years.

Three OAA staff members serve as academic advisors for ENGR-NMS students and are the primary personnel who support the College's Academic Advising Center, located just inside the main entrance to the Engineering Building in the heart of the University's campus. Two of the three OAA advisors are dedicated full-time (1.0 FTE) to freshmen in ENGR-NMS; the third advises continuing students and serves as the coordinator for all academic advising in the College.

The Academic Advising Center holds regular walk-in advising hours and students can also arrange appointments by email, when necessary.

The University and College regard advising, mentoring, career counseling, and retaining students a priority. Below is a short list of events and projects to assist students become all they can be:

- In AY 2014-15, the College successfully submitted a proposal to the University (Student Affairs: Academic Initiatives and Student Success) to secure funding for a Career Engagement Coordinator (Heather Moore), who now works to develop internship and employment opportunities for engineering students
- UA Career Services has a permanent staff member who serves as a liaison to the College of Engineering (and the constituent Departments) and to prospective employers of engineers; the liaison maintains a listserv to distribute employment/internship opportunities directly to engineering students
- UA Career Services holds a major career fair each semester and maintains an on-line listing of employment opportunities known as Wildcat JobLink.
- College of Engineering students—specifically, Engineering Student Council—annually host a major career fair exclusively for engineering students; 40 to 50 companies/organizations have participated each of the last several years
- Bio5/BIOSA and College of Optical Sciences each host career fairs that engineering students can, and do, attend
- Students in ENGR 102a and ENGR 196d (co-convened as the *Introduction to Engineering Lecture Series*) are required to develop a resume and attend the UA Career Services fall-semester career fair; nearly every freshman engineering student is enrolled in either ENGR 102a or ENGR 196d.
- Engineering freshmen in Honors College have the option to take ENGR 196a (*Survey of Engineering Professions*), a course taught annually by Prof. Paul Blowers.

Advising in the Degree Program

As mentioned, advising begins in detail during orientation, at which time any student who matriculates directly into an engineering degree program is introduced to the relevant academic advisor(s). These matriculates are able to meet with the advisor for their degree program during the afternoon session to ask program-specific questions and, with guidance from the advisor, choose program-specific classes for their first semester, if appropriate. Subsequent advising of the student is handled primarily at the department/degree-program level for the duration of the student's tenure in the degree program.

D.2. ABE Department

Once students have been matriculated into the College of Engineering, incoming students first meet with the ABE Academic Program Coordinator. She informs the students about the BE program, assists them with developing a four-year plan, and reminds them of deadlines. Every faculty member provides informal and formal career counseling to students taking their courses, working in their laboratories, conducting independent studies and research, and through club activities. The ABE faculty considers student advising and mentoring to be just as important as teaching and instruction; therefore, the 11 regular faculty members (out of 14 ABE full time faculty) who have primarily teaching and research responsibilities are all actively involved in student advising, and/or mentoring and career counseling. For undergraduate student advising, during the first two years the students are mainly served by the Undergraduate Coordinator. However, in addition, the students are assigned an academic faculty advisor based on their interest area. The primary areas of focus and advisors are biological (Yoon and Cuello), controlled environment agriculture (Kacira and Giacomelli), water resources (Slack, Waller, Poe, Livingston, and Yitayew), and biosystems informatics (An and Hurwitz). We attempt to distribute students across the teaching faculty; however, typically Slack, Poe, and Livingston together are assigned more students for advising. Students are encouraged to meet with their specific advisor at least once a semester, however, when such a meeting cannot be arranged, a meeting is arranged between the student and another faculty member whose expertise is related to the student's interest. All students are provided with the electronic location of our website, which contains many valuable items, including the ABE Undergraduate Program Manual which details curricular requirements, a typical 4-year plan, elective offerings in BE and other departments, contact information for advisors, and all degree requirements. The undergraduate tab on the ABE website also provides course descriptions, admissions information, ABET assessment information, videos of recent internships, employment opportunities, career counselling, where our students are getting jobs, scholarships, and financial aid information.

E. Work in Lieu of Courses

E.1. College of Engineering

In lieu of course work, students may establish credit or proficiency/competency in various disciplines at the University by any of several modes. They are:

- Advanced Placement (AP) program, administered by the College Board
- International Baccalaureate (IB) program

- Cambridge International Examination (CIE) program
- College-Level Examination Program (CLEP), administered by the College Board
- Departmental proficiency/competency or exemption examinations
- Special examinations for credit or grade

In no case may the sum of credits earned through the above examinations and/or University of Arizona correspondence courses exceed 60 units applied toward an undergraduate degree. Students may also receive credit for U.S. Military Service and Training.

Advanced Placement Program

The University accepts Advanced Placement (AP) exam scores (as well as an International Baccalaureate and Cambridge International exam scores) as a basis for awarding credit toward a degree. Students may take AP exams prior to coming to the University. Exams are administered through the College Board at high schools each May.

AP credit is considered credit-by-examination from the University's perspective. Credit is determined from the AP credit table that applied on the date the exam was taken. A complete table of AP credit is printed annually in the University of Arizona General Catalogue and is publicly available (on-line) to any prospective or current student. Credits earned based on AP exam performance may be counted toward major or minor fields of study or General Education requirements. Table 1-E.1 is excerpted from the AY15-16 General Catalogue to give the reader a feel for the layout and organization of the Advanced Placement Table.

International Baccalaureate Program

The University accepts International Baccalaureate (IB) exam scores as a basis for awarding credit toward a degree. Students who complete the International Baccalaureate Diploma Programme may take IB exams prior to coming to the University.

The University of Arizona accepts certain higher-level (HL) International Baccalaureate exams for credit, plus one standard-level (SL) exam in computer science. IB credit is considered credit-by-examination. Credit is determined from the IB credit table, published annually in the General Catalogue, which applies to the date when the IB exam was taken. Credits earned based on IB exam performance may be counted toward major or minor fields of study or General Education requirements. Table 1-E.2 is an excerpt from the IB credit table in the 2015-16 General Catalogue.

Cambridge International Examinations

The Cambridge International Examinations (CIE) Program is available to freshmen in the 2015-16 Catalog and beyond.

The University of Arizona accepts CIE Advanced--AS- and A-level--scores as a basis for awarding credit toward a degree. Students who complete CIE classes in their high school may take Cambridge International exams prior to coming to the University. Exams are administered through Cambridge International at high schools each May.

CIE credit is considered credit-by-examination. Credit is determined from the CIE credit table that applies to the date when the IB exam was taken. Credits earned based on the exam score may

be counted toward the student's major or minor fields of study or General Education requirements. Table 1-E.3 is an excerpt from the CIE credit table in the 2015-16 General Catalogue.

College-Level Examination Program (CLEP)

The University accepts CLEP for college credit, if satisfactory scores are attained. Passing scores for subjects credited through the CLEP are recorded simply as CR (credit), and may not necessarily be stated in terms of a specific course equivalent. No record is made of failing scores.

CLEP examinations are available through the Testing Office at the University. However, not all CLEP exams are awarded credit; credit is determined from the CLEP credit table that applies to the date when the exam was taken. Table 1-E.4 is an excerpt from the CLEP credit table in the 2015-16 General Catalogue. Credits earned are based on the student's exam performance and may be applied toward the major, minor, or General Education requirements.

Prospective and currently enrolled students using these examinations cannot earn credit through CLEP for subjects or courses equivalent to, or at a lower level than, other courses for which they have already earned credit through formal course work. Students are encouraged to consult with their academic advisor to make sure they are eligible to take a specific subject exam.

Table 1-E.1. Excerpt from the Advanced Placement Table in the 2015-16 University of Arizona General Catalogue.

APPLICATION TO UA DEGREE					
AP Exam name	Score	General Education and Foundations	*	Course Credit	AP Credit
Biology	4 or 5	T2 Natural Sciences and T1 ECOL 170	OR*	MCB 181R, 181L, & ECOL 182R & 182L	8 units
	3	T1 Natural Sciences	OR*	MCB 170C1	4 units
Calculus AB	3, 4 or 5	Satisfies math requirement for all students		MATH 125	3 units
Calculus BC	4 or 5	Satisfies math requirement for all students		MATH 125 & 129	6 units
	3	Satisfies math requirement for all students		MATH 125	3 units
Calculus BC or AB sub-score	3, 4 or 5	Satisfies math requirement for all students		MATH 125	3 units
Chemistry	5	T1 CHEM 170 and T2 Natural Sciences	OR*	CHEM 151 & 152	8 units
	4	T2 Natural Sciences or T1 CHEM 170	OR*	CHEM 151	4 units
Computer Science A	3, 4 or 5	None		C SC 127A	4 units
Physics C: Electricity	5	T2 Natural Sciences or T1 PHYS 170	OR*	PHYS 241	4 units
	3 or 4	T2 Natural Sciences or T1 PHYS 170	OR*	PHYS 103 & 182	4 units
Physics C: Mechanics	5	T2 Natural Sciences or T1 PHYS 170	OR*	PHYS 141	4 units
	3 or 4	T2 Natural Sciences or T1 PHYS 170	OR*	PHYS 102 & 181	4 units
Statistics	4 or 5	Satisfies "G" & "M" math strand requirements		MATH 263	3 units
	3	Satisfies "G"&"M" math strand requirem't		MATH 163	3 units

Table 1-E.2. Excerpt from the International Baccalaureate Table in the 2015-16 University of Arizona General Catalogue. All accepted IB exams are higher-level, unless specified as standard-level.

APPLICATION TO UA DEGREE					
Exam Name†	Score	General Education and Foundations	*	Course Credit	IB Credit
Biology	6 or 7	T2 Natural Sciences and T1 ECOL 170	OR*	MCB 181L & 181R, and ECOL 182L & 182R	8 units
	4 or 5	T2 Natural Sciences or T1 ECOL 170	OR*	ECOL departmental elective credit	4 units
Chemistry	6 or 7	T2 Natural Sciences and T1 CHEM 170	OR*	CHEM 151 & 152	8 units
	4 or 5	T2 Natural Sciences or T1 CHEM 170	OR*	CHEM departmental elective credit	4 units
Computer Science - standard level exam	5, 6 or 7	None		C SC 127A	4 units
Computer Science - higher level exam	5, 6 or 7	None		C SC 127B	4 units
Mathematics	5, 6 or 7	Satisfies math requirement for all students		MATH 120R & MATH 125	6 units
Physics	6 or above	T2 Natural Sciences and T1 PHYS 170	OR*	PHYS 102 & 103 and 181 & 182	8 units

Table 1-E.3. Excerpt from the Cambridge International Exam Table in the 2015-16 University of Arizona General Catalogue.

APPLICATION TO UA DEGREE					
Cambridge International Exam Name	Score	General Education and Foundations	* —	Course Credit	CIE Credit
Biology AS-level	D or better	T2 Natural Sciences or T1 ECOL 170	OR**	MCB 181R & 181L	4 units
Biology A-level	D or better	T2 Natural Sciences and T1 ECOL 170	OR**	MCB 181R & 181L and ECOL 182R & 182L	8 units
Chemistry AS-level	D or better	T2 Natural Sciences or T1 CHEM 170	OR**	CHEM 101A and CHEM department elective credit	4 units
Chemistry A-level	A or better	T2 Natural Sciences and T1 CHEM 170	OR**	CHEM 151 & 152	8 units
	B or C	T2 Natural Sciences or T1 CHEM 170	OR**	CHEM 151	4 units
	D or lower	T2 Natural Sciences or T1 CHEM 170	OR**	CHEM 101A and CHEM department elective credit	4 units
Computer Science AS-level	E or better	None		None	0 units
Computer Science A-level	E or better	None		None	0 units
Design & Technology AS-level	E or better	None		None	0 units
Design & Technology A-level	E or better	None		None	0 units
Mathematics AS-level	E or better	Satisfies math G- and M-strand requirements		MATH 112	3 units
Mathematics A-level	E or better	Satisfies math G- and M-strand requirements		MATH 120R	4 units
Mathematics-Further A-level	E or better	Satisfies math requirement for all students		MATH 163, 125, and 129	9 units
Physics AS-level	E or better	None		general elective credit	4 units
Physics A-level	E or better	None		general elective credit	8 units

Table 1-E.4. Excerpt from the College-Level Examination Program (CLEP) Table in the 2015-16 University of Arizona General Catalogue.

		APPLICATION TO UA DEGREE			
CLEP Exam Title	Score	General Education and Foundations	*	Course Credit	CLEP Credit
Calculus with Elementary Functions	50	Satisfies Math requirement for all students		MATH 125	3 units
College Algebra	50	Satisfies -G- & -M- Math strand requirement		MATH 112	3 units
General Biology	50	T2 Natural Sciences or T1 ECOL 170	OR*	ECOL departmental elective credit	3 units
General Chemistry	50	T2 Natural Sciences or T1 CHEM 170	OR*	CHEM 151	4 units
Precalculus	50	Satisfies 'G' & 'M' Math strand requirement		MATH 120R	3 units

Proficiency/Competency and Exemption Examinations

General Information

A number of colleges and departments regularly offer exemption or proficiency/competency examinations covering introductory or basic areas of their disciplines. These examinations are designed and graded by the individual departments. No credit is awarded on the basis of successful performance on these, but they allow a student two privileges: (a) the opportunity of enrolling in advanced-level courses in the area of proficiency; or (b) the opportunity of satisfying various college or departmental "area" or proficiency requirements without taking prescribed courses.

Proficiency/competency or exemption examinations for many courses are available to any student currently enrolled in a degree program at the University. Capable students wishing to increase their elective freedom are encouraged by university policy to examine the opportunities provided through the various proficiency examinations.

At the discretion of the department, the proficiency examination may include laboratory projects or other evidence of satisfactory skills in addition to or instead of the written examination. A fee is normally charged for these examinations.

Second Language Proficiency/Competency Examinations

Second language requirements vary by degree type and are only relevant to an engineering student if the student is pursuing a (second) degree or minor outside of the College of Engineering. It is possible for students to satisfy second language requirements in whole, or in part, by passing a non-credit proficiency/competency examination at the two- or four-semester level.

Passing the proficiency examination at the required level in a foreign language fulfills the language requirement. Passing a course for which the required level is prerequisite also establishes proficiency in that language. Credit may not be earned merely by passing the proficiency/competency examination.

The procedures and general regulations for proficiency/competency or exemption examinations are as follows:

- Proficiency/competency or exemption examinations are available only to degree-seeking students.
- In no case does passing an exemption or proficiency/competency examination lower the total number of units required for the bachelor's degree.
- In normal circumstances, a student may not take a proficiency/competency examination for the same course more than twice.
- Proficiency/competency or exemption examinations are normally given early in the semester or during orientation. The student must contact the appropriate department concerned for additional information and instructions.
- Students wishing to sit for a proficiency/competency or exemption examination in a language not normally taught must contact the Department of Linguistics for information.
- The exemption or proficiency examinations are administered only on the University of Arizona campus. Proficiency/competency established at another institution, or a proficiency examination score from another institution, is not transferable to the University of Arizona.
- The results of exemption or proficiency/competency examinations, if successful, are reported in writing directly to the Office of the Registrar, with a copy to the student.
- The student's academic record will be annotated with a statement indicating the student passed the proficiency/competency examination at the appropriate level.

Special Examinations for Credit or Grade

Any student currently enrolled or previously withdrawn in good standing at the University of Arizona may earn credit toward an undergraduate degree through the use of special examinations. The responsibility for preparatory study for these examinations rests entirely with the student; faculty members are under no obligation to assist with such preparation.

Special examinations are constructed and administered by the department concerned. They are designed to reflect and explore the scholastic equivalent of the course, and are more comprehensive than the usual "final exam." The examinations may be written or oral, or both, and they may include course projects, laboratory projects, written reports, or other evidence of proficiency.

Undergraduate courses currently offered by the University and designated in the Catalog as "Special exam: course may be taken by special exam for credit (not for grade)" may be taken for credit by examination. Courses designated "Special exam: course may be taken by special exam for credit and grade" may be taken for grade by examination and credit by examination. Other courses generally have been excluded from this option; at department discretion, however, any course may be made available for grade by examination or credit by examination.

Effect on GPA

Special Examination for Credit: Passing grades, recorded as "CR" (credit), become a permanent part of the student's record but are not used in computing the cumulative grade-point-average (GPA). Failing grades are not recorded.

Special Examination for Grade: All grades, whether passing or failing, are permanently recorded and used in computing the cumulative GPA.

Limitations

The credit so earned may not duplicate units already presented for admission to the University. Nor may the credit be in a course which is equivalent to, or more elementary than, another course in which the student is enrolled or for which the student has already received credit. The head of the examining department has the responsibility of determining the application of this limitation in each student's case.

The procedures for special examinations for credit or grade are as follows:

1. Applications for Special Examination for Credit or Special Examination for Grade may be obtained from the Office of the Registrar.
2. The application must be approved by the student's advisor.
3. The examining instructor and the head of the examining department must determine the eligibility of the applicant and sign the application.
4. The application is returned to the Office of the Registrar, and the examination fee is paid at the Bursar's Office. No department may schedule a special examination until notified by the Bursar's Office that the fee has been paid.
5. The examination is scheduled by the faculty member responsible, normally during the same semester in which the application is made.
6. The grade ("CR" or letter grade) is reported to the Office of the Registrar. The examination, together with the student's graded examination paper and any appropriate evaluations of oral performance or projects, is then filed with the department for at least one year.
7. The student may change the type of special examination for those courses designated "available by special exam for credit and grade" in the catalog any time before the scheduled hour of the examination by filing a new application. No additional fee will be charged.

Credit for U.S. Military Service and Training.

A Guide to the Evaluation of Educational Experiences in the Armed Services, by the American Council on Education (ACE), is used by The University of Arizona as a basis for evaluating U.S. Armed Forces training.

ACE Military Credit for Undergraduates

Military credit evaluation is completed only after a veteran or student on active duty has been admitted to the University and has submitted all required documentation. The UA will accept up to 30 units of ACE-recommended military credit as transfer work toward a baccalaureate degree. The specific credits are for training programs offered by different branches of the U.S. Armed Forces and certified by ACE, including basic training. This credit will be awarded as general elective credit or department elective credit. Credit for military service experiences also may be acquired through standardized examinations (see the preceding discussion on CLEP and Special Examinations for Credit or Grade). Documented training experience that falls outside of the regular transfer credit policies of the University, such as credit for Military Occupational Specialties (MOS), will only be considered on a case-by-case basis through a Transfer Credit Appeal available through the Office of the Registrar.

Undergraduate Credit for Military Service

For at least eighteen months of consecutive active duty in the armed forces, terminated under honorable conditions, 4 lower division units of military science elective credit will be awarded toward a baccalaureate degree, as long as the total credit for military training and service does not exceed 30 units. A student who has earned a commission in the U.S. Armed Forces, may petition the Office of the Registrar for an additional 12 upper division units of military science, naval science, or aerospace studies elective credit that will apply toward a second baccalaureate degree.

E.2. ABE Department

This is done at the college level.

F. Graduation Requirements

All students at The University of Arizona must apply for degree candidacy in order to graduate and receive a degree.

GPA Requirements

Cumulative GPA: A graduation average of 2.000 for all University Credit⁵ course work undertaken and for any work satisfied by the Special Examination for Grade is required for the bachelor's degree. Note: the graduation grade average is based only on University Credit grades awarded prior to the graduation date, when all degree requirements have been satisfied.

Major GPA: Majors for undergraduate degrees require a 2.000 or better grade point average (major GPA) for all University Credit work in the major as defined on the Academic Advisement Report (AAR) or for any work in the major satisfied by the Special Examination for Grade. All grades for repeated courses will be calculated in the major GPA, with the exception of grades that have been replaced by the Grade Replacement Opportunity (GRO) and those removed from the grade point average through Academic Renewal.

F.1. University Credit Requirements

A minimum of 30 units of University Credit from The University of Arizona is required for the bachelor's degree. It is further required that 18 of the final 30 units offered toward the degree be University Credit. In other words, no more than 12 of the final 30 units to complete the degree may be credit-by-exam (i.e., CLEP, Special Examination for Credit), correspondence credit, or transfer credit.

Major-related course work should include no fewer than 18 units of University Credit. Major-related course work is defined as the major, pre-major, supporting course work, and/or professional core. This requirement applies to all majors in the student's academic program.

⁵ University credit is the term used to identify all credit offered by The University of Arizona with the exception of correspondence credit and Special Examination for **Credit**. Only the grades of courses taken for University credit and by Special Examination for **Grade** are used in calculating the grade-point-average.

General Education Requirements

The following is a summary of the requirements attendant to the General Education program at The University of Arizona.

Tier 1 General Education Courses

Traditions & Cultures – Students must take any 2 of the following 4 courses

TRAD101 – 160A - Non-Western Cultures and Civilizations
TRAD102 – 160B - Western Cultures and Civilizations: Classical to Renaissance
TRAD103 – 160C - Western Cultures and Civilizations: Renaissance to Present
TRAD104 – 160D - Topics in Culture and Civilization

Individuals & Societies – Students must take any 2 of the following 3 courses

INDV101 – 150A - Mind, Self and Language
INDV102 – 150B - Social Interaction and Relationships
INDV103 – 150C - Societal and Institutional Systems

Tier 2 General Education Courses

Arts or Humanities – Students must take 1 course from a set of courses designated to fulfill this requirement.

Individuals & Societies – Students must take 1 course

The selection of courses in each of the above topical areas is defined by the University-wide General Education Committee and is common across all colleges. Currently available courses are described in the Schedule of Classes.

Diversity Emphasis, English Composition and Second Language for General Education

In addition to the Tier 1 and Tier 2 course requirements, engineering students must fulfill the following general education requirements:

- Diversity emphasis: One course in a student's degree program must focus on one of the following areas: Gender, Race, Class, Ethnicity, Sexual Orientation, or Non-Western Studies. A complete list of Diversity Emphasis courses with descriptions is available in the General Catalog.
- English composition: Students must complete a composition requirement through one of the following strands, depending on placement:
 - two-course (6 units) sequence of ENGL 101 and ENGL 102
 - two-course (6 units) sequence of ENGL 107 and ENGL 108 (for International students)
 - one-semester (3 units) of ENGL 109H (Honors)

With advanced placement, a student may either: (a) place out of ENGL 101 and, so, take only ENGL 102, or (b) place into ENGL 109H.

- Second language: Engineering students must take the language placement examination if they propose to do a minor or a second major in another college. Second language proficiency is not a requirement for students in the College of Engineering, a variance granted to students of the College in accord with University guidelines for exceptions to the General Education requirements.

F.2. The AAR and Additional Requirements for Graduation with an Engineering Degree

The specific requirements for each engineering degree are described by the University's student information system in the form of the AAR or Academic Advisement Report generated by the UAccess system. As described above in *Section B (Evaluating Student Performance)*, the AAR is an individualized report of a student's progress toward completing degree requirements. It is an automated degree audit that shows the student how their UA and transfer courses, as well as credit by exam, apply to their degree requirements in the following categories: General Education, major(s), minor(s), electives, and University unit requirements. Thus, at any time, a student can see how the courses they have completed apply to degree requirements and what requirements are yet to be satisfied.

A student's AAR is:

- available online via UAccess Student (uaccess.arizona.edu), where the AAR can be viewed and printed by the student
- available for undergraduate programs existing since Fall 1997

Maximum Number of Community College Credits: A maximum of 64 units of community college course work may apply toward graduation. For an engineering degree, a minimum of 64 units of course work must be completed at a 4-year institution, military institution, or as test credit.⁶

Degree Check

Well in advance of graduation, every student passes through a process known as degree check. The goal of the process is to ensure that, in the semester prior to graduation, the student is on a trajectory such that, at the proposed time of their graduation, the student will meet all University and College of Engineering degree requirements, including those predicated on ABET criteria. Details of the degree check process are described above in *Section B (Evaluating Student Performance)*.

Graduation Services

After degree check, Graduation Services Advisors are responsible for making a final audit of each student's coursework to ensure that all University requirements for the student's degree have been

⁶ The B.S. Materials Science & Engineering requires a minimum of 58 units of course work at a 4-year institution, military institution, or as test credit.

met. As noted, students in the College of Engineering are advised to apply for their degree check one semester before they plan to graduate.

At the time of the final audit, if the Graduation Services Advisor finds any remaining requirements, s/he contacts the student's advisor to see if the problem can be resolved. Degree check is designed to keep these instances to a minimum. In the (rare) event that it is decided that the student is actually missing a requirement, either the Graduation Services Advisor or the student's engineering advisor will contact the student.

If the final audit shows that all requirements will be completed by the graduation date, then the degree will be posted as scheduled. Degree posting begins the day after grades for the semester are finalized (usually one week after the end of final exams). Degree posting generally takes two to four weeks for the December and May classes, and one to two weeks for the August graduating class. Students can see their degree has been posted by checking their Cumulative Profile in UAccess Student. Diplomas are ordered each week, and generally arrive within two to three weeks of the degree posting.

F.3. ABE Department

Students must complete a rigorous curriculum including courses in mathematics, science, engineering, and general education completed within 128 semester credit hours. The process for ensuring that each graduate complete all graduation requirements for the program is provided by continuous team advising between the Academic Program Coordinator and Faculty Advisor prior to the Senior Degree Check as described above. All students at The University of Arizona must apply for degree candidacy in order to graduate and receive a degree. The University requires a GPA of at least 2.0 for graduation. In addition, the College of Engineering requires that graduates have averages of 2.0 in both the major and any additional minors. The ABE department had two additional requirements: 1) all students must complete an internship (ABE 393) and 2) take the Fundamentals of Engineering exam. We ensure that the students have internships through their senior degree check, and registering for the FE exam is a mandatory requirement for ABE 498B.

G. Transcripts of Recent Graduates

The ABE department will pull the following transcripts from the Spring 2016 graduation class:

1. Victoria Karlsson (AMP), water resource emphasis
2. Alex Downs, biological engineering
3. Marko Obradov, Mechanical minor
4. Kenneth Hickman, Plant Sciences minor, water resource emphasis

Because we do not have official tracks within the BE major, there are no program options designated on the transcripts. The transcript indicates: college (College of Engineering), degree awarded (BSBE), and any appropriate minor.

CRITERION 2. PROGRAM EDUCATIONAL OBJECTIVES

A. Mission Statement

As a public research university serving the diverse citizens of Arizona and beyond, the mission of the University of Arizona is to provide a comprehensive, high-quality education that engages our students in discovery through research and broad-based scholarship. We aim to empower our graduates to be leaders in solving complex societal problems. Whether in teaching, research, outreach or student engagement, access and quality are the defining attributes of the University of Arizona's mission.

B. Program Educational Objectives

The Educational Objectives of the Biosystems Engineering B.S. Program at the University of Arizona are to produce graduates:

1. Who are effective engineers within natural resources and biotechnology related industries; and
2. Who have the foundation to perform and lead engineering projects and make significant contributions; or are
3. Enrolled in an advanced engineering or medical or other professional degree program and are successful in those.

These objectives can be found by the general public on the ABE Department Web Page: <http://www.cals.arizona.edu/abe/content/program-educational-objectives-and-outcomes> and

<http://www.cals.arizona.edu/abe/content/abe-mission>

This set of revised objectives was developed at a meeting of the ABE Advisory Council on November 14, 2002, reviewed by the faculty during the faculty retreat on January 6, 2003, and approved by the faculty with minor revisions. The objectives and mission have been evaluated again at faculty retreats and at the ABE Advisory Council in the spring of 2005, 2006, 2007, 2008, and 2009. In 2010, minor changes were made to the mission statement. The educational objectives are reviewed annually at the ABE Advisory Council meetings each fall, generally in November. The most recent such meeting was on October 23, 2015, where a review of the Program Educational Objectives was an agenda item and the results of this discussion are captured in the minutes of that meeting.

C. Consistency of the Program Educational Objectives with the Mission of the Institution

The BS-BE Educational Objective to

produce graduates who are effective engineers within natural resources and biotechnology related industries,

and the Objective to

produce graduates who have the foundation to perform and lead engineering projects and make significant contributions

both are fully consistent with the University Mission to

to provide a comprehensive, high-quality education that engages our students in discovery through research and broad-based scholarship and to empower our graduates to be leaders in solving complex societal problems.

The BS-BE Educational Objective to

produce graduates who are enrolled in an advance engineering or medical or other professional degree programs and are successful in those

is also consistent with the University Mission to

empower our graduates to be leaders in solving complex societal problems.

D. Program Constituencies

The primary constituencies of the Biosystems Engineering Program have been defined as students, alumni and employers, either current or potential, of program graduates and the faculty of the Department.

The program educational objective: *to produce graduates who are effective engineers within natural resources and biotechnology related industries*, obviously meets the needs of BE students to obtain a degree which has prepared them to become engineers and find employment in their field. It also meets the needs of employers who seek engineers who are technical competent and capable in their field. This objective also meets the need of alumni to who have a solid engineering background that can serve them throughout their career. Finally, it also meets the needs of Faculty whose job it is to produce effective engineers and the needs of employers who want to employ effective engineers.

Similarly, the program educational objective: *to produce graduates who have the foundation to perform and lead engineering projects and make significant contributions*, meets the needs of both students and alumni by ensuring that they are adequately prepared to become effective engineers and make significant contributions in their field. It meets the needs of employers by ensuring that BE graduates have the proper foundation to perform and lead engineering projects and make significant contributions to their employer. The needs of the faculty are also met as it is their job to produce graduates with sufficient foundations to perform and lead engineering projects.

The program educational objective: *to produce graduates who are enrolled in an advance engineering or medical or other professional degree programs and are successful in those*, meets

the needs of those students and/or alumni who wish to pursue advanced engineering or professional degrees by ensuring that they are adequately prepared to do so. In the longer run, it satisfies the needs of employers who require employees with advanced engineering or professional capabilities. As with the other objectives, the needs of the faculty are met as it is their job to produce graduates who have the background to successfully pursue advanced or professional degrees.

E. Process for Review of the Program Educational Objectives

A draft set of ABE Program Educational Objectives were developed by ABE Departmental faculty in 1997 to ensure that the program would meet accreditation requirements for "Agricultural and similarly named engineering programs." These draft objectives were then presented to the Departmental Advisory Council in a council meeting during the fall 1997 semester. This council was established in 1994 and is comprised of leaders of firms or organizations which either hire our graduates or have an interest in hiring them or which work with our Department in research or development. In addition to these members the council includes alumni (some of whom may also fall into the first category), one current undergraduate student, one current graduate student and one faculty member with the Department Head serving as an "ex-officio" member. Council membership varies between ten and fifteen and was 14 at the time of the October 2015 meeting. Members in the first category include officers of engineering and environmental consulting firms, USDA-ARS laboratory or center leaders, biomedical devices, biotechnology firms, and bioenergy companies. The Council meets a minimum of one time per year to provide advice and direction to the Department and for Department programs. A copy of the By-Laws of the Council which defines the makeup of the council and its role will be available at the time of the visit or will be provided on request. Similarly, a list of current council membership will be available at the time of the visit or provided on request.

As an outcome of the fall 1997 Advisory Council meeting, a revised set of program objectives were developed and submitted to the council membership via mail for final comment. Minor revisions were incorporated and this version was presented to the ABE faculty for approval. These original program objectives were very detailed and, in fact, mirrored ABET Criteria 1, 2, 3a-k and program specific criteria.

Program objectives are reviewed annually by the ABE Advisory Council at their fall meeting and by the ABE faculty at a retreat in spring of each year. At the Spring 2002 faculty retreat, the faculty recommended that the original set of objectives be shortened and more specifically address what we would like graduates of the program to be doing in the first few years after graduation. A new set of four objectives was developed and sent to the ABE Advisory Council for review and comment. At the fall 2002 Advisory Council meeting, the council recommended shortening the list of objectives to three that were similar to the current objectives. These new objectives were subsequently reviewed and adopted by the faculty with minor revisions at their January 2003 retreat.

Each year at the spring ABE faculty retreat and at the fall ABE Advisory Council meeting, these program objectives were reviewed and discussed. No changes were made except to adapt the name to the new ABET program criteria for "Biological and similarly named programs". This change

in criteria necessitated changes to two required courses (ABE 423 and ABE 447 described below) to ensure that all graduates obtained training in advanced biological techniques. Outside of these course modifications, there were no changes in program objectives.

Both the Advisory Council and the Department faculty continue to review the objectives each year and will continue to modify them as necessary. The most recent meeting of the Advisory Council (see the most current members and list of Advisory Council in Appendix O) was on October 23, 2015, where a review of the Program Educational Objectives was an agenda item and the results of this discussion are captured in the minutes of that meeting which will be available at the time of the visit or will be provided on request.

The Advisory Council also reviews the Departmental Strategic Plan, which defines the broader goals of the Department and the strategy for achieving them. This plan is also reviewed annually by the ABE faculty and underwent major review and revision at a two day retreat in May 2001. The most recent version of the ABE Department Strategic Plan was updated in April of 2010 and again in February of 2013 and will be available for review at the time of the visit or will be provided on request.

CRITERION 3. STUDENT OUTCOMES

A. Student Outcomes

As a first step toward achieving Program Educational Objectives, BE students are expected to fulfill a set of learning outcomes which prepare them upon graduation to achieve the Educational Objectives of the Program. Thus, based on the ABET Criterion 3 (a-k) and Program Specific Criteria for *Biological and Similarly Named Engineering Programs*, the faculty developed a set of desired learning outcomes which would meet these criteria and the program educational objectives. The BE Learning Outcomes are defined as a combination of knowledge and skills that a BE student is expected to attain at the time of graduation. Thus, a University of Arizona Biosystems Engineering graduate, at the time of graduation:

- a. Can apply mathematics, science and engineering principles to solve problems.
- b. Can design and conduct experiments and analyze and interpret data.
- c. Can design a system, component or process to meet desired needs within realistic constraints.
- d. Can function on multidisciplinary teams.
- e. Can identify, formulate and solve engineering problems.
- f. Has an understanding of professional and ethical responsibility.
- g. Can communicate effectively.
- h. Has the broad education necessary to understand the impact of engineering solutions in global, economic, environmental, and societal context.
- i. Recognize the need for and the ability to engage in lifelong learning.
- j. Has a knowledge of relevant contemporary issues.
- k. Can use the techniques, skills, and modern engineering tools necessary for engineering practices.

B. Relationship of Program Outcomes to the Program Educational Objectives

As noted earlier in the report, the Educational Objectives of the Biosystems Engineering Program at the University of Arizona are to produce graduates:

1. Who are effective engineers within natural resources and biotechnology related industries;
2. Who have the foundation to undertake engineering projects and make significant contributions; or are
3. Enrolled in an advanced engineering, medical or other professional degree programs and are successful in those.

Based on these educational objectives and the Mission of the ABE Department as shown in section Criterion 2 of this report, a set of measurable program outcomes was defined by the ABE faculty. These program outcomes reflect both the ABET criteria 3 (a-k) and the ABET program specific criteria for Biological and similarly named programs as well as the program educational objectives.

Table 3-1 illustrates how the UA BE Program Outcomes relate to the UA BE Program Educational Objectives. As a first step towards achieving the Program Education Objectives, BE students must

satisfy the Program Outcomes. The letters in each cell (H, M, L, or blank) indicate the level of contribution that each outcome makes towards the objectives. It can be seen from this table that each of the outcomes has a close relationship to educational objectives. In this case, there are no blank cells indicating that all learning outcomes contribute to each of the educational objectives. By satisfying all outcomes, graduates will be on a path to meet the program objectives shortly after their graduation. Taken together, Tables 3-1 and 5-3 show how Learning Outcomes are related to both ABET Criteria and to the Program Educational Objectives. We also present matrix of courses and activities that relate to BE Learning Outcomes in Table 5-4, while a more in depth table for specific foundation, required and elective courses, and their alignment and mapping against student learning outcomes are provided in Appendix I1.

Table 3-1. Matrix of UA BE Educational Objectives and Learning Outcomes.

		UA BE Educational Objectives Produce graduates who are:		
BE Program Outcomes		Effective engineers within natural resources and biotechnology related industries, and	Who have the foundation to perform and lead engineering projects and make significant contributions	Enrolled in an advanced engineering or medical or other professional degree program and are successful in those
a	Can apply mathematics, science and engineering principles to solve problems	H	H	H
b	Can design and conduct experiments and analyze and interpret data	H	H	H
c	Can design a system, component or process to meet desired needs within realistic constraints	M	M	H
d	Can function on multidisciplinary teams	H	H	L
e	Can identify, formulate and solve engineering problems	H	H	H
f	Has an understanding of professional and ethical responsibility	H	H	M
g	Can communicate effectively	H	H	M
h	Has the broad education necessary to understand the impact of engineering solutions in global, economic, environmental and societal context	H	L	M
i	Recognize the need for and the ability to engage in lifelong learning.	H	H	H
j	Has a knowledge of relevant contemporary issues	H	H	L
k	Can use the techniques, skills, and modern engineering tools necessary for engineering practices.	H	H	M
H = High Contribution, M = Medium Contribution, L = Low Contribution, Blank = Little or no contribution				

CRITERION 4. CONTINUOUS IMPROVEMENT

A. Student Outcomes

The Biosystems Engineering Baccalaureate program at The University of Arizona was designed to train students in the application of engineering and life sciences to address problems in the areas of natural resources and biotechnology. This program meets the ABET 2016-2017 Criteria for Accrediting Engineering Programs such that our students meet or exceed the stipulated program outcomes (a-k, detailed below). Additionally, the Biosystems Engineering program meets or exceeds the ABET program criteria for “*Biological and similarly named Engineering programs*” which include training students such that at the time of graduation, they have proficiency in mathematics through differential equations, a thorough grounding in chemistry and biology, and a working knowledge of advanced biological sciences consistent with our program educational objectives. Students must demonstrate competence in the application of engineering to biological systems in order to obtain the B.S. degree.

We have established a comprehensive process for developing our program outcomes, evaluating the extent to which these meet the needs of our clientele, and assessing the degree to which the program meets the desired outcomes (for students at the time of graduation), and to which the outcomes meet our program objectives for alumni shortly after their graduation.

A.1. Process for Establishing and Revising Program Outcomes

Academic Programs Assessment Committee

The primary function of the ABE Academic Programs Assessment committee has been to: 1) Review ABET accreditation criteria to ensure that the faculty and Department Head are apprised of the criteria and make recommendations to the faculty and the Head to ensure that the BE program is meeting the criteria; 2) Implement, maintain, and improve assessment tools for continuous improvement of all ABE Academic Programs; and 3) Analyze assessment data and formulate recommendations for improving each program based on these analyses.

Biosystems Engineering Continuous Improvement Process

Figure 4-1 is a schematic of the continuous improvement process developed by the ABE assessment committee and which has been used to assess the degree of achievement of both program learning outcomes and program educational objectives. The key elements of this process began with the development of a set of detailed, program specific educational objectives. These objectives were developed in conjunction with constituents that were defined as the ABE faculty, students, alumni and employers of BE graduates.

An ABE Advisory Council, which was formed in 1995, was used as the primary external forum to review and modify educational objectives proposed by the faculty initially during the 1996-97 academic year. The Advisory Council membership, which periodically meets, includes alumni, industry, representatives, an undergraduate student representing ABE/BE undergraduates and a graduate student representing ABE graduate students. The process for development of the initial

program educational objectives was defined in Criterion 2 of this self-study; a parallel process was utilized to develop the Biosystems Engineering program outcomes.

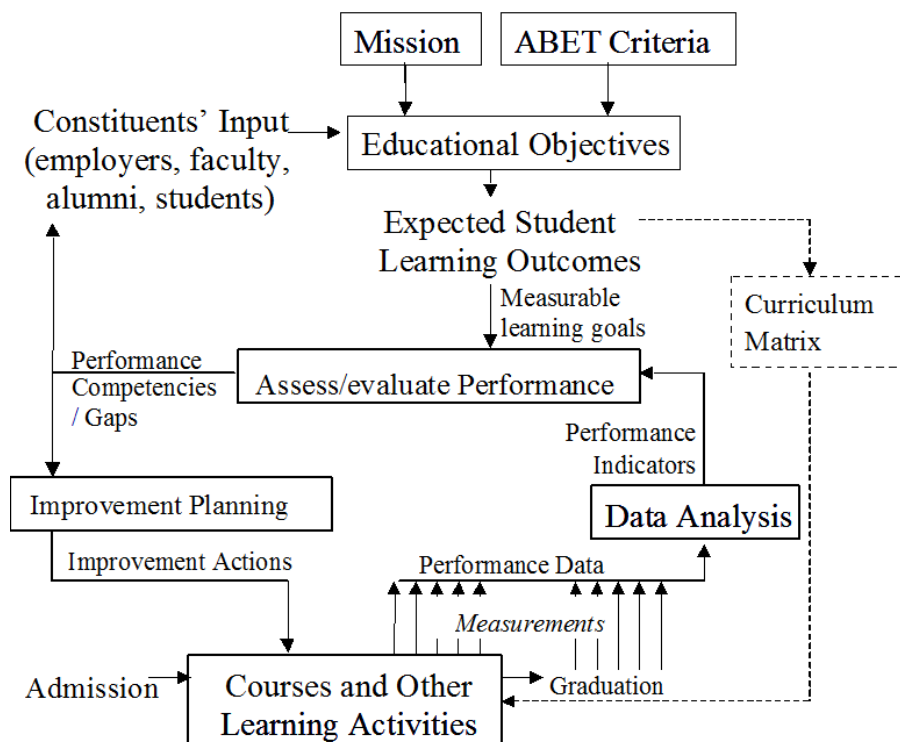


Figure 4-1. Overall flow chart for the ABE continuous improvement process used for the Biosystems Engineering degree program.

ABE Undergraduate Program Committee

The ABE Undergraduate Program committee is charged with ensuring that the Biosystems Engineering curriculum provides students with the experience necessary to meet the Biosystems Engineering Program Educational Objectives and the Program Outcomes. Specifically, the charges for this committee are:

1. Review, plan, revise, and update courses and advisory materials for the academic undergraduate programs of the department; ensure that curriculum is maintained to meet ABET Criteria.
2. Review departmental offerings in computer classes (ABE 120, ABE 205, and ABE 221) and ensure that they are current, appropriate, and meet the needs of both the ABE department and other relevant programs.
3. Develop a strong program of recruiting and placement for undergraduate students.
4. Provide advice to the department on how best to use funds provided by the differential tuition paid by Biosystems Engineering students with advanced standing; review year-end report of how differential tuition funds were spent to the benefit of the undergraduate program.
5. Identify and nominate deserving undergraduate students for College and University Awards.

6. Encourage students to apply for scholarships available to undergraduate students.
7. Actively seek to establish new and continuing sources of funding for such scholarships.
8. Participate on both CALS and ENGR Undergraduate Studies Committees.

This committee is comprised of faculty appointed by the Department Head and ABE Academic Program Coordinator. Past Department Heads have also included one undergraduate student for representation. Courses and curriculum issues are first brought to the Departmental committee which, in turn, makes recommendations to the ABE faculty as a whole. Upon approval by the ABE faculty, any curriculum changes are forwarded to the College of Engineering Undergraduate Studies Committee. The chair of the Biosystems Engineering Curriculum Committee serves as the Departmental representative to the ENGR Undergraduate Studies Committee.

College of Engineering Undergraduate Studies Committee

The Undergraduate Studies Committee consists of one faculty member selected by each department from the corresponding departmental committee, two staff members selected by the College Staff Team, and a student representative selected by the Engineers' Council. The Academic Dean serves as an ex-officio member of this committee. The Dean convenes the first meeting of each academic year, when necessary, and arranges for the election of a chair from the membership of the committee.

The primary function of the Undergraduate Studies Committee is to deal with curriculum development and other matters concerning undergraduate studies that involve multiple programs within the College or cannot be appropriately dealt with at the department level. This committee also serves as a forum for communicating and discussing curriculum changes affecting more than one department. Additionally, the Engineering Department at Pima Community College (located only several miles from the UA campus) is invited to assign a faculty member to serve as a non-voting member of the committee. Having this participation by Pima CC has been fundamental to ensuring course translation across institutions.

A.2. Documentation

The assessment process for the biosystems engineering program utilizes many tools. Documentation is provided below and in the attached appendices. Copies of reports and examples of student work will be made available to the evaluation team upon the site visit.

The BE Assessment Process and Assessment Tools:

Figure 4-1 provided an overview of the continuous improvement process, a critical element of which is the assessment process. The Agricultural and Biosystems Engineering Department has developed and maintained an assessment process which includes the following assessment tools:

1. **Documentation that students are completing courses required in the curriculum:** The BE curriculum is specifically designed to provide formal coursework and educational experiences, which addresses each of the expected learning outcomes. The matrix in Table 4-3 illustrates how specific courses and electives address each of the program outcomes.

- a) Students must complete all required courses in the curriculum provided in Appendix E1. The student must complete the curriculum with an overall GPA of 2.000/4.000 as well as an overall GPA of 2.000/4.000 in all ABE courses.
 - b) The University of Arizona maintains a Student Academic Advisement Report (SAAR), which shows student progress towards completing degree requirements. These progress reports are reviewed each semester for each student by faculty advisors to ensure that the students are making reasonable progress. Appendix E3 provides an example of a SAAR for a student near graduation.
2. **Pass/fail data for Fundamentals of Engineering (FE) exams from the State Board of Technical Registration:** We utilize the performance of our students and graduates on the FE exam as an added measure of how well we are achieving our desired learning outcomes. We require that all graduating seniors take the FE exam. Individual student scores are compared with a metric of satisfactory performance shown in Table 4-5. We obtain a summary of student performance on the sub-topics of the exam. This information is provided in Tables 4-2, 4-3, and 4-4 and in Figures 4-2 and 4-3.
3. **Exit surveys administered to graduating seniors during their final semester:** Graduating seniors are required to complete an “exit” survey near the end of the semester in which they are graduating. The questionnaires used in this survey query students on how well they believe their educational experience has addressed each of the desired program outcomes. The questionnaires ask questions related to involvement in professional societies and their participation in internships. Students respond to each question by responding; *exceptionally well*, *more than adequately*, *adequately*, and *less than adequately*. A sample of this questionnaire, administered by the College of Engineering, is provided in Appendix G1. (Please note that this is an online survey, and Appendix G1 displays question 42, *To what degree did your engineering education enhance your ability to: ...* There are 24 items in the list. There are 62 total questions in the entire survey).
4. **Surveys sent to BE alumni after graduation:** Questionnaires were sent to alumni who had graduated between 2009 and 2015. In addition to a request to “rate” how well their educational experience achieved the program outcomes, they are asked specific questions about whether or not their educational experience met their career needs, what they suggest be changed and whether or not there was topical material that they learned on the job that should have been included in their education but was not. This report presents the results of the surveys. An example of the questionnaire is provided in Appendix G2.
5. **Student evaluations of ABE classes through a University Administered Teacher – Course Evaluation (TCE):** This evaluation is administered each time a class is offered and provides information about the instructor as well as course content. For our assessment process we have chosen to focus primarily at results of four of the questions. A summary is presented in Tables 4-8 and 4-9.

- Q1. What is your overall rating of this instructor's teaching effectiveness?
 Q2. What is your overall rating of this course?
 Q3. How much do you feel you have learned in this course?
 Q4. What is your rating of this instructor compared with other instructors you have had?

6. **Results of a *Comprehensive Academic Program Review*:** The University of Arizona requires that each academic program undergo a comprehensive review every seven years. The current cycle is such that this review provides a thorough *intermediate time frame* evaluation of the Biosystems Engineering program as well as other programs of the Department (graduate ABE and undergraduate agricultural systems management programs). The most recent such review was undertaken during the 2015-2016 academic year with the resulting report presented to the Department and the University Provost in April 2016. We view this review as an important element of our Program Assessment process. A summary of those recommendations are presented in Appendix H.
7. **Evaluation of design projects by representatives from industry/agencies:** Beginning with the Spring 2010 semester, we included outside representatives from industry or appropriate government agencies in the evaluation of the design projects of our seniors, specifically as they relate to the desired program outcomes and professional component. We have found individuals from both industry and government willing to participate and to provide substantial feedback to the students.
8. **Evaluation of performance criteria in individual courses:** ABE faculty developed a quantitative process to assess student performance to meet program outcomes as assessed in individual courses. Assessments were made in multiple courses using a variety of tools including homework, projects, exams, presentations, and laboratory exercises. A summary of this methodology is presented in Appendix L, and the results of the assessments are summarized in Tables 4-12 and 4-13 and in Appendix M.
9. **Periodic review of assessment outcomes by a standing faculty committee each year:** The Department has established an ABE Academic Program Assessment Committee which has the responsibility to collect and evaluate the results of the surveys, advisory council recommendations, learning outcomes, design project judge's evaluations periodically and reporting those results to the faculty and the advisory council. This report is usually provided at the annual faculty retreat in the Spring semester and to the fall meeting of the advisory council. The assessment committee may also make recommendations to the faculty as a whole or to the curriculum committee about suggested steps to take to improve the program as a result of the assessment process.

A.3. Achievement of Program Outcomes

Metric Goals for Successful Achievement Levels

General Criteria for Assessing Program Achievement Levels

The general criteria established by the BE program for assessing achievement levels is summarized in Table 4-1. In this assessment scheme, a rating of 2 is the minimum level of quality of outcomes

necessary to produce graduates that will ultimately achieve the program educational objectives following their graduation.

General qualitative and quantitative criteria for each achievement level are given. Quantitative criteria are based on a *target* value or score, to which the score is compared. The target depends on the specific assessment tool in question. For example, in the assessment of FE exam results, the *score* achieved is the average score of BE program students while the *target* score is the national average score achieved by all agricultural or biological engineering program students. Comparisons of scores achieved to targets may be done directly (e.g. whether the score achieved meets or exceeds target) or through a calculated Index (e.g. $85 \leq \text{Index} < 100$), where Index is the ratio of Score to Target ($\text{Index} = 100 \times \text{Score}/\text{Target}$).

Table 4-1. General criteria for assessing achievement of learning outcomes and program education objectives.

Achievement Level		Criteria for Assessing Achievement Levels			Interpretation and Actions Indicated
Numeri c	Verbal	Qualitative	Quantitative		
		Accept-ability	Score vs Target	Index = 100X Score /Target	
1	Very Low	Not Acceptable	Score achieved is more than 30% below Target	Index below 70	Inadequate. Program/process component significantly below the norm. Corrective action needed. Continued performance at this level must be prevented.
2	Low	Barely Acceptable	Score achieved is 15% to 30% below target	Index between 70 and 85	Borderline adequate. Fails to measure up to the norm. Further investigation is warranted. May require corrective action.
3	Mediu m	Fully Acceptable	Score achieved is no more than 15% below target	Index between 85 and 100	Adequate. Program/process component meets or nearly meets the norm. No corrective action needed. Consider action to strengthen as time and resources permit.
4	High	More than Acceptable	Score achieved meets or exceeds target	Index between 100 and 115	Positive point. Program/process component exceeds the norm. No corrective action required. Ensure that changes elsewhere do not adversely affect this program/process component
5	Very High	Exemplary	Score achieved exceeds target by 15% or more	Index above 115	This component is a major strength for the program/process. No corrective action required. Possible feature to be emphasized in external communications, or role model for other program/process components.

A.4. Assessment Results

FE Exam Results

Table 4-2 displays the results of FE exams taken by ABE/BE students in 2010-2013 provided by the State Board of Technical Registration. A summary comparison of student performance on the FE exam to the target performance is presented in Table 4-3 and Figure 4-2. FE exam format and scoring has been changed since 2014, thus the results for 2014 and 2015 are presented in Table 4-4 and Figure 4-3.

Overall for years 2010-2013, scores of the BE students averaged 97.2% of the national average of the scores of all biological engineering students thus achieving performance level 4 for the program as a whole. Performance levels on specific topic areas were generally 3's and 4's. The lowest indices were obtained for strength of materials (index of 87.3), engineering mechanics (index of 87.7). There is sizeable variation from year to year, especially in the fluid mechanics which has a low index of 64.2 in 2011 while a high index of 96.9 in 2013, with an average index of 84.4. The highest index were from probability and statistics (109.0), advanced engineering math (108.7), chemistry (107.4), math (101.1), biology (103.9), computers (103.9) and thermodynamics (96.4). For the 2014-2015, scores of the BE students averaged 71% of the national average of the scores of all biological engineering students thus achieving performance level 2 for the program as a whole. However, performance levels on specific topic areas were generally 3's and 4's. A single student in 2015 performed very poor in the exam, thus affected the overall performance level. The lowest indices were obtained for material sciences (index of 0.88), dynamics (index 0.87) and fluid mechanics (index of 0.82) in 2014 while the lowest indices were in Chemistry (index of 0.83), Engineering economics (0.78), Ethics (0.77), Safety, Health and Environment (0.81) in 2015. One student performed very poor in Electricity and Magnetism in 2015, thus the average index for that topic is fairly low with index of 0.45, however for this topical area our students performed fairly well in the previous years. We will further investigate the reason for this and take action to improve. Our students performed fairly well on Math (0.98-1.07), Probability and Statistics (1.0-0.86), Instrumentation and Data Acquisition (1.17-1.05), Heat, Mass and Energy Transfer (0.96-0.95), Fluid Mechanics (0.82-1.03) in 2014 and 2015.

An important point to make is that the FE exam is required of all University of Arizona Biosystems Engineering students. We do not know to what degree this is required at peer institutions, but believe that if the exam were not required then predominantly it would be the strongest students who would take the exam and thus have a higher national index than if all students were required to take the exam. Despite this, UA BE students perform very well on the exam and have a pass / fail index of 98.8 for 2010-2013 period, clearly indicating that UA BE students performed at least as well as their peers. The pass / fail rates were low with 82 and 60%, compared to ABET comparator rates of 0.88 and 0.87, for years 2014 and 2015, respectively.

FE Exam topic areas do not directly coincide with the demonstrable abilities derived from ABET criterion 3 (a-k) and the specific program criteria for biological and similarly named engineering programs. However, as shown in Table 4-8, they are related and hence can serve to assess program performance in certain of the demonstrable ability areas. From this table, it can be seen that the FE Overall exam results indicate a medium to high (average 3.3) level of achievement on eight Learning Outcomes (except d, g, i), indicating that these outcomes are being achieved.

Comments. Having biology, thermodynamics, probability and statistics, math, heat, mass and energy transfer, instrumentation and data acquisition as the strengths of our students performance is no surprise. These are major emphases of required and elective courses in our program. Thermodynamics and heat transfer are a primary foci as required topics in ABE 284 while transport phenomena has been the primary focus of one course (ABE 484, until 2012, then changed to AME 431 or 432 with heat transfer focus). These topics are key components of many of our design elective courses.

The weakness in electricity and magnetism parallels the generally poor feedback received on the physics sequence at the University of Arizona (Phys 141 = statics; Phys 241 = electricity and magnetism). We believe that this also impacts the student performance on strength of materials (an application of Phys 141 skills). We have been placing more emphasis in ABE 447 (the course which predominantly utilizes electricity and magnetism). Student feedback on the ABE 447 course has greatly increased past several years, and so we are confident that our students have a good understanding of application of electricity and magnetism in general.

An important point to raise here is that the FE scores shown here are for nearly all of the Biosystems Engineering students in our program. We made taking the FE exam a requirement connected with the ABE 496a and ABE 498b courses. It is not necessary that students pass the exam but that they register while taking 496a and take the exam while taking 498b. Other biological engineering programs across the country may not require that all of their students take this exam (we know of few that do). Most likely if students are voluntarily taking the FE exam they are most likely the stronger students and performing statistically better than if all students were required to take the exam. Given this perspective, our students having a passing rate equivalent to their peers across the country is certainly acceptable and is perhaps a desirable goal.

Table 4-2. Index of UA BE scores to national average Biological Engineering scores on FE Exam for 2010-2013.

University of Arizona Biosystems Engineering FE Scores 2010-2013																		
Year	n	Topic Area																
		Math	Prob&Stats	Chemistry	Computers	Ethics	Engineering Economics	Engineering Mechanics	Strength of Materials	Material Properties	Fluid Mechanics	Electr&Magnetism	Thermo	Advanced Eng Math	Biology	Apps of Eng Mechcs	Engin of Matrs	% Pass.
		Average % Correct Response and Index in Topic Area																
2010	13																	
UA-BE Avg		69.0	65.5	70.8	75.5	81.7	59.9	68.4	48.8	45.7	63.1	42.2	47.2	70.0	46.0	43.7	46.0	85.0
US Avg		61.7	61.7	73.4	70.3	81.7	56.3	69.0	51.2	55.9	65.2	47.8	47.3	60.7	69.0	51.0	60.3	74.8
Index		111.9	106.2	96.5	107.5	100.0	106.4	99.1	95.3	81.7	96.8	88.2	99.6	115.4	66.7	85.6	76.2	113.6
2011	10																	
UA-BE Avg		67.3	69.5	67.7	82.5	67.7	62.7	51.8	55.0	51.0	35.8	41.0	45.8	79.3	88.0	37.0	38.7	78.0
US Avg		69.3	66.0	72.7	72.5	74.0	66.2	59.5	51.7	58.0	55.8	53.5	52.8	74.0	68.7	48.0	45.7	80.0
Index		97.1	105.3	93.1	113.8	91.4	94.7	87.1	106.5	87.9	64.2	76.6	86.8	107.2	128.2	77.1	84.7	97.5
2012	7																	
UA-BE Avg		74.5	65	73.5	75	89	68.5	55.5	39	48	49.75	41.25	49.75	68	91.5	55	57	75
US Avg		77	63.5	73.5	78.5	84.5	72.75	58	53	57	62.25	57.25	57	73	83	63	66.5	82
Index		96.8	102.4	100.0	95.5	105.3	94.2	95.7	73.6	84.2	79.9	72.1	87.3	93.2	110.2	87.3	85.7	91.5
2013	5																	
UA-BE Avg		68	66.25	73	75.5	80	73.25	69.5	39.5	79.5	69.75	60.5	68.75	93.5	62.5	59.5	66	75
US Avg		72	54.25	68	76.5	82	61.75	58.5	53.5	64.5	72	52.25	61.5	78.5	56.5	59	60	81
Index		94.4	122.1	107.4	98.7	97.6	118.6	118.8	73.8	123.3	96.9	115.8	111.8	119.1	110.6	100.8	110.0	92.6
Weighted Average	9	100.1	109.0	99.2	103.9	98.6	103.5	100.2	87.3	94.3	84.4	88.2	96.4	108.7	103.9	87.7	89.2	98.8
Performance Level		4	4	4	4	3	4	4	3	3	3	3	3	4	4	3	3	3

Table 4-3. Index of UA BE scores to national average Biological Engineering scores on FE exam.

Year	# of students	Math	Prob& Stats	Chemistry	Comp	Ethics	Engin Econ	Engin Mech	Strength of Matr	Material Props	Fluid Mechs	Electr& Magsm	Thermo	Advncd Enging Math	Biology	Apps of Enging Mechcs	Engin of Matr	% Pass.
2010	13.0	111.9	106.2	96.5	107.5	100.0	106.4	99.1	95.3	81.7	96.8	88.2	99.6	115.4	66.7	85.6	76.2	113.6
2011	10.0	97.1	105.3	93.1	113.8	91.4	94.7	87.1	106.5	87.9	64.2	76.6	86.8	107.2	128.2	77.1	84.7	97.5
2012	7.0	96.8	102.4	100.0	95.5	105.3	94.2	95.7	73.6	84.2	79.9	72.1	87.3	93.2	110.2	87.3	85.7	91.5
2013	5.0	94.4	122.1	107.4	98.7	97.6	118.6	118.8	73.8	123.3	96.9	115.8	111.8	119.1	110.6	100.8	110.0	92.6
Average	8.8	100.1	109.0	99.2	103.9	98.6	103.5	100.2	87.3	94.3	84.4	88.2	96.4	108.7	103.9	87.7	89.2	98.8
Std. dev.	3.0	6.9	7.7	5.3	7.2	5.0	10.0	11.6	14.1	16.9	13.6	17.0	10.3	10.0	22.7	8.5	12.6	8.8

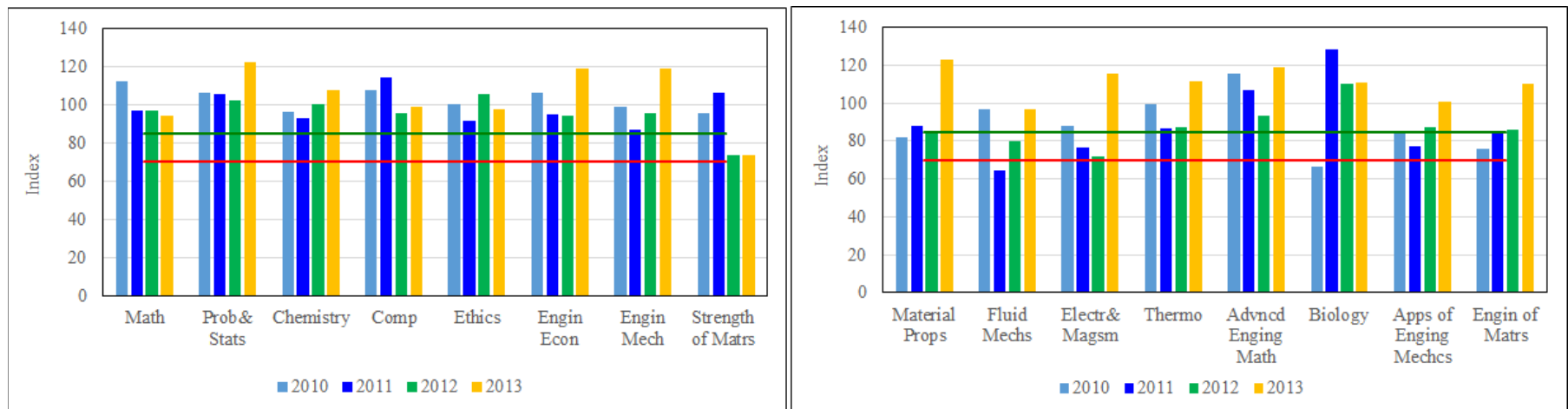


Figure 4-2. Graphical representation of indices for BE students on the FE exam.

Table 4-4. Ratio scores of UA Biosystems Engineering students on FE Exam for 2014 and 2015.

Topics	Ratio Score 2014 (Inst. Ave. P-Index / ABET Comp. P-Index)	Performance level	Ratio Score 2015 (Inst. Ave. P-Index / ABET Comp. P-Index)	Performance level
Math & Adv. Engr. Math	0.98	3	1.07	4
Prob & Stats	1.00	4	0.86	3
Chemistry	1.02	4	0.83	2
Inst. & Data Acquisition	1.17	5	1.05	4
Ethics & Prof. Prac.	1.02	4	0.77	2
Safe., Health & Envr.	1.14	4	0.81	2
Engr. Econm.	0.93	3	0.78	2
Statics	0.91	3	1.0	4
Dynamics	0.87	3	0.97	3
Strength of Matrs	0.94	3	0.95	3
Material Sci.	0.87	3	0.88	3
Fluid Mechanics	0.82	2	1.03	4
Elect., Power & Magn.	1.05	4	0.45	1
Heat, Mass & Enrg. Trans.	0.96	3	0.95	3
	Institution	ABET Comparator	Institution	ABET Comparator
# of Examinees Taking	11	125	5	100
# of Examinees Passing	9	110	3	87
% Examinees Passing	82%	88%	60%	87%

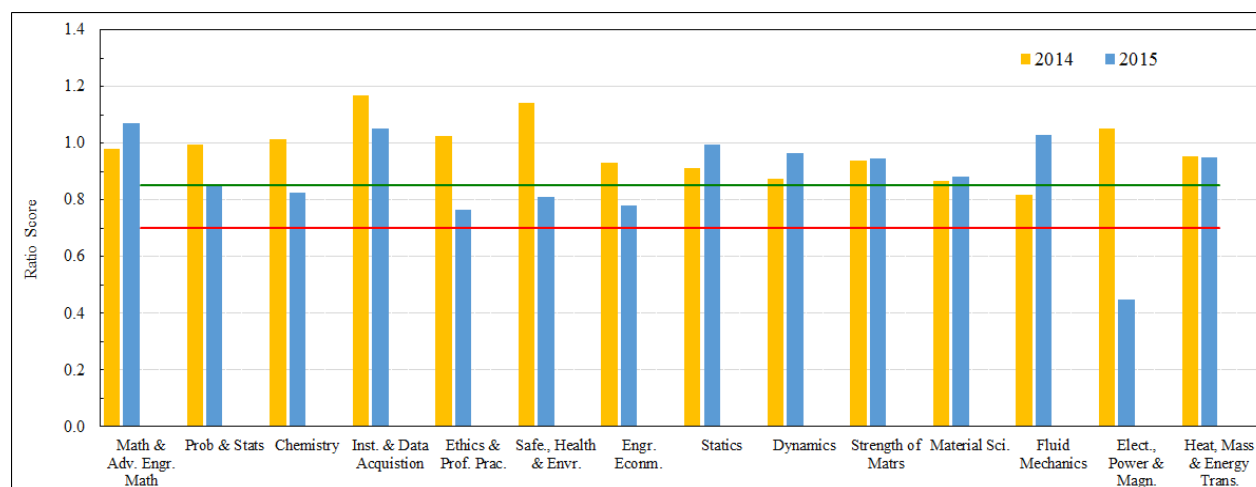


Figure 4-3. Graphical representation of ratio scores of BE students on FE exam for 2014 and 2015.

Table 4-5 quantifies how student performance on the FE exams is used to characterize to what degree the BE Learning Outcomes have been addressed. Only eight outcomes can be adequately addressed with this tool. An average of scores in each subcategory is used to determine an overall score for that outcome. Student performance rates from a 2.7 to 4.5 with an overall average of 3.3 which we consider based on Table 4-1 to be fully acceptable. Our students perform on par with their peers at other institutions.

Table 4-5. Achievement in desired ability areas as determined by FE exam results.

	<i>Outcomes Achievement as Determined by FE Exam Results (2010-2015)</i>															
	Topic Area															
	Biology	Chemistry	Computers	Inst.&Data Aq.	Engin mech. ¹	Elect. & Mag	Engr Econ	Ethics	Fluid Mech	Mat. Sci/Str/ Mat. ³	Math ²	Thermo	Heat, Mass, Energy Trs.	Prob & Stat	Safety&Health Env.	Prog. Perf. Level
	FE Exam Performance Levels in Tested Topic Areas															
	4	3.3	4	4.5	3.4	2.7	3.0	3.0	3.0	3.0	3.5	3	3.0	3.7	3.0	3.3
	FE Exam Performance Levels for Related Abilities															Avg
BE Learning Outcomes																
Apply knowledge of mathematics and science to solve problems	4	3.3	4	4.5	3.4	2.7			3.0	3.0	3.5	3	3.0	3.7		3.3
Design and conduct experiments and analyze and interpret data				4.5												4.5
Design a system, component, or process to meet desired needs within realistic constraints			4		3.4											3.4
Function on multidisciplinary teams																N/A
Identify, formulate, and solve engineering problems			4		3.4		3.0		3.0	3.0		3				3.1
Understand professional and ethical responsibility								3.0								3.0
Communicate effectively																N/A
Understand the impact of engineering solutions in a global, economic, and societal context															3.0	3.0
Recognize the need for and the ability to engage in lifelong learning																N/A
Have a knowledge of contemporary issues															3.0	3.0
Use techniques, skills, and modern engineering tools necessary for engineering practice				4.5												4.5
1 = comprised of engineering mechanics, statics and dynamics 2 = comprised of mathematics and advanced engineering mathematics 3 = comprised of strength of materials, material properties, engineering of materials, material science. NA = not assessed by this tool																

Senior Exit Surveys

All seniors graduating during an academic year complete the survey regardless of the time of graduation. The senior exit survey is primarily aimed at assessing the level of achievement of learning outcomes and thus specifically asks graduating seniors to “self-assess” their level of achievement of each of the outcomes. We use the senior exit survey results, together with TCE results, FE exam results and alumni surveys, and to gauge longer term trends in how we are meeting outcomes and to determine where adjustments may be needed. Table 4-6 shows the results of these surveys, conducted with 53 students, since the last accreditation from 2010-2014.

Table 4-6. Results of Senior Exit Surveys for graduates (n=53).

Outcome	To what degree did your engineering education enhance your ability to:	Exceptionally Well	More than Adequately	Adequate	Less than Adequately	Adequate and Higher
a	Apply knowledge of mathematics and science to solve problems	25.1%	44.0%	28.9%	2.8%	97.9%
b	Design and conduct experiments and analyze and interpret data	24.5%	33.4%	29.6%	12.6%	87.5%
c	Design a system, component, or process to meet desired needs within realistic constraints	30.2%	22.6%	41.5%	5.7%	94.3%
d	Function on multidisciplinary teams	26.4%	24.5%	35.8%	11.3%	86.8%
e	Identify, formulate, and solve engineering problems	26.4%	45.3%	26.4%	1.9%	98.1%
f	Understand professional and ethical responsibility	41.5%	26.4%	30.2%	1.9%	98.1%
g	Communicate effectively	35.8%	34.9%	24.5%	4.7%	95.3%
h	Understand the impact of engineering solutions in a global, economic, and societal context	22.8%	31.3%	32.3%	11.9%	86.4%
i	Recognize the need for and the ability to engage in lifelong learning	18.9%	28.3%	50.9%	0.0%	98.1%
j	Have a knowledge of contemporary issues	28.3%	43.4%	26.4%	0.0%	98.1%
k	Use techniques, skills, and modern engineering tools necessary for engineering practice	15.1%	28.3%	37.7%	15.1%	81.1%
	Average	26.8%	33.0%	33.1%	6.2%	92.9%

The senior exit survey results shows that the perceived achievement levels have been high for nearly all outcomes. In general, BE seniors appear to be highly satisfied with their educational training. We should note that majority of the satisfaction levels (ave. adequate or higher) are equal or higher than 90% indicating a high achievement for outcomes a, c, f, g, i, j.

We can then note that the lowest level of achievements are the 81.1%, 86.4% in the outcome “have a knowledge of contemporary issues,” “understand the impact of engineering solutions in a global, economic, and societal context,” “function on multidisciplinary teams,” “use techniques, skills, and modern engineering tools necessary for engineering practice” which indicates these would be areas in which to focus improvement efforts. We are pleased to note that the highest average ratings are for the ability to apply math and science to solve engineering problems; the ability to design a system, component or process to meet desired needs within realistic constraints; and the ability to design a system or component. It seems that the students are graduating from the program with a confidence in their ability to solve problems and create/develop/do design. Their ability to actually solve these types of problems is also borne out in the results of the FE exams.

Alumni Surveys

Alumni surveys were implemented in the fall of 2015. The surveys were sent to a total of 93 alumni who had graduated between 2009 and 2015. We received 22 responses with respondents from each of the seven years. The survey asked the same questions of alumni as were asked of the graduating seniors. In addition, there are several questions asked by the College of Engineering relating to the student’s experience in the College and the University. Table 4-7 illustrates the results of surveys.

The results shows that all ratings are above 4.0 indicating a high level of achievement in all categories. The alumni gave highest scores to understand professional and ethical responsibility; understand the impact of engineering solutions in a global, economic and societal context; design a system, component or process to meet desired needs within realistic constraints, and function on multidisciplinary teams, which are skill that our advisory council tells us is absolutely necessary.

Table 4-7. Results of Alumni Surveys for graduates between 2009 and 2015 (n=22).

Outcome	To what degree did your engineering education enhance your ability to:	Response
a	Apply knowledge of mathematics and science to solve problems	4.1
b	Design and conduct experiments and analyze and interpret data	4.2
c	Design a system, component or process to meet desired needs within realistic constraints	4.3
d	Function on multidisciplinary teams	4.3
e	Identify, formulate and solve engineering problems	4.2
f	Understand professional and ethical responsibility	4.5
g	Communicate effectively	4.2
h	Understand the impact of engineering solutions in a global, economic and societal context	4.4
i	Recognize the need for and the ability to engage in lifelong learning	4.3
j	Have a knowledge of contemporary issues	4.0
k	Use techniques, skills and modern engineering tools necessary for engineering practice	4.0
5=high, 4=moderately high, 3= moderate, 2=low, 1=not at all.		

Student Evaluations of ABE Classes through a University Administered Teacher – Course Evaluation (TCE)

Every class at the University of Arizona is evaluated each time it is taught using an instrument developed by the Office of Instructional Assessment. The Teacher-Course Evaluation (TCE) is administered by that office and results are posted on a web site (<http://tce.arizona.edu/>) which can be accessed by anyone with a University of Arizona account and password. Thus, students as well as others can access information about classes in all departments. While the questionnaire addresses many issues, four questions are useful to the outcomes assessment for our Biosystems Engineering program. These questions are:

1. What is your overall rating of this instructor's teaching effectiveness?
2. What is your overall rating of this course?
3. How much do you feel you have learned in this course?
4. What is your rating of this instructor compared with other instructors you have had?

This information is useful when used in conjunction with other assessment tools, especially the senior exit survey. We focus most on the trends observed rather than making too much emphasis on year to year variation, especially when there are small changes in course content, student population, and the faculty teaching the course.

TCE of Required ABE Classes

Table 4-8 shows results of responses to four questions shown above for ABE required courses (those required courses taught by department faculty). These courses are required of all BE majors, regardless of their particular area of focus and form the core uniqueness of the BE curriculum. As was the case with the senior exit and alumni surveys, the rating scale is from 1-5 with 1 being *little or none* and 5 denoting *a lot* (or high level of achievement). Again, we use this data to *track* courses and identify trends. Thus, it does not make sense to look at the averages of the results since 2010 but to identify areas where problems may be occurring and where change is required. As can be seen from the table, ABE 423 course had low scores for two consecutive years. The reason for this is that the original course instructor left the department in 2012, and another ABE faculty started teaching the course for the 1st time in 2014 and then 2015. Thus, it took some time for the new instructor to adjust the course. Considering the suggestions from the students based on TCE comments, emphasizes modeling of biological systems was transformed to fit the needs of the biosystems engineering students and included different programming components. Thus, the TCE scores indicated some improvements in 2016. The rest of the required courses in general consistently have ratings with 3-4 or greater.

TCEs of Elective ABE Classes

Table 4-9 shows results of responses to the TCE question for those classes taught by ABE faculty which are elective classes for the major. These classes fall primarily into two main groups: biological/biosystems related classes and water/natural resources related classes. Thus ABE 426, 452, 455, 456, and 458 represent courses related to water/natural resources and ABE 479, 481, 483, 486, and 489 are courses related to biological/biosystems. These ratings are generally in the medium-high to high-very high category with average scores for each course well above 3.0. This is not too surprising since students take these courses by choice and generally feel that they relate more directly to their focus area than do some of the “required” courses. Table 4-9 provides results of responses for these same set of classes (elective ABE classes) for the first question (*overall rating of the course*). Thus, from the student’s perspective at least, these courses appear to be achieving their purposes, and this is somewhat borne out by both the senior exit survey results and the alumni survey results which have similar ratings in the two learning outcome areas *can analyze and design biological processes and systems* and *can analyze and design natural resource systems*.

Table 4-8. TCE (Teacher Course Evaluation): **ABE required courses.**

Course	ABE 201 Intro to Biosystems				ABE 205 Engr. Anlty. Comp. Skills			
Calendar year	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2010	*	*	*	*	4.00	3.40	3.70	4.00
2011	*	*	*	*	3.80	3.30	3.30	3.90
2012	4.20	3.50	3.50	2.90	3.80	3.20	3.50	4.00
2013	3.10	2.80	2.70	2.70	2.80	2.50	2.90	3.30
2014	4.30	3.80	4.0	3.90	3.10	2.80	3.20	3.20
2015	4.01	3.65	3.33	3.65	3.20	2.70	3.10	3.70
2016					3.90	3.30	4.0	3.40
Average	3.90	3.44	3.38	3.29	3.27	3.03	3.39	3.79

Course	ABE 221 Introduction to CAD				ABE 284 Biosystems Thermal Engr			
Calendar year	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2010	3.60	2.70	3.50	4.00	4.40	4.20	3.90	4.20
2011	3.60	3.50	3.70	4.30	3.90	3.60	3.50	3.70
2012	3.30	3.20	3.50	4.10	3.90	3.60	3.50	3.90
2013	3.60	3.20	3.40	4.00	3.30	2.90	3.10	3.40
2014	3.25	2.85	3.60	4.00	3.90	3.30	3.30	3.70
2015	3.43	3.52	3.55	3.09	3.70	3.21	3.43	3.24
2016	3.26	3.31	3.89	2.84				
Average	3.43	3.18	3.59	3.76	3.74	3.32	3.37	3.59

Course	ABE 423 Biosys. Anlysis+Design				ABE 447 Sensors & Controls			
Calendar year	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2010	4.60	4.50	4.30	4.10	4.40	4.10	4.40	4.60
2011	4.50	4.20	4.20	3.90	4.20	3.80	3.90	3.80
2012	4.30	4.00	3.80	3.70	3.30	3.20	3.20	3.30
2013	*	*	*	*	3.92	3.73	3.65	3.67
2014	2.30	2.00	2.40	2.50	3.90	3.50	3.50	4.20
2015	2.30	2.10	2.20	2.50	3.67	2.89	3.67	2.95
2016	3.22	3.00	2.89	2.89				
Average	3.50	3.30	3.30	3.30	3.90	3.50	3.70	3.80

Course	ABE 498A Biosys. Engr Design I				ABE 498b Biosys. Engr Design II			
Calendar year	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2010	3.60	3.30	3.40	3.20	*	*	*	*
2011	4.10	3.50	3.50	3.70	4.00	3.70	3.80	3.50
2012	*	*	*	*	4.30	4.10	4.20	4.30
2013	4.00	3.90	4.00	3.60	4.30	3.80	4.30	4.70
2014	3.40	3.00	3.00	3.40	*	*	*	*
2015	3.47	3.24	2.94	3.29	*	*	*	*
2016	3.47	3.24	2.94	2.94	3.25	2.58	3.75	3.08
Average	3.67	3.36	3.30	3.36	3.96	3.55	4.01	3.90

Note: Symbol “*” indicates the terms that the TCEs scores were not tallied due to low TCE participation and/or the course was not offered during that term.

Table 4-9. TCE (Teacher Course Evaluation): ABE elective courses.

Course	ABE 426 Watershed Engineering				ABE 452 Sustain+Innov. Global			
Calendar year	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2010	*	*	*	*	3.30	3.20	3.20	3.00
2011	4.30	3.80	4.10	4.00	*	*	*	*
2012	4.30	3.80	3.80	3.80	4.00	3.60	3.80	3.40
2013	4.40	4.10	4.20	4.00	4.00	3.60	3.60	3.80
2014	4.20	3.90	4.00	4.00	3.40	3.10	3.10	2.90
2015	4.19	4.19	4.00	4.19	3.10	2.70	3.00	2.70
2016	3.69	4.19	3.55	3.69	4.04	3.60	3.30	3.56
Average	4.18	4.00	3.94	3.95	3.71	3.32	3.36	3.27

Course	ABE 455 Soil+Water Rsrcs Engr.				ABE 456 Irrigation Sys. Design			
Calendar year	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2010	*	*	*	*				
2011	*	*	*	*	3.60	2.90	3.10	3.60
2012	*	*	*	*	*	*	*	*
2013	*	*	*	*	*	*	*	*
2014	4.60	4.40	4.20	3.80	5.00	4.80	4.20	3.80
2015	4.58	4.18	3.94	4.44	4.60	4.30	4.40	4.20
2016	4.58	4.17	3.94	4.34				
Average	4.59	4.25	4.03	4.19	4.40	4.00	3.90	3.87

Course	ABE 458 Soil WtInd Wstwr Reus				ABE 459 Design of onsite Wstwr Trtmnt Systms			
Calendar year	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2010	4.00	4.00	3.60	3.90	4.60	4.00	4.00	4.20
2011	*	*	*	*	*	*	*	*
2012	*	*	*	*	3.50	2.90	3.20	3.40
2013	*	*	*	*	*	*	*	*
2014	4.10	3.70	3.70	3.80	4.30	3.40	3.70	4.30
2015	4.20	4.10	3.90	3.80	3.72	3.44	3.56	3.40
2016	4.03	3.88	3.24	3.78	3.88	3.45	3.56	3.55
Average	4.08	3.92	3.61	3.82	4.00	3.44	3.60	3.77

Course	ABE 479 Appl Instrmt. in CEA				ABE 483 Cont. Environ. Systm			
Calendar year	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2010					3.40	2.90	2.60	2.90
2011	4.60	4.40	4.00	4.30	4.20	4.20	4.10	4.20
2012	4.60	4.40	4.60	3.80	4.30	4.00	3.90	3.90
2013	4.70	4.60	4.70	4.70	3.90	3.70	3.80	3.80
2014	4.90	4.10	4.10	3.70	4.20	3.80	3.70	3.90
2015	4.40	4.20	4.40	3.80	3.77	3.50	3.75	2.76
2016	4.80	4.60	4.45	4.55				
Average	4.67	4.38	4.38	4.14	3.96	3.68	3.64	3.58

Course	ABE 481A Engr/Biological Process				ABE 481B Cell+Tissue Engr.				ABE 486 Biomat-Tissue Interac.			
Calendar year	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2010	3.50	3.20	3.30	3.30	*	*	*	*	*	*	*	*
2011	2.90	2.60	2.90	2.90	*	*	*	*	3.60	3.50	3.70	4.10
2012	3.10	2.50	2.90	2.80	3.90	3.40	3.60	4.10	3.90	3.50	3.30	3.80
2013	3.10	2.60	2.80	2.80	3.00	2.60	2.80	3.10	*	*	*	*
2014	*	*	*	*	4.00	3.50	3.60	3.90	4.00	3.60	3.50	3.80
2015	*	*	*	*	4.10	3.60	3.50	4.30	3.19	2.66	3.52	2.89
2016	*	*	*	*	3.87	3.01	4.16	2.72				
Average	3.15	2.73	2.98	2.95	3.77	3.22	3.53	3.62	3.67	3.32	3.51	3.65

Note: Symbol “*” indicates the terms that the TCEs scores were not tallied due to low TCE participation and/or the course was not offered during that term. The ABE 481A course has not been taught by the ABE Faculty as of Fall 2014.

Results of a *Comprehensive Academic Program Review*

The University of Arizona mandates a comprehensive review of each academic program in the University every seven to ten years. This review differs considerably from an ABET Accreditation Review in that it investigates all academic programs in a department (both undergraduate and graduate) at the same time and with the same set of criteria. The primary criteria by which each program is reviewed are: *resource criteria* (adequacy of resources to effectively carry out departmental programs), *student selectivity* (adequacy of selection process for both undergraduate and graduate students to ensure quality) and *reputation of the faculty* (ranking and status of the faculty within their professions both nationally and internationally).

The most recent academic program review of ABE Department programs was conducted during Spring 2016. The process requires preparation of a *self-study* by department faculty and culminates with a two day on-site visit to the campus by a review team. The University of Arizona guidelines require that the review team include department alumni (Water Resources Engineer/Senior Project Manager at CH2M), a community member (Vice President, Wholesum Family Farms, Inc.), two internal reviewers from University of Arizona (Dept. Head School of Plant Sciences, and a faculty member from Department of Chemical and Environmental Engineering), and three external reviewers who are regarded as nationally recognized leaders in the fields covered by department programs (Dept. Head, Agricultural and Biological Engineering, the University of Illinois-Urbana Champaign; Chair, Agricultural and Biosystems Engineering, North Dakota State University; and Dept. Head, Agricultural and Biological Engineering, Purdue University).

The report of the Comprehensive Review Team from 2015-2016 is presented in Appendix H. In summary, the team reported favorably on our program. Relative to the undergraduate program, among the strengths identified were:

- The Department’s national ranking, 19th in the nation, considering the small size of the unit and all of the changes experienced (referring to two faculty leaving the department and forming of Biomedical Engineering Department and losing substantial amount of our students to that department).
- The Department’s active participation in general education with their offering of two general education courses and one service class, all with high enrollments,
- The impressive hands-on learning opportunities for undergraduate
- The strong emphasis in the Department to integrate teaching and research activities,
- Department’s 100% placement for undergraduate students, the significant number of honor students that are part of their program, their strong senior design program, and the access students have to the Department shop enabling them to “build anything”.

Among the recommendations provided relative to the undergraduate programs were:

- The Department’s emerging emphasis on systems/informatics/analytics should be considered as a potential strong integrator of the Department’s domains and core competencies,

- An additional 0.5 FTE staff position for student recruitment, retention, placement, and alumni relationships would strengthen the Department's undergraduate program. Explore strategic alliances and joint recruitment activities with other departments in College of Engineering, College of Agriculture and Life Sciences.
- Coordinate and increase activity and partnering with students from other departments in College of Engineering for students design projects and teaming up.

We have already started addressing some of the recommendation presented above and will continue our efforts in the coming years.

Evaluation of Design Projects by Representatives from Industry/Agencies

As part of our effort to improve our assessment process, we use a program of evaluation of senior design projects (ABE 498b) by engineers from industry or relevant government agencies. The evaluation is part of Engineering Design Day competition where our students are required to participate. They are evaluated by judges who are practicing engineers from both industry and government agencies. The judges are asked to review the design, the poster, and oral presentation by the design team. They are provided with an evaluation form and are asked to rate each project in several categories: *creativity of design, quality of design and implementation, engineering analysis, and effectiveness of the oral presentation*. Each of these categories is rated on a scale of 1-5, with 5 being superior and 1 being unsatisfactory. Every year for the past 6 years the ABE 498b had at least two teams participating in the competition with teams from the entire College of Engineering. ABE students won several awards almost each year in competition. Table 4-10 provides a summary of the evaluation of samples of projects that competed during 2010-2016.

The overall performance of our design teams in all the different categories they were judged was above the competent level which is defined by the *good* score. The data we obtain every year provides information for our assessment database that we continue to use for continuous improvements.

The overall average score is 3.7 indicating that these practicing engineers rated the senior design projects as being overall above “good” and close to “excellent.” Review teams consisted of a mix of engineers from a wide variety of disciplines who were asked to gauge numerous designs which spans the College of Engineering Senior design experience. An important difference between the ABE senior design projects and others judged on the same day lies in the budget made accessible to the students which is often less for the ABE teams than for ENGR teams. This difference is, in essence, due to larger corporate sponsors for the ENGR senior design teams.

Course Assessments

The ABE faculty developed a process for evaluating student performance in required and elective classes toward meeting our program outcomes (a-k). Each outcome is assessed in multiple courses and with multiple assessment tools including homework assignments, exams, projects, presentations, and laboratory exercises. The metric for assessment of each outcome is provided in detail in Appendix L. One example summary of the analysis for outcome “a” is shown below in Table 4-11 with all of the detailed assessment data from required courses are presented in Appendix M. A 1-5 scale with 5 being a high level of performance was utilized, following the format of Table 4-1. The metrics for each outcome are dependent on the quantifiable components which together

demonstrate competence in that specific outcome. Assessment was performed by the faculty member responsible for each required course (and of some elective courses). Assessment tools were selected by the individual faculty. A summary of the results of this course-based outcomes assessment, from required courses, is provided in Table 4-12 below. All outcomes were rated with scores in the range of 4.11 to 5.00. The metric for each score varies with the learning outcome and can be seen in more detail in Appendix M. These results indicate that faculty are quite satisfied with the levels of student performance, however some improvements in the course content or focus were made to several courses based on the observations of the instructor and feedbacks from the students.

Table 4-10. Summary of performance on Senior Design Projects as rated by external evaluators.

Year	Project title	Creativity of Design	Design	Engineering Analysis	Presentation	Average
2010	Solar Desalinization	4.7	4.5	4.5	4.8	4.6
2010	Algae Harvesting	3.9	4.3	4.1	4.1	4.1
2012	Portable Aquaponics	3.8	3.8	3.8	3.8	3.8
2012	Pilot Plant to Convert Waste Cooking Oil to Biodiesel	2.5	2.5	2.5	5.0	3.1
2012	Development of Very Quick PCR Device	3.8	5.0	5.0	5.0	4.7
2013	Rapid Temperature Gradient Based, Wire Guided PCR	4.8	4.1	3.6		4.2
2013	Hydroponic Barley Fodder System	5.0	4.2	4.0		4.4
2013	Extraction System for Sweet Sorghum	3.5	4.0	2.5		3.3
2014	Archimedes Screw Pump	3.8	4.2	3.8	4.0	4.0
2014	Onion Bulb Harvester	3.4	3.5	3.0	3.8	3.4
2014	Concentration Sweet Sorghum Juice via Reserves Osmosis	2.9	2.9	2.5	3.1	2.9
2014	Tanque Verde High School Aquaponics System	3.0	3.8	3.1	3.7	3.4
2015	Lettuce Wash Water Recycle System	3.6	3.9	3.4	3.6	3.6
2015	De-Watering System for Algae	3.8	3.9	3.4	3.6	3.7
2015	Smart Hoophouse	3.6	4.0	3.9	3.6	3.8
2015	Graywater Utilization System	2.5	2.3	2.2	3.0	2.5
2016	Cont. Env. Agric. Plant Production	4.2	4.5	3.7	5.0	4.4
2016	Cont. Env. Agric. Irrigation Infrastructure	3.6	4.0	3.6	4.4	3.9
2016	Cont. Env. Agric. Mushroom Production	3.0	4.0	3.2	3.2	3.4
2016	Optically-Paired Microfluidics for <i>E. coli</i>	3.1	3.0	2.6	3.3	3.0
2016	Macadamia Nut Harvester	3.7	4.0	3.2	3.8	3.7
Average		3.6	3.8	3.4	3.9	3.7
Scores: 5= superior 4= excellent 3= good 2= marginal 1= unsatisfactory						

Table 4-11. Total summary of Outcome “a” in multiple ABE required courses.

a) Can apply mathematics, science and engineering principles to solve problems				ABE 423 SP 15/16		ABE 205 SP 15/16		ABE 284 FA 15		Weighted average
				Assessed by: P. Waller		Assessed by: P. Waller		Assessed by: M. Kacira		
Performance Criteria	Level 5	Level 3	Level 1	Weighted average	Total # students	Weighted average	Total # students	Weighted average	Total # students	
Mathematical reasoning	Applies higher level mathematics (through differential equations) and or scientific principles of chemical, biological, physical systems to solve biosystems engineering problems	Can apply higher level mathematics with assistance to set up biosystems engineering problems	Poor skills in the use of higher level mathematics and in the connection between mathematical models and physical systems	3.84	15	3.01	28	4.25	161	3.70
Significance of data	Presents quantities with appropriate units and significant digits	Most quantities are expressed in proper units and with appropriate significance	Quantities often reported with incorrect or missing units and inaccurate significance	4.21	14	n/a	28	4.45	109	4.33
Utility of answers	Recognizes practical significance of answers (size, shape, rate are reasonable in number)	Usually provides a correct answer but does not readily check practicality	Poor understanding of interpretation of answers	4.21	14	n/a	28	3.85	55	4.03

Weighted Average = 4.13

Table 4-12. Summary of student learning outcomes assessed in required ABE courses.

BE Learning Outcomes		2015-2016	Assessed in Required ABE Courses
a	Can apply mathematics, science and engineering principles to solve problems	4.12	205, 284, 423, 498a, 498b
b	Can design and conduct experiments and analyze and interpret data	4.20	447
c	Can design a system, component or process to meet desired needs within realistic constraints	4.77	498a, 498b
d	Can function on multidisciplinary teams	4.37	201, 423, 498a, 498b
e	Can identify, formulate and solve engineering problems	4.11	284, 498a, 498b
f	Has an understanding of professional and ethical responsibility	4.82	496
g	Can communicate effectively	4.57	201, 496, 498a, 498b
h	Has the broad education necessary to understand the impact of engineering solutions in global, economic, environmental and societal context	4.85	201, 496
i	Recognize the need for and the ability to engage in lifelong learning.	5.00	201
j	Has a knowledge of relevant contemporary issues	4.96	201, 496
k	Can use the techniques, skills, and modern engineering tools necessary for engineering practices.	4.22	205, 221, 423, 447, 498a, 498b
Scores: 5 = highest level of performance, 3 = adequate level of performance, 1 = poor level of performance			

While the results appear to be markedly similar in scores, the individual components of the analysis provide some useful insight into assessing components of the Biosystems Engineering program. The assessment results showed average rates ranged from 4.11-5.0 and so are not major concerns. However based on individual course and components assessed in a given outcome, faculty observe that utility of answers, making assumption when solving engineering problems, mathematical reasoning were areas requiring greater emphasis. Therefore, more focus and components were added in ABE 205, 284, ABE 423. Another are for further enhancement was on experimental design, data collection and interpretation. To improve student competency in this area, lectures were added on experimental design, data interpretation to ABE 423 and 447. Some of our elective courses such as ABE 479 also focus on student data collection and interpretation with student team projects as well as with lab activates through autonomous data acquisition. Table 4-13 summarize student learning outcomes assessed in elective ABE courses. Overall scores range from 4.07-4.89. Although it is close to highest level of performance, the lowest scores was found with 4.07 rate with identify, formulate and solve engineering problems, and it is due to a low score in one of the courses, ABE 426, and majority of the students did not chose to do the homework which was used for assessing this particular outcome.

Table 4-13. Summary of student learning outcomes assessed in elective ABE courses.

BE Learning Outcomes		2015-2016	Assessed in Elective ABE Courses
a	Can apply mathematics, science and engineering principles to solve problems	4.16	426, 455, 456, 458, 459, 483
b	Can design and conduct experiments and analyze and interpret data	4.62	426, 479
c	Can design a system, component or process to meet desired needs within realistic constraints	4.58	426, 456, 458, 459, 479
d	Can function on multidisciplinary teams	4.84	452, 479
e	Can identify, formulate and solve engineering problems	4.07	426, 455, 456, 458, 459, 483
f	Has an understanding of professional and ethical responsibility	4.53	452
g	Can communicate effectively	4.55	452
h	Has the broad education necessary to understand the impact of engineering solutions in global, economic, environmental and societal context	4.89	452
i	Recognize the need for and the ability to engage in lifelong learning.	4.38	452
j	Has a knowledge of relevant contemporary issues	4.29	452, 481b, 486
k	Can use the techniques, skills, and modern engineering tools necessary for engineering practices.	4.27	426, 456, 458, 479, 483
Scores: 5 = highest level of performance, 3 = adequate level of performance, 1 = poor level of performance			

The ABE Department maintains a well-established process for continual review of program objectives, program outcomes, student performance, and satisfaction by alumni. While the overall evaluations have been highly supportive of our program, individual areas have been identified as needing some improvement. These have been addressed within our continuous improvement process and the impact of these changes assessed. We will continue to maintain these procedures to ensure that the Biosystems Engineering program meets the needs of our constituents.

B. Continuous Improvement

Previous sections discussed the data bases, documentation and processes used to assess success in achieving the stated Biosystems Engineering student learning outcomes as well as to determine the appropriateness of the program educational objectives for the BE program. It is imperative that continuous improvement is closely related to having the right program educational objectives and program outcomes as well as the level of achievement. It also relies upon looking at the program broadly as a whole. Post course assessment of specific student learning outcomes identified with each of the courses (see course mapping matrix in Appendix I1), design day evaluation scores, fundamentals of engineering exam scores were the primary data used to assess achievement of the student learning outcomes. The required Teachers Course Evaluations by the

students has standard questions focused on students perception of what is working for the course as a whole and what needs to change.

Senior exit survey by each of the graduates as well as alumni survey were used as fundamental sources of information regarding the level of satisfaction on program curriculum components as well as the broader issues. Both of these stakeholder surveys include qualitative questions on program's strength, weaknesses and suggestions for improvements. Other valuable qualitative inputs are also gathered from the Industrial Advisory Council which met every year.

Some of these changes made in the program and courses were summarized in the previous section. In general, in most cases, the assessment and evaluation of the program outcomes did not show a pressing need for change. Since the last ABET review of the BE program and as a result of the periodic assessment process a number of changes to the curriculum have been instituted. Some of these changes were made at the College of Engineering level due to the College instituting a common curriculum for all freshmen engineering students. Other changes were program specific and were put in place to provide a more standard series of foundation courses. In addition to changes in the major requirements, we have modified the minor requirements to bring them more in line with minor requirements of other engineering programs at the University of Arizona.

Specific changes to the curriculum since 2009 review

- ABE 205 (Engineering Analytic Computer Skills) is now a more formal class which is taken in the spring of sophomore year. This class covers Excel, Visual Basic, Access, and Matlab with an emphasis on flow charts, graphing, regression analysis, if-then, do loop, statistics, functions, and subroutines. Applications include biological energy, growth, and CO₂ models.
- Requirement of taking AME 250 (dynamics) has been removed from the curriculum because of the limitation of upper division units to graduate. This change was done with the approval of the Industrial Advisory Committee. Students minoring in Mechanical Engineering still take this course. We saw a slight, 10% drop in FE exam questions relating to dynamics and found this to be acceptable.
- ABE 484 (Transport Phenomena Applied to Biological Systems) is no longer being offered. Students are now required to take an ABE 400-level elective (based on faculty academic advisors' approval), or AME 431 (Numerical Methods in Fluid Mechanics), or AME 432 (Heat Transfer).
- ABE 201 (Intro. to Biosystems Engineering) used to include time to introduce the sophomores to the fabrication shop. We found this to be ineffective as the majority of the students had time constraints on when they could be at the shop. We also identified the need to boost the student's knowledge of micro-computing such as with low cost do-it-yourself (DIY) based Arduino and Raspberry PI micro-computers. In 2015, we substituted the shop time for a lecture and 2 labs using Arduino micro-computers. We also introduced an experimental 1 unit shop fabrication course. We found that the micro-computing curriculum was well received. Thus, we have decided to expand it in 2016.

- ABE 479 (Applied Instrumentation in Controlled Environment Agriculture), which used to be only graduate level course, but due to interest and suggestion from the previous ABET/APR reports for adding more hands-on, design related components to BE courses, ABE 579 has been offered both as undergraduate and graduate level course since 2009.
- ABE 423 (Biosystems Analysis and Design) that emphasizes modeling of biological systems was transformed to fit the needs of the biosystems engineering students and included different programming components.
- Several new courses were added to the program ABE 482 (Integrated Engineered Solutions in the Food-Water-Energy Nexus), ABE 487 (Metagenomics: From Genes to Ecosystems) as a result of identifying the need for some of the topics that were not covered in the other courses and with new faculty hires who are able to introduce additional topics to the existing ones.

As part of the long-range strategic planning to the program improvement, there were a number of new hires since the last ABET review including Dr. Peter Livingston Associate Professor of Practice (in the water area) and Dr. Bonnie Hurwitz (Bioinformatics). These new hires were made both because they fit the strategic plan for the program but also in some cases because the college or university identified these areas as critical to the University and have subsidized the hires.

C. Additional Information

On average, our students find jobs or go to graduate school within six months of graduating, and often graduate with a job in hand. Table 4-14 shows where our undergraduates are getting jobs.

Table 4-14. A selection of companies where our graduates with BS degrees get employment [2008-2016 graduates].

Company	# of students	Company	# of students
Alvarez & Marsal	1	Phoenix Manufacturing, Inc.	1
CH2M (Hill)	3	Sarver Health Center/UMC	1
Cognizant	2	Solon Energy GmBH	1
CR Bard	1	SpaceX	1
Epic Systems	1	Stantec	1
George Cairo Engrg	1	The Forages	1
Hercules Offshore	1	USDA-NRCS	1
Intel Corporation	1	Vante	1
John Deere	1	Ventana-Roche	3
Kimley-Horn	1	Vidler Water Company	1
Monsanto	1	Graduate programs/Universities	7
NextMed	1	Zilkha Biomass Enrgy LLC	1
NuVasive	1		

Copies of the assessment instruments or materials referenced in 4.A. and 4.B will be available for review at the time of the visit. These will include samples of instruments used for course assessments via course portfolios, Industry Advisory Council meeting minutes, and those meeting minutes where the recommendations were made for actions to make changes in the program.

CRITERION 5. CURRICULUM

A. *Program Curriculum*

The University of Arizona is on the semester system. The curriculum for ABE is presented in Table 5-1.

The *first year* of the curriculum is generally preparatory in nature and is common for all engineering majors. The freshman year curriculum includes basic math (calculus 1 and 2), science (chemistry and physics), communication (English composition), and general education courses. Additionally, Introduction to Engineering (ENGR 102) includes several small design projects, which introduce students to the engineering approach, design concepts, computer skills, and teamwork.

During their *second year*, students continue with math (vector and differential equations) and science (physics – electricity and magnetism) topics and begin a sequence of basic engineering sciences taught in ABE and in other engineering programs including Civil Engineering (CE) and Aerospace and Mechanical Engineering (AME). In this second year, students also complete eight credits of biological electives unique to the BE major which include two laboratory sections (1 credit each). ABE 201, Introduction to Biosystems Engineering is specifically aimed at introducing biosystems engineering with emphasis on biological laboratory skills and basic fabrication, foundations of modeling biological processes, team work and professional skills, and the societal and global context in which the profession is practiced. Students also take ABE 284 (Biosystems Thermal Engineering) which covers introduction to thermodynamics and heat transfer. In the second semester sophomore year, students take ABE 205 (Engineering Analytic Computer Skills) which provides a computational background using Excel, Visual Basic in Excel (VBA), Access, and Matlab to solve engineering problems often using differential equations.

The *third year* of the curriculum continues to prepare students for major design experiences through courses like Computer Aided Design (ABE 221), Fluid Mechanics (CE 218 or AME 331), Engineering Management (SIE 265), and Probability and Statistics (SIE 305). During the Junior year, they also begin the upper division courses in the major which provides them additional tools for analysis and design (ABE 423 Biosystems Analysis and Design, ABE 447 Sensors and Controls, AME 431 Numerical Methods in Fluid Mechanics and Heat Transfer or AME 432 Heat Transfer, or an ABE 4XX elective) and lets them begin to focus on an area of concentration through technical electives. They continue with coursework under the University general education requirements that also contributes to their understanding of contemporary issues, communications, and the impact of engineering solutions in a global/societal context.

During the *fourth and final year* of the curriculum, the students enroll in a two-semester senior design sequence of courses that culminates in a capstone design, typically in the final semester (ABE 498b Biosystems Engineering Design 2). During the first semester of the capstone sequence (ABE 498a Biosystems Engineering Design 1), students are assigned one “mini-design project” which normally requires eight weeks to complete. These projects provide a means to extend the student’s understanding of the design process through a practical and unique project. Teams of 3-

5 students undertake each of these design projects. Over approximately the final month of the fall semester, students are assigned and begin to develop their full senior design project which is completed in the second semester. In this way, students have an opportunity to apply the skills learned in their mini-project to a challenge of greater scope and requiring a comprehensive design of a system or a product. When possible and appropriate, these projects are provided by industry or clients outside of the university such as a consulting firms, water users association, a biotechnology company, a farmer's organization, etc. Ideally, the students undertake a design for an actual client. These projects include aspects of health and safety, economics, manufacturability, environmental, sustainability, ethical, social, and political aspects, as they are applicable in each specific case. During the first semester of the final year, students also take ABE 496a, Seminar in Engineering Careers and Professionalism. This course focuses on continuing education, ethics, and engineering. Another course ABE 452 also covers the topics on ethics and evaluates student learning performance.

As seniors, the students complete the remaining required upper-division courses in the major including those focused towards analysis and design of biological and water resources engineering. Typically it is in this last year that students take most of the design oriented electives (ABE courses which allow the students to focus in bioprocesses and public health topics, controlled environment agriculture, water resources, bioinformatics, and cross-application areas). The design oriented electives include nine units of advanced engineering topics. Students also must complete nine units of technical electives which may include more engineering course work or topics from the sciences (chemistry, biological and life sciences, optics, environmental sciences, etc.). Students do take some of these elective courses in their third year of study.

Students then complete the remaining technical electives to provide a greater focus in one of the major areas of interest in biological or water resources engineering. If a student wishes to achieve additional depth and skills in machine systems, they may take some technical electives in Aerospace and Mechanical Engineering. For additional depth in the sensors and controls area in addition to those covered in core course ABE 447 and elective course ABE 479, other technical electives may be taken in Aerospace and Mechanical Engineering or Electrical and Computer Engineering. Additional soil and water resource expertise is obtained through Civil Engineering; Hydrology and Water Resources; Watershed Management; or Soil, Water, and Environmental Sciences. Students who wish to focus in Biomedical Engineering or Pre-Health may take some of their technical electives in Biomedical Engineering, Physiology, or Molecular and Cellular Biology. Whatever the focus, the technical electives must include a minimum of five units of engineering topics to meet the ABET Basic Level Requirements.

The Biosystems Engineering (BE) pre-health track has been developed to prepare students for entry into medical schools. Completion of the BE pre-health track not only provides students with the necessary biological basics, but also helps them develop excellent problem solving skills. Students completing their study in the BE pre-health track satisfy all of the requirements for acceptance into medical school at the University of Arizona and for the majority of medical schools in the United States. The pre-health track required students to take also courses in Organic Chemistry (CHEM 241B and 243B), Cell and Tissue Engineering (ABE 481b) in their third and fourth years.

Table 5-1. Biosystems engineering curriculum.

Course Department, Number, Title	Req Or Elect	Subject Area (Credit Hours)				Last two terms offered	Max Section Enrollment
		Math & basic Science	Eng Topics Design*	Gen Ed	Other		
FIRST SEMESTER							
Math 125 Calc I	R	3				F15/S16	40
Chem 151 (with Lab)	R	4				F15/S16	250/25
Engl 101	R			3		F15/S16	25
Engr 102, Intro to Engineering	R		3*			F15/S16	45
Tier I Gen Ed	SE			3		F15/S16	500/50
SECOND SEMESTER							
Math 129 Calc II	R	3				F15/S16	35
Chem 152 (with Lab)	R	3				F15/S16	250/25
Phys 141 (with lab)	R	4				F15/S16	250/25
Engl 102	R			3		F15/S16	25
Tier 1 Gen Ed	SE			3		F15/S16	500/50
THIRD SEMESTER							
CE 214, Statics	R		3			F15/S16	80
ABE 284, Biosystems Thermo	R		3			F14/F15	80
ABE 201,Intro to Biosystems Eng	R		2			F14/F15	40
Math 223, Vector Calc	R	4				F15/S16	35
MCB 181, or MCB 184, or PLS 240	R	4				F15/S16	300/40
FOURTH SEMESTER							
ABE 205, Eng Analytic Comp Skills	R		3			S14/S15	100/30
Phys 241 Intro. Elect. & Magnetism	R	4				F15/S16	100
Math 254, Ordinary Diff Equations	R	3				F15/S16	35
Ecol 182, or MIC 205, or PSIO 210	R	3				F15/S16	575
Tier I Gen Ed	SE			3		F15/S16	500/50
FIFTH SEMESTER							
CE 218 or AME 331, Fluid Mech	R		3			F15/S16	80
SIE 265, Eng Management	R		3			F15/S16	100
ABE 221, CAD	R		3			F15/S16	350 (OL)
ABE 447, Sensors and Controls	R		3			F14/F15	70
SIE 305, Eng Probability and Stats	R	3				F15/S16	135
SIXTH SEMESTER							
ABE 423 Biosyst Anal & Design	R		3*			S14/S15	30
ABE Design Elective	SE		3*			F15/S16	30
ABE Tech Elective	SE		3			F15/S16	30
AGTM 422 or ENGL 308	R			3		F15/S16	30
Tier I Gen Ed	SE			3		F15/S16	500/50
SEVENTH SEMESTER							
ABE 496, Careers in Eng	R		1			F14/F15	30
ABE 498A, Capstone Design	R		3*			F14/F15	30
ABE Tech Elective	SE		3			F15/S16	30
ABE Design Elective	SE		3*			F15/S16	30
ABE Internship	R		1			F15/S16	30
AME 324A, Mech Behavior of Mat	R		3			F15/S16	115
Tier II Gen Ed	SE			3		F15/S16	500/50

EIGHTH SEMESTER							
ABE 498B, Capstone Design	R		3*			S14/S15	30
AME or ABE Tech Elective	SE		3			F15/S16	30
ABE Tech Elect	SE		3			F15/S16	30
ABE Design Elect	SE		3*			F15/S16	30
Tier II Gen Ed	SE			3		F15/S16	500/50
ABET BASIC-LEVEL REQUIREMENTS		34	61	27			
OVERALL TOTAL CREDIT HOURS FOR COMPLETION OF PROGRAM		122					
PERCENTAGE OF TOTAL		28%	50%	22%			
Minimum Semester Credit Hours		32	48				
Minimum Percentage		25%	37.5%				
*Design Intensive Class OL on-line Class enrollments with a ###/## indicate a large lecture with smaller lab or discussion sections.							

The students must complete technical electives (9 units) and ABE electives (9 units). Technical electives typically are in the fields of biology, chemistry, or engineering courses and are taken in the 3rd to 4th years. ABE design electives include 400-level ABE courses which contain significant engineering content.

ABE design and technical electives are presented in the table as grouped categories, and eligible design and technical elective classes are found in Table 5-2. Design electives provide a critical component of the curriculum as they give the students a more in depth experience in applying their fundamental knowledge to design solutions to practical problems within their area(s) of focus. Students must complete 9 units (three courses) of design electives. At least two out of three of these must be ABE prefixed courses. Additionally, students must complete 9 units of technical electives. These can include courses from chemistry, biology, or other engineering programs. The technical electives provide students with greater breadth of foundations or applications which indirectly connect with their engineering design electives. Students are guided by their faculty advisor on choice of design and technical elective classes. This allows the students to design their curriculum to meet their desired career paths, which are referred to as the emphasis areas. For example, a student interested in the water emphasis area would take ABE 426, ABE 455, ABE 457, and ABE 458 to provide insight on hydrology and irrigation. These classes include design problems in hydrology, soil and water engineering, and irrigation system design. Table 5.2 provides the design and technical elective class choices for each of the four emphasis areas. Our emphasis areas are:

1. Water Resources
2. Biosystems Informatics
3. Controlled Environment Agriculture
4. General Biosystems Engineering

Table 5-2. Emphasis areas and associated elective options.

Water	Bioinformatics	Controlled Environment Agriculture	Public Health Engineering
ABE 422	ABE 416	ABE 447	ABE 480
ABE 426	SIE 430	ABE 479	ABE 481A
ABE 427	STAT 412A	ABE 475	ABE 481B
ABE 455	ABE 487	ABE 481A	ABE 484
ABE 456	ABE 413	ABE 483	ABE 486
ABE 458		ABE 497C	ABE 488
ABE 459		ENTR 454	ABE 489A

General education courses (18 units required) are taken throughout the student academic career.

Curriculum Alignment with Program Educational Objectives (PEO)

The Biosystems Engineering curriculum meets the educational objectives of our program. The 2016 ABE curriculum is aligned with, and supports the department's Program Educational Objectives (PEO's). The Educational Objectives of the Biosystems Engineering B.S. program at the University of Arizona are to produce graduates:

1. Who are effective engineers within natural resources and biotechnology related industries; and
2. Who have the foundation to perform and lead engineering projects and make significant contributions; or are
3. Enrolled in an advanced engineering or medical or other professional degree program and are successful in those.

PEO 1

The ABE department makes sure that all of our students have a well-rounded education in natural resources and biotechnology, PEO 1. This is accomplished by including the following required classes in our student's curriculum: Biological/Plant Sciences/Ecology, 2 semesters of lecture with labs; Chemistry classes, 2 semesters of lecture with labs; ABE 201, which is an introductory class on bioengineering that includes weekly labs in a wide variety of natural resource and biotechnology topic areas, including bio fuels, solar energy, growing algae, and nanotechnology; ABE 284, which is a class focusing on thermodynamics and heat transfer taught by ABE faculty so that it uses biosystem engineering examples; ABE 423, which is a senior level required course in biosystems analysis and design; ABE 447, our sensors and controls class which combines practical practices in instrumentation monitoring and control of natural resource and biosystem based environments, including temperature, humidity, light intensity, and velocity of sap moving through plants.

PEO 2

PEO 2, foundation to perform and lead engineering projects, comes out of our basic science, and technical and design elective classes. Our students graduate ready to do work. Before our students graduate they have all worked in small and large group settings to solve engineering problems. All have the opportunity to lead engineering projects. This is especially true in ABE since they are in small (3 to 4 student) design teams. Team building starts day 0 at the University of Arizona, when the freshmen are in a common introduction to engineering design class. They model, design,

build, and test solar ovens; and design and execute experiments requiring multiple variables. They work in small groups in class debating engineering ethics and presenting on short technical topics in the sophomore class on introduction to Biosystems engineering. They also work in small groups on weekly labs, including building solar fountains, testing drip irrigation systems, and crushing sorghum stalks into a sugar solution that can be made into ethanol. The students use Microsoft Project to schedule their design projects. This program teaches them to determine the critical path to success without sleepless nights and weekends in the shop fabricating their capstone projects.

Their Capstone projects typically contribute significantly to advancing Biosystem engineering. They have included fast PCR designs, portable fast e-coli detection and quantification equipment, and autonomous nut harvesting equipment. Their projects have impacted many high school students through the implementation of recirculating aquaponics projects built at one high school, and then duplicated at many schools because of the efficiency of the system.

PEO 3

We also produce students ready to be highly successful in graduate school. We had our first class of students graduate out of our accelerated master's program. All that entered the program graduated with master's degrees one year after obtaining their Bachelor's degrees. We have had National Science Foundation scholarships awarded to two seniors in the last 2 years. The value of these awards is estimated to be over \$500,000 through their graduate program, thus, this is an example of how we meet PEO 3. Our students are accepted all over the US for graduate schools and have reported that they are well prepared.

We have also presented how Biosystems Engineering student learning outcomes are mapped with program educational objectives. Furthermore, a matrix of how our curriculum (foundation, required and elective courses) is aligned with student learning outcomes are illustrated and mapped on a table in Appendix II.

Curriculum structure and its pre-requisite structure supporting attainment of student outcomes

The Department follows the ABET learning outcomes a-k, which are outcomes the students must have at the time of graduation. These outcomes are:

- a. Can apply mathematics, science, and engineering principles to solve problems
- b. Can design and conduct experiments and analyze and interpret data
- c. Can design a system, component, or process to meet desired needs within realistic constraints
- d. Can function of multidisciplinary teams
- e. Can identify, formulate, and solve engineering problems
- f. Has an understanding of professional and ethical responsibility
- g. Can communicate effectively
- h. Has the broad education necessary to understand the impact of engineering solutions in global, economic, environmental, and societal context
- i. Recognize the need for the ability to engage in lifelong learning

- j. Has a knowledge of relevant contemporary issues
- k. Can use the techniques, skills, and modern engineering tools necessary for engineering practices.

Table 5-3 is a matrix which illustrate how the UA BE Program Outcomes relate to the ABET Program Specific Criteria for Biological Engineering. The letters in each cell (H, M, L or blank) indicate the level of contribution that each outcome makes towards the program specific criteria. In this case, not all cells contain an H, M or L indicating that not all outcomes relate directly to each of the ABET Criterion 3 (a-k). However, there are no blank rows or columns in the matrix which indicates that achievement of the BE Program Outcomes will also achieve all of the ABET Program Specific Criteria for Biological Engineering.

Table 5-3. Matrix of BE learning outcomes and program specific criteria.

BE Program Outcomes		Program Specific Criteria			
		Demonstrate proficiency in mathematics through differential equations	Demonstrate proficiency in chemistry and biology	Demonstrate a working knowledge of advanced biological sciences	Demonstrate competence in application of engineering to biological systems
a	Can apply mathematics, science and engineering principles to solve problems	H	H		H
b	Can design and conduct experiments and analyze and interpret data		H	M	H
c	Can design a system, component or process to meet desired needs within realistic constraints				H
d	Can function on multidisciplinary teams		L		H
e	Can identify, formulate and solve engineering problems	M			M
f	Has an understanding of professional and ethical responsibility				M
g	Can communicate effectively		M		H
h	Has the broad education necessary to understand the impact of engineering solutions in global, economic, environmental and societal context			M	H
i	Recognize the need for and the ability to engage in lifelong learning.			L	L
j	Has a knowledge of relevant contemporary issues			L	
k	Can use the techniques, skills, and modern engineering tools necessary for engineering practices.				M
H = High Contribution, M = Medium Contribution, L = Low Contribution, Blank = Little or no contribution					

Relationship of Courses in the Curriculum to the Student Learning Outcomes

A set of required courses and student selected electives provides breadth and depth to meet the learning outcomes for our program. Table 5-4 displays the required courses and groups similar

courses (e.g. mathematics) together to demonstrate how curricular activities satisfy the program outcomes. The matrix shown in Table 5-4 provides an overview of the ways by which the required and elective courses in the BE program meet the BE Learning Outcomes, which, in turn, contributes to achievement of the program educational objectives. The relative importance of each activity or course in providing instruction which meets the various objectives is ranked as having a high contribution (H), medium contribution (M), low contribution (L) or little or no contribution (Blank) to achieve the program outcomes. The ratings presented are a composite derived from individual instructor course classification content statements and an ABE faculty evaluation. A more in depth table for specific foundation, required and elective courses and their alignment and mapping against student learning outcomes are provided in Appendix II.

The basic mathematics (10 units of calculus, 3 units of differential equations and 3 units of statistics), science (8 units of chemistry, 8 units of physics, and 8 units of biology), engineering science (statics, dynamics, mechanics of materials, fluid dynamics, thermodynamics) and computer instruction (introduction and computer aided drawing) instruction (outcomes a-d & h) are essential to the abilities required in the practice of biosystems engineering, as shown in Table 5-4. The matrix also indicates how the capabilities developed in the lower division mathematics, science, and computer courses are extended by application to analysis and design in the required upper division courses in sensors and controls (ABE 447), modeling and analysis (ABE 423), biological thermodynamics (ABE 284), and advanced transport phenomena (ABE 484, or now AME 431 Numerical Methods in Fluid Mechanics and Heat Transfer, or AME 432 Heat Transfer); in the technical electives in the area of BE concentrations (ABE 45X, ABE 48X, typically for water resources and biological systems, respectively); and in the capstone design courses (ABE 498a,b). Biosystems engineering students must complete 9 units of technical electives (advanced chemistry, biology, or engineering courses) and 9 units of engineering design electives (must be upper division engineering courses most typically from the ABE department).

The freshman engineering course (ENGR 102) introduces the engineering profession (outcomes h, i, and j), application of engineering methodologies (outcome k) to solution of team design projects (outcome d). The science and engineering science courses develop an understanding of the physical principles required for analysis (outcomes a) and conducting experiments (outcome b). The abilities to design and conduct experiments and analyze data (outcome b) and solve open ended problems (outcome e) are further developed and applied in the upper division ABE courses. The projects with laboratories and use of instrumentation in ABE 447 and 423 (along with those in the technical and design electives, i.e. ABE 479, ABE 483) provide considerable experience with conducting experiments and analyzing data while the capstone design projects (ABE 498a,b) require extensive information gathering and the solution of open ended problems.

Effective communication (outcome g) instruction begins in the freshman engineering, freshman composition (ENGL 101 and ENGL 102), and general education courses. University writing proficiency requirements are met by obtaining a grade of “B” or better on the second semester freshman composition class (ENGL 102), through the Technical Writing course (ENGL 308), and through writing emphasis in upper division ABE courses. If a student does not obtain a “B” or better in ENGL 102, they are required to take an additional writing class. ENGL 308 provides extensive training in written and oral technical communications (outcome g). Upper division ABE courses have extensive communication requirements of both written reports and oral presentations

and are critiqued to provide guidance. ABE 447 requires several laboratory reports. ABE 423, 498a, and ABE 498b and several design electives (ABE 479, 481a, 484, 489b) all require oral presentation as well as written reports of project results. ENGR 102 provides sizeable teamwork instruction (outcome d) before teams are assigned projects. Many of the laboratory and design projects, in (ABE 423, 447 and 498a,b), require teams to jointly conduct the laboratory evaluation and/or prepare the design. These teams are usually composed only of engineering students.

The understanding of professional and ethical responsibilities (outcome f) and the global/social impacts of engineering (outcome h), recognizing the need for lifelong learning (outcome i), and developing a knowledge of relevant contemporary issues (outcome j) are important components of lower division freshman engineering and general education, particularly social science, courses, but also in ABE 496a. ABE 496a is taken by fourth year students simultaneously in the fall. For approximately one half of the class periods, these students meet together and share their experiences in the workplace (internships, independent studies, travel / study abroad, laboratory exercises, and design projects) from the senior level students to the early career students. Presentation topics include professional registration (FE / PE exams), ethics and professional responsibilities, career advancement and job searches, the impact of engineering on grand challenges and the broader impact of engineering on society. These address outcomes g, h, i, and j. Sophomores also compete in a professional bioethics competition. Professional ethics and engineering registration are specifically addressed in ABE 496a and the ABE 498a design course. Mentors and professional societies also provide guidance to those utilizing these available resources. Human factors engineering, safety and risk, and environmental impact instruction are specific topics in upper division ABE courses.

The capability for self-initiated and self-guided, life-long learning (outcome i) is an element of both basic and upper division courses, but again, are specifically addressed in 496a. The course aim to instill an understanding that the continuing discovery of knowledge and development of informational resources and analytical tools will require continuous learning to be effective engineers. Some departmental and foundation resources are available for support of student participation in regional and national professional meetings. Appendix II has a more detailed listing of how specific elective courses address specific learning outcomes.

Table 5-4. Matrix of courses and activities that relate to BE learning outcomes.

Curriculum and Educational Activities	Program Outcomes										
	Can apply mathematics, science and engineering principles to solve problems	Can design and conduct experiments and analyze and interpret data	Can design a system, component or process to meet desired needs within realistic constraints	Can function on multidisciplinary teams	Can identify, formulate and solve engineering problems	Has an understanding of professional and ethical responsibility	Can communicate effectively	Has the broad education necessary to understand the impact of engineering solutions in global, economic, environmental and societal context	Recognize the need for and the ability to engage in lifelong learning.	Has a knowledge of relevant contemporary issues	Can use the techniques, skills, and modern engineering tools necessary for engineering practices.
Program Outcomes	a	b	c	d	e	f	g	h	i	j	k
Engr 102	H			H				M	M	M	M
Math 125, 129, 223, 254	H										
Chem 151, 153	H	H					M				L
Biolog Sci. (8 units)	H	H		M			M				L
Phys 141, 241	H	H		L			M				L
Engineering Science	H				H						
ENGL 101, 102, 308							H				
CE 218 or AME 331	H				H						
SIE 265	H				H						
SIE 305	H	H	M	L							
AME 324A	H				H						
ENGR 211P	H	M		M							
General Education							M	M	H		
ABE 201				H			H	H	H	H	
ABE 205	H			H							H
ABE 284	H				H						
ABE 296a				H		H	H	H	H	H	
ABE 221	M	L	H	L	M		L			M	H
ABE 393								H	H	H	
ABE 423	H	H			H						H
ABE 447		H		M					L		H
ABE 484 (now AME 431/432 or ABE elec.)	H	H	H	M	H	L		L	L		H
ABE 496a						H	H	H		H	
ABE 498a	H		H	H	H		H				H
ABE 498b	H		H	H	H		H				H
Design Elect (9 units)	H	H	M	M	M	H	H	M	L	M	
Tech Elect (9 units)	H	H		M	M	M	M				
H = High Contribution, M = Medium Contribution, L = Low Contribution, Blank = Little or no contribution											

Prerequisite structure and flow chart

Students majoring in biosystems engineering need to follow the sequence of pre-requisites as shown below in Figure 5-1. Please note that all engineering students enter the University of Arizona as “*Engineering*” students. They are not required to pick a major until the end of their sophomore year, although many pick a major at the end of their freshman year. All engineering students have a common freshman year. Some courses may be moved in sequence but may impact courses down-stream in the curriculum. Students work out a class plan with the ABE academic advisor and their faculty advisor to make sure they have taken the required pre-requisites. The College of Engineering has a strict policy on students that have not been accepted for “*Advanced Standing*” taking upper division classes. This is a secondary method to make sure that pre-requisites are taken before students are allowed to take upper division classes. Students must meet with the ABE academic advisor to complete the necessary paperwork to attain Advanced Standing. Advanced standing indicates that students admitted to the College of Engineering are ready for junior and senior engineering classes, 300 and 400 level courses. Advanced standing requires successful completion of the courses listed in the freshman and sophomore curricula of the chosen degree, with at last 12 units completed at the University of Arizona.

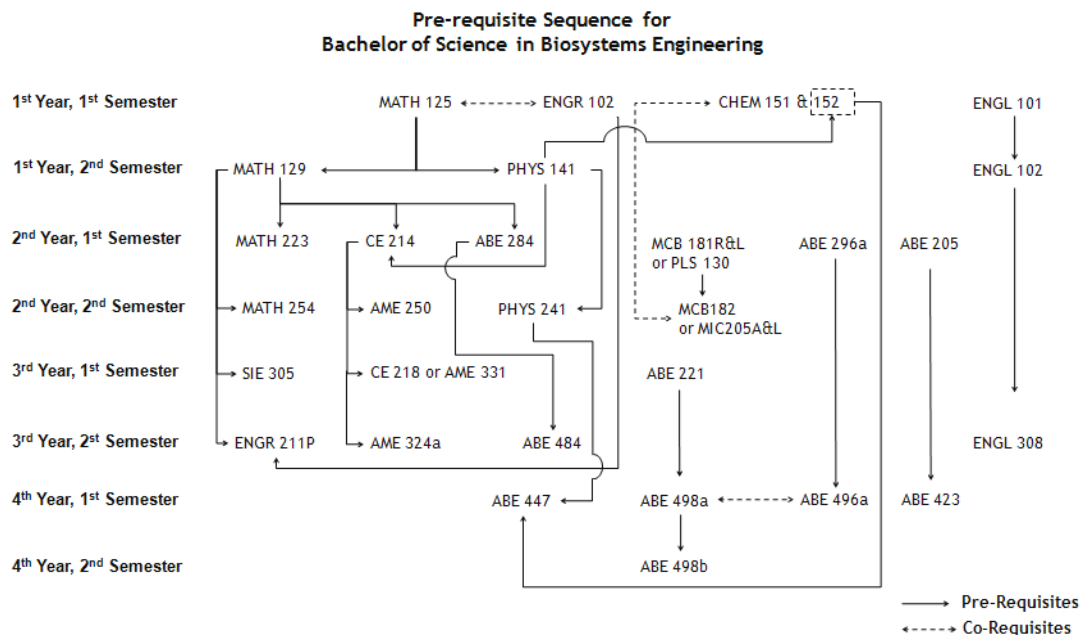


Figure 5-1. Course flow chart based on pre-requisite sequences.

Subject Area Requirements

General education courses (18 units required) are taken throughout the student academic career. The following discussion describes how our program meets the requirements in terms of hours and depth of study for each subject area (Math and Basic Sciences, Engineering Topics, and General Education) specifically addressed by either the general criteria or the program criteria.

Basic Sciences and Math

The courses in this group are identified in Table 5-1. These courses inculcate all of the scientific and math principles from which the engineering principals are founded, and more specifically those that meet our program requirements. All engineering programs at the University of Arizona

require two semesters each of chemistry and physics, and all of these classes include associated labs. Biosystems engineering requires additional background in biology, hence we also require one semester of either standard scientific biology or plant sciences; and the second semester can be another biology class with an ecology emphasis, standard biology, or human anatomy and physiology. The human anatomy and physiology class was added for students that are planning on a health related graduate program.

Our math requirement is a minimum of 13 units of calculus, which takes the students through ordinary differential equations. Many incoming freshmen take Math 122A/122B their first semester. This 5 unit class meets daily and the first month (2 units worth of class time) is a pre-calculus class that prepares the students for calculus. The ABE academic advisor recommends this class to many of our incoming freshmen. The 13 units of calculus through differential equations meets ABET requirements and provides a strong background to our students. We also require at least one statistics class.

Engineering Classes

We require our students to have a strong background in traditional engineering classes like statics, fluid mechanics, thermodynamics, and strength of materials; however we encourage them to take them in our department so that they are exposed to biosystems engineering examples. Our basic engineering course is in the area of thermodynamics, which integrates controlled environment (greenhouse) examples.

The background for our students is well rounded to provide training so that our students can hit the ground running. Students are required to have Advanced Standing before taking any 300 or 400 level classes. All ABE students are required to take the following engineering courses:

- Engr 102, Introduction to Engineering
- CE 214, Statics
- ABE 201, Introduction to Biosystems Engineering
- ABE 205, Engineering Analytic Computer Skills
- ABE 221, Introduction to Computer Aided Design
- ABE 284, Biosystems Thermal Engineering
- ABE 393, Internship
- ABE 423, Biosystems Analysis and Design
- ABE 447, Sensors and Controls
- ABE 496, Seminar in Engineering Careers and Professionalism
- ABE 498 A & B, Senior Capstone Design
- CE 218 or AME 331, Fluid Mechanics (students minoring in mechanical engineering take AME 331, students with a water emphasis take the civil engineering class)
- SIE 265 Engineering Management I
- SIE 305, Engineering Probability and Statistics

The internship (ABE 393) must be approved by the student's faculty advisor. The approval is in the form of a contract between the student, intern sponsor, and University of Arizona. The ABE Department feels that the one or more internships that the students have is very valuable because they gain practical experience and are exposed to potential employers. The Department also

requires the students to take 9 units of technical elective and 9 units of design electives. These classes are typically within their emphasis areas. The classes are outlined in Table 5-2.

In conclusion, upon graduation our students have a firm background in math, science and engineering and are ready to go to work or continue with graduate school.

Capstone Design Experience

The ABE major design experience, Capstone Design for Biosystems Engineers (ABE 498a and 498b), prepares our students for engineering practice. We are very proud of our major design experience classes. All students must take two semesters, 6 units, of Capstone Design. The purpose of the class is to have the students design and build a prototype of their project. Every year the students are offered a variety of projects to design and build. The projects have been solicited from industry and faculty.

Each student design project is run just like a typical industry engineering project. The project must have a well-defined goal of designing, building, and evaluating a particular biosystem for a specified task, subject to fixed budget and with time constraints. Team members must determine appropriate roles and set of responsibilities for each member at the beginning of the project. Periodic written reports and oral presentations are required of each team. The project teams have an instructor with industrial experience assigned as well as the project sponsor who is either an industrial contact or faculty member. The ABE 498a and 498b course instructor is responsible for keeping the team on track, and grading their work. The students must draw upon the laboratory skills learned in their eight semesters of laboratory and theoretical coursework, their knowledge of biosystems and processes, as well as their experience in writing reports and making oral presentations, which are required as part of their coursework in the curriculum.

For example, in 2015/2016 the student design projects included:

- Watermelon Bin Dumping System
- Microbubble detection instrument
- Robotic data collection platform
- Bee monitoring system
- Bird detection radar system
- Growth Chamber
- Home Irrigation System smart controller with leak detection
- Autonomous Macadamia Nut harvester
- Portable E-coli detection/quantification device

During the first week the instructor introduces the potential projects to the students. Students are given the opportunity to provide a preference for the projects they want to work on. They also provide the instructor with a matrix of skills and interests (see Table 5.6). The instructor then matches skills and project preferences to the students. This does not result in every student getting assigned to projects they want to work on because sometimes their skills are needed to round out a particular project's design requirements.

Table 5-6. Capstone design skills/interest matrix.

Skill	Rank (1-5)	Comments
Drafting (Solid Works)		
Nano scale control		
Biosystems Processes		
Computer programming		
Computer modeling		
Controlled Environment		
Algae related tasks		
Power and machinery		
Mechanical engineering		
Shop/welding		
Thermo Dynamics		
Rank 1 - did not do well in this subject 5 – I excel in this subject area.		

Upon review of project and student needs the projects chosen in 2015/2016 included the growth chamber, macadamia nut harvester, and E-coli detection/quantification device. Two of these designs (chamber and harvester) were funded by industry and the third was internally funded by the ABE Department.

The first semester is for project design. The students are introduced to the design process (Figure 5-2), including use of engineering standards and process diagrams. Students then research basics of the project so that they can identify alternative solutions. An alternatives analysis is completed and presented to the project mentor. The mentor helps, but typically does not dictate which alternative solution moves to formal design and construction. Once they have a clear idea on what they are designing they build a critical path schedule for completing design and construction of the project. They use Microsoft Project to build the schedule. By the end of the first semester most teams have a final design of their project and some may have purchased long lead items so that they are delivered prior to their return from winter break. They are not allowed to purchase any items until they have a final design of their project.

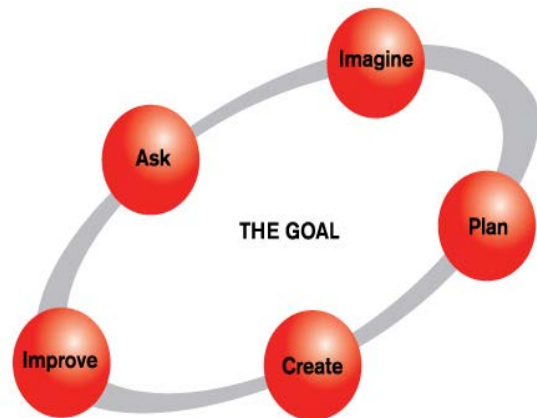


Figure 5-2. Design process.

It is amazing to watch the students bring together their individual talents to make the project a reality. Whether it is programming micro computers or welding steel and aluminum, every student's skills are utilized by the team. They also cross train each other, because one person cannot or does not want to be responsible for a component of the final product without having it checked over by a team mate. The students typically bring together their technical background from solid works, strength of materials, instrumentation and control, micro-computer programming with the shop skills they learn in this class. Every student spends time in the shop going through safety classes and learning how to use the machinery available to them. It is exciting to see the classroom engineers become like children playing in a sand box when they are learning how to machine, bend, and weld metal.

The two semester class culminates with a College of Engineering sponsored design competition. This competition results in the award of nearly \$20,000 in prizes and the 150+ projects designed and constructed by over 500 senior engineering students were judged by 130 working or retired engineers. A sample of a 2016 judging sheet from one of the judges is shown in Figure 5-3. Five to six judges rate each project. The average judges scores for 2010-2016 period are presented in Table 5-7. Each judge grades the project based on creativity, quality of the design, amount of analysis that went into the design, and presentation. The blank cells indicate that the judges did not provide score. The presentations scores are based on a 10 minute presentation by team and a poster on the project. The overall average score is 3.7 indicating that these practicing engineers rated the senior design projects as being overall above "good" and close to "excellent."

**COLLEGE OF ENGINEERING
Engineering Design
Program**

Please rate each of the projects according to the following scale in each of the four categories.
5 = Superior 4 = Excellent 3 = Good 2 = Marginal 1 = Unsatisfactory

Time	Team	Scoring Categories			
		Creativity	Quality of Design and Implementation	Analysis	Presentation
9:00 - 9:20 AM	15102 - Red Cactus Wildlife Vertical Takeoff and Landing Unmanned Aircraft System	4	4	4	4
Comments: Standard Design + Analysis done at RTN (very good)				Award Recommendation: Raytheon Overall Design	
9:25 - 9:45 AM	15004 - Macadamia Nut Harvester	4	4	3	3
Comments: Creative Solution by students unfamiliar with Fabrication				Award Recommendation: Phoenix Analysis & Design	
9:50 - 10:10 AM	15061 - Temperature Testing System For Buried Gas Pipes	3	3	3	3
Comments: Standard type of Solution. Pretty Good Engineering but not enough analysis				Award Recommendation: None	
10:15 - 10:35 AM	15001 - ASME Human-Powered Vehicle	3	3	3	4
Comments: Good engineering more build & try				Award Recommendation: A?	

Figure 5-3. Example of 2016 design day judging sheet from one of the judges.

Table 5-7. Summary of performance on Senior Design Projects as rated by external evaluators.

Year	Project title	Creativity of Design	Design	Engineering Analysis	Presentation	Average
2010	Solar Desalinization	4.7	4.5	4.5	4.8	4.6
2010	Algae Harvesting	3.9	4.3	4.1	4.1	4.1
2012	Portable Aquaponics	3.8	3.8	3.8	3.8	3.8
2012	Pilot Plant to Convert Waste Cooking Oil to Biodiesel	2.5	2.5	2.5	5.0	3.1
2012	Development of Very Quick PCR Device	3.8	5.0	5.0	5.0	4.7
2013	Rapid Temperature Gradient Based, Wire Guided PCR	4.8	4.1	3.6		4.2
2013	Hydroponic Barley Fodder System	5.0	4.2	4.0		4.4
2013	Extraction System for Sweet Sorghum	3.5	4.0	2.5		3.3
2014	Archimedes Screw Pump	3.8	4.2	3.8	4.0	4.0
2014	Onion Bulb Harvester	3.4	3.5	3.0	3.8	3.4
2014	Concentration Sweet Sorghum Juice via Reserves Osmosis	2.9	2.9	2.5	3.1	2.9

Year	Project title	Creativity of Design	Design	Engineering Analysis	Presentation	Average
2014	Tanque Verde High School Aquaponics System	3.0	3.8	3.1	3.7	3.4
2015	Lettuce Wash Water Recycle System	3.6	3.9	3.4	3.6	3.6
2015	De-Watering System for Algae	3.8	3.9	3.4	3.6	3.7
2015	Smart Hoophouse	3.6	4.0	3.9	3.6	3.8
2015	Graywater Utilization System	2.5	2.3	2.2	3.0	2.5
2016	Cont. Env. Agric. Plant Production	4.2	4.5	3.7	5.0	4.4
2016	Cont. Env. Agric. Irrigation Infrastructure	3.6	4.0	3.6	4.4	3.9
2016	Cont. Env. Agric. Mushroom Production	3.0	4.0	3.2	3.2	3.4
2016	Optically-Paired Microfluidics for <i>E. coli</i>	3.1	3.0	2.6	3.3	3.0
2016	Macadamia Nut Harvester	3.7	4.0	3.2	3.8	3.7
Average		3.6	3.8	3.4	3.9	3.7
Scores: 5= superior 4= excellent 3= good 2= marginal 1= unsatisfactory						

Materials that will be available for review during the visit

Course portfolios for all of the ABE required courses and selected elective courses (ABE426, ABE 455, ABE 479, ABE 481b) will be provided within a binder at the time of the site visit. The course portfolios will include ABET formatted course syllabus, examples of student work (Homework, Exam, Quiz and Design Projects) in each of the ABE courses used in the assessment with one that meets expectations and one that does not meet expectations, detailed summary of the course outcome assessment tables, example of a lecture, will be available for review at the time of the visit. In addition, upon request, there will be a copy of minutes of the Undergraduate Study Committee Meetings, Alumni Survey, Senior Student Exit Surveys made available.

B. Course Syllabi

Appendix A provides syllabi for each course used to satisfy the mathematics, science, and discipline-specific requirements required by Criterion 5.

CRITERION 6. FACULTY

A. Faculty Qualifications

The faculty of the Department of Agricultural and Biosystems Engineering (ABE) is currently composed of 14 core faculty members (please see list below and Table 6-1.). In addition, there are around 13 faculty members (see list below) who have non-salaried joint appointments with ABE.

The curriculum vitae for full-time core ABE faculty members are provided in Appendix B and also detailed information about these faculty members are provided in Faculty qualifications and work load Tables 6-1 and 6-2. Following is a list of ABE core faculty members, non-salary supported jointly-appointed faculty members and their primary areas of expertise relative to the curricular areas of our program. Our department also has strong collaborations and ties with the faculty and research experts from other units in the University, outside the University from Government institutions and industrial sector, both nationally and internationally.

Current full time core Agricultural and Biosystems Engineering Department faculty

Last Name, First Name	Title	Focus Area/Expertise
An, Lingling	Associate Professor	Statistical Bioinformatics, Computational Biology
Andrade Sanchez, Pedro	Associate Professor/ Extension Specialist	Precision Agriculture
Cuello, Joel L.	Professor	Bioprocess Engineering, Biolmagineering: Innovations for People & the Planet, Algae Innovations for Food, Nutraceuticals & Biofuels, Vertical Farming, Strategic Social Agriculture
Farrell-Poe, Kathryn L.	Professor/Extension Specialist	Water Quality, Water Resources Engineering, Onsite Wastewater Education, Safe Drinking Water Education
Giacomelli, Gene A.	Professor	Controlled Environment Agriculture
Hurwitz, Bonnie	Assistant Professor	Systems Biology, Functional Metagenomics, Big Data, Bioinformatics, Computational Biology
Kacira, Murat	Professor	Controlled Environment Agriculture (CEA), Computer Vision, Computational Fluid Dynamics, Alternative Energy integrated CEA systems
Livingston, Peter	Associate Professor of Professional Practice	Biofuels, Irrigation, Onsite Wastewater Treatment, Agricultural Equipment Development
Poe, Stephen, E.	Professor	Agricultural Systems Management, Water Quality, Landscape irrigation

Last Name, First Name	Title	Focus Area/Expertise
Siemens, Mark	Associate Professor/Extension Specialist	Specialty Crop Mechanization and Automation, Agricultural Machinery and Equipment, Conservation Tillage Systems
Slack, Donald	Professor	Irrigation and Drainage Systems Design and Management, Renewable Energy, Water Resource Engineering
Waller, Peter M.	Associate Professor	Irrigation and Drainage Systems Design and Management, Modeling Surface Energy Balance and Algae Growth in Algae Raceways
Yitayew, Muluneh	Professor	Hydraulics, Hydrology, Irrigation Engineering, Geospatial Analysis of Natural Resource Systems
Yoon, Jeong-Yeol	Professor	Biosensors for:, Medical Diagnostics, Air Quality, Tissue Engineering and Organ-on-a-chip, Food Safety and Water Quality, Fast PCR

Joint appointment faculty who teach undergraduate courses in biosystems engineering

Last Name, First Name	Title	Focus Area/Expertise
Kubota, Chieri	Professor, School of Plant Sciences	Controlled Environment Plant Physiology
Ogden, Kimberly	Professor, Chemical and Environmental Engineering	Bioprocess Engineering

Joint appointment faculty who typically do not teach in the biosystems engineering program but provide guest lecturing in classes, serve on graduate student committees, and participate in seminars in ABE. (Note that Dr. Kamel Didan will be a full time core ABE faculty starting from July 2016)

Last Name , First Name	Title	Focus Area/Expertise
Barton, Jennifer	Interim Vice President for Research, Professor; Biomedical Engineering, Electrical and Computer Engineering, Optical Sciences	Optical Imaging, Clinical and Cancer Imaging
Didan, Kamel	Associate Research Professor, Electrical and Computer Engrg	Remote sensing, Landscape Ecology
Duan, Guohong Jennifer	Associate Professor, Civil Engineering	Hydraulics & Hydrology
Fitzsimmons, Kevin	Professor, Soil, Water and Environmental Sciences	Aquaculture, Freshwater and Marine Algae
Franklin, Edward	Associate Professor, Agricultural Education	Agricultural Technology Management
Hawkins, Richard "Pete"	Professor, School of Natural Resources and Environment	Hydrology and Water Resources
Pepper, Ian	Professor, Soil, Water and Environmental Sciences	Molecular Ecology of Soils, Transport of Microbial Pathogens in Soil, Water, and Air, Water Quality

Last Name , First Name	Title	Focus Area/Expertise
Piegorsch, Walter	Professor, Mathematics, Chair of the Graduate Program in Statistics	Biometry, applied statistics
Rorabaugh, Patricia	Assistant Professor of Practice, School of Plant Sciences	Controlled Environment Agriculture Hydroponics Crop Production
Seraphin, Supapan	Professor, Materials Science and Engineering	Carbon Nanotubes, Nanoparticles, Electron microscopy and imaging
Tamimi, Akrum	Associate Research Scientist, Soil, Water and Environmental Sciences	Welfare economics, development economics, health economics, and environmental economics

The 14 regular fulltime faculty members and 13 faculty with joint appointments who have primarily teaching and research responsibilities provide adequate coverage of all the curricular areas in the program. Following section is a breakdown of how the primary curricular areas of the Department are covered by these full-time members and their composition.

Faculty expertise related to curricular areas

Curricular Area	Faculty Expertise and Coverage
Biological Engineering	An, Cuello, Hurwitz, Ogden, Yoon
Bioinformatics	An, Hurwitz
Controlled Environment Agriculture	Cuello, Giacomelli, Kacira, Kubota
Pre-Health	Piegorsch, Yoon
Water Resources and Environment	Andrade-Sanchez, Didan, Farrell-Poe, Fitzsimmons, Poe, Siemens, Slack, Waller, Yitayew

Regular teaching faculty members have had significant experience in the foregoing areas through both research and practice. All things considered, the teaching members of our faculty are well rounded both in terms of breadth and depth in the areas covered by the program curriculum. Their curriculum vitae in Appendix B reflect their activities in these areas in terms of research, teaching, publications, professional activities, honors and awards received, and participation in professional societies related to these areas.

All members of the faculty regularly engage in continuing professional development, most often through attendance and active participation in regional, national, international, and local meetings of professional societies and scientific working groups. Many of the faculty are members of more than one professional society and actively participate in more than one society. Some of our faculty members also have leading roles in these scientific societies and serve as members of organizing and scientific committees for national and international conferences. Our faculty provide leadership and service to national and international committees to promote research and training. For instance, Dr. Kitt Farrell-Poe is a member (since 2002) and served as the President of Consortium of Institutes for Decentralized Wastewater Treatment between 2005 and 2007. Dr. Slack has been member of ABET Engineering Accreditation Commission Executive Committee, served as Commissioner for ABET Engineering Accreditation Commission, ABET Program Evaluator for Agricultural and Biological and Civil Engineering Programs, and has been among ABET Board of Delegates. Dr. Yoon served as the President of Institute of Biological Engineering. Dr. Kacira served as Chair of Commission Horticultural Engineering and Working Group

Computational Fluid Dynamics under International Society of Horticultural Science (ISHS), and Chair of Commission Structures and Environment under ASABE, and Editorial Board Member, Euro. Journal of Hort. Sci. Dr. Siemens served as Chair of Specialty Crop Production Engineering Committee under ASABE. Dr. Giacomelli served as Working Group Chair of Greenhouse Design under ISHS) and UA representative for National Greenhouse Manufacturers Association. Dr. Cuello has been a member of U.S. National Academies Committee for the Sustainable Development of Algal Biofuels and served as Knowledge Partner UA Liason for Global Forum for Innovations in Agriculture (GFIA). Dr. Livingston has been PEV for ABET and has been serving as a member in the College of Engineering Undergraduate Studies Committee. Dr. Andrade-Sanchez has been member of Precision Agriculture Committee of ASABE. Dr. Hurwitz has been on panels for NSF. Dr. Poe has been serving as National FFA Superintendent and Associate Ag. Mechanics. Dr. Yitayew has been PEV for ABET. And, multiple faculty members has been serving as *AdHoc* reviewers and has been panelist for funding agencies nationally and internationally such as USDA, NIH, NSF, BARD, National Research Council of Canada, and others.

Our faculty have also received prestigious award due to excellence in their research, teaching and outreach activities. For example, about 60% of our faculty members received scientific awards and recognitions between 2009 and 2015. Some of these awards include ASABE superior paper awards, outstanding paper award (Euro Ag. Engr.), excellence in global education (UA), leading edge research (UA), administrator of the year (UA), excellence in research (WAED), Innovator award (Tech Launch Arizona), Outstanding Alumnus, Outstanding Reviewer (COMPAQ, Elsevier), and Fulbright and NSF Fellowships. Detailed list for awards and honors received by faculty are provided in faculty vitae in Appendix B.

Further detailed information about faculty qualifications are provided in Table 6-1 and with the faculty biosketches presented in Appendix B.

B. Faculty Workload

Table 6-2 provides a summary of faculty workload in terms of workload expectations or requirements. Our department follows the guidelines established by the College of Agriculture and Life Sciences for expected workloads (<http://cals.arizona.edu/dean/facultyworkload/>). Based on the CALS workload guidelines, tenure and tenure eligible faculty with 1.0 FTE in instruction have responsibilities equivalent to and including instruction, advising, and recruitment. In doing so, the expectation is to teach 6-8 courses per year and this assumes the course is 3 units. However, flexibility is also provided to the department head to assess the needs of the department and assign teaching loads across the faculty based upon those needs. As seen from the workload data on Table 6-2 and based on the expected guidelines, the faculty in our department either meets or in few faculty cases exceeds the expectations for the teaching load.

For research work load and expectations, the CALS follow the following guidelines:
The guidelines below should be interpreted based on:

1. Research/scholarly activity as defined in an individuals' position description,
2. Indexed to 100% research appointment (prorated based on FTE, i.e., divide

- guideline expectations in half for a 50% research appointment), and
3. A rolling three-year period.

It is expected that faculty will make contributions in each of the three categories below annually:

1. Investigator (including PI, Co-PI, I, or Co-I) of extramural grant, contract (with credit as listed on proposal routing sheet) or gift funding with total costs equivalent to a minimum of 50% of annual salary.
2. Four peer-reviewed publications complete / in print (in journal/publication indexed by ISI Web of Science; i.e., excluding 1-page abstracts or articles, conference proceedings, etc.) and/or patent applications per year as an author or co-author.
3. Author or co-author of a research-based book chapter, review article, or monograph; OR director of a completed thesis or dissertation; OR editor or author of a research-based book; OR invitation for national or international talks;
OR evidence of having submitted at least two proposals annually for extramural research support, as Investigator (including PI, Co-PI, I, or Co-I) for an extramural grant, contract (with credit as listed on proposal routing sheet) or gift, with total costs equivalent to a minimum of 50% of annual salary.

As seen from the workload data and information provided on Table 6-2 and faculty biosketches, and based on the expected guidelines summarized above, the faculty in our department either meets or exceeds the expectations for the research load.

C. Faculty Size

The faculty of the Department of Agricultural and Biosystems Engineering (ABE) is currently composed of 14 core faculty members (please see list below and Table 6-1.). In addition, there are around 13 faculty members (see list below) who have non-salaried joint appointments with ABE from the Department of Chemical and Environmental Engineering; the School of Plant Sciences; Soil, Water and Environmental Sciences; Mathematics; Department of Electrical and Computer Engineering; and Materials Science and Engineering. Dr. Mark Riley was the department head from May 2009 to September 2012, Dr. Donald Slack served as an interim department head from October 2012 to January 2014, and Dr. Kitt Farrell-Poe now serves as department head beginning in February 2014.

The 14 core faculty members are comprised of 8 full professors, 4 associate professors, 1 assistant professor, and 1 professor of practice. Since the last ABET review in 2010, two faculty members (Drs. Kacira and Yoon) have been promoted from associate to full professor, and three faculty members have been promoted from assistant professor to associate professor (Drs. An, Sanchez and Siemens). Since last review in 2010, two faculty members, Drs. Mark Riley and Christopher Choi, left the department and started their positions in University of Nebraska (as department head) and University of Wisconsin (as faculty member), respectively.

With 14 core faculty and highly supportive jointly-appointed faculty, we have sufficient faculty size to cover the necessary required courses and for a suite of enriching elective courses. At times,

we rely on our jointly-appointed faculty to assist with teaching. We are increasing our capacity to teach in the areas of biosystems informatics and remote sensing. Our strategic plans include new hires in bioinformatics with focus on health, food, water and energy nexus, and in automation and robotics (i.e., both for field and controlled environment based crop production), and 2 replacement hires in water resources (within the next 3-5 years).

Our faculty members also work closely and have developed significant interactions with local, national, and international industry partners. The department frequently benefits from these interactions in various ways. Our industrial partners are involved in senior design projects, reviewing and judging senior design projects, reviewing class materials, and providing guest lectures. Our faculty members have formed ties with consulting firms, Arizona agricultural producers, commercial greenhouse growers, irrigation equipment manufacturers, the growing bio-industry in southern Arizona, as well as various local, state, and federal government agencies. Examples include the Pima County Wastewater Department, Natures Sweet, Wholesum Farms, DesertTech, Zelen Environmental, Bosque Engineering, BioVigilant, Pinal Energy, Sweet Ethanol, George Cairo Engineering, Roche-Ventana, and others. These relationships, along with other interactions with industrial and professional practitioners in the nation and internationally, also help our students find internship opportunities during their educational programs and also find jobs after their graduation.

High-quality teaching is the standard in our department with the average overall teacher effectiveness rating based on core courses from students' evaluations at 3.7 out of 5 over the past seven years.

The Department sponsors a number of extra-curricular activities to cultivate faculty-student interactions, hands-on experiential learning in research settings including activities for the ASAE Student Branch, Alpha Epsilon, student-club activities, and research projects. The Department also sponsors a faculty-student picnic every semester.

Finally, the ABE faculty considers student advising and mentoring to be just as important as teaching and instruction; therefore, the 11 regular faculty members (out of 14 ABE full time faculty) who have primarily teaching and research responsibilities are all actively involved in student advising, and/or mentoring and career counseling. For undergraduate student advising, during the first two years the students are mainly served by the Undergraduate Coordinator. However, in addition, the students are assigned an academic faculty advisor based on their interest area. The primary areas of focus and advisors are biological (Yoon and Cuello), controlled environment agriculture (Kacira and Giacomelli), water resources (Slack, Waller, Poe, Livingston, and Yitayew), and biosystems informatics (An and Hurwitz). We attempt to distribute students across the teaching faculty; however, typically Slack, Poe, and Livingston together are assigned more students for advising. Students are encouraged to meet with their specific advisor at least once a semester, however, when such a meeting cannot be arranged, a meeting is arranged between the student and another faculty member whose expertise is related to the student's interest. All students are provided with the electronic location of our website, which contains many valuable items, including the ABE Undergraduate Program Manual which details curricular requirements, a typical 4-year plan, elective offerings in BE and other departments, contact information for advisors, and all degree requirements. The undergraduate tab on the ABE website also provides

course descriptions, admissions information, ABET assessment information, videos of recent internships, employment opportunities, career counselling, scholarships, and financial aid information.

When students enter the program, they and their faculty advisor prepare an unofficial plan of study which includes the sequence of courses and when these should be taken. This information is placed in a student's personal file which is held in the departmental main office. The plan of study serves as a guide for course sequences but often evolves as a student's interests change during their academic career. This plan of study is reviewed by the student and faculty advisor prior to the student's registration for the next semester's course offerings. If a student cannot meet with their specific advisor, this document can serve as a resource for the substitute advisor to provide appropriate direction. Students and advisors can monitor a student's progress through use of the online Student Academic Advisement Report (SAAR). The SAAR lists program requirements, courses completed by the student, and remaining course requirements. Both student and advisor can access this information at any time. Students are asked to bring a current SAAR to meetings with their advisors. When a student is within one and a half semesters of completing the degree requirements, they are asked to prepare a final degree check with their advisor. At this time, the advisor formalizes which courses are utilized as technical electives, as biological science electives, and as credits in engineering design and engineering science. This information is utilized by the ABE Academic Program Coordinator and the College of Engineering Academic Dean's Office to update the student's online academic records. At this time, the ABE department head also reviews the sequence of course selections for electives.

Outreach to local and national communities is an exceptional strength of our faculty and this department in the form of workshops, short courses, field days, seminars, and lectures. Our faculty is also actively involved in university service. For instance, Dr. Farrell-Poe is chair of the UA Continuing Status & Promotion Committee, UA Society of Women Engineers Faculty Advisor, UA-CALS Faculty Guidance Committee member. Dr. Slack has served as member of University of Arizona, International Travel Safety Oversight Committee, Subject Matter Expert, and University of Arizona Arid Lands Steering Committee. Dr. Cuello has been UA Faculty Senator, served as chair and member of CALS Faculty Council, and chair of CALS Faculty P&T Committee. Dr. Poe has been member of UA Committee on Academic Freedom and Tenure and CALS Post Tenure Review Committee. Dr. Kacira has been serving as Director of Grad. Studies for CEA Track in Applied Biosciences under GIDP program, and Executive Comm. Member in GIDP (2011-present), and was member of UA-College of Agric. and Life Sciences Vision 2021 Committee. Dr. Andrade-Sanchez has been member of CALS Cooperative Extension Integrated Crop Management Working Group. Dr. Livingston serves as member of College of Engineering Dean's Undergraduate Curriculum Committee. Dr. Waller has been Chair of CALS CyberIntelligence Committee. All of our faculty members also serve in departmental committees in either member and chair capacities.

D. Professional Development

All ABE Faculty belong to and are active in one or more professional societies. Faculty are encouraged to participate in professional meetings both to present professional papers and to

participate in workshops. The Department budget supports, to a certain extent, travel to such meeting although faculty must pay their own dues and subscriptions. Departmental funds are not sufficient to fully cover cost of participation in professional meetings. However, most faculty have sufficient grant funding to allow them to fully cover expenses associated with participation in professional development activities. Several faculty members have served as instructors for continuing education programs or short course associated with professional meetings and such participation often provides funding to cover travel and expenses of participation. CALS also has some funding reserved to assist faculty professional development.

Faculty participate in a Western Regional Teaching workshop sponsored by Western Regional Colleges of Agriculture. CALS pays travel and registration expenses and the Department pays hotel and miscellaneous expenses. There are also several in-state workshops each year for faculty from the three Arizona Universities and at least one of the ABE faculty participates in these workshops with expenses paid by the Department and the College. For faculty representing CALS Agricultural Experiment Station in USDA regional committee meetings are also funded by the College. Additional information is provided on the regular faculty in Appendix D.

Numerous opportunities for faculty professional development are also available at the University and College level. Some examples of recently offered development activities are given below.

D.1. Professional Development Activities at the University Level

UA Research Development Services provides support for proposal development to faculty at all ranks. Some of the seminars and programs that were offered during the Spring 2016 semester are listed below:

- Weekly announcements for funding opportunities.
- Seminar titled “Write Winning Grant Proposals” - The widely acclaimed seminar by Grant Writers' Seminars & Workshops (GWSW) comprehensively addresses both practical and conceptual aspects that are important to proposal-writing success. The principles and fundamentals of good proposal writing are emphasized, along with "how-to" practical tips and strategies.
- General NSF Sessions – Seminars are provided on the following topics:
 - NSF Budget Overview - This session provides information on the preparation of an NSF budget, with a spotlight on the NSF CAREER budget at the end of the session. In addition, information on UA's F&A rates and allowable costs will be provided.
 - NSF Broader Impacts - This session provides an overview of both the NSF Broader Impact requirements and the resources available at the UA. Participants will learn how to develop strong broader impact statements that reflect their areas of interest and expertise, and that build upon and incorporate institutional resources. Evaluation and assessment are also covered.
 - NSF Program Officer Panel - This session features current and recently returned (rotators) program officers from NSF. After the panel discussion, participants will be able to ask the program officers questions.
 - NSF Data Management

- NEH Summer Stipends Program - This session will provide an overview of the NEH Summer Stipends program, including research activities generally funded by NEH, successful application development, and submission of the application.
- Engaging DARPA - During the Fall of 2014, University of Arizona provided a series of workshops for faculty on obtaining DARPA funding.

Tech Launch Arizona (TLA) offers professional development opportunities for faculty in regards to inventions, intellectual property (IP), and industry. Some of the seminars and programs that were offered during the Spring 2016 semester by TLA are listed below:

- A monthly newsletter that discusses IP issues, SBIR and STTR opportunities
- Weekly Lunchtime Chats, e.g.,
 - The How, When and Why of Invention Disclosures
 - Lean Launch for UA Inventors and Inventions
 - Protecting and Commercializing a Great Lab Discovery: Real-Life Stories from a University Patent Attorney
 - From Bench to Bedside: Protecting and Licensing Intellectual Property
 - Who Really Funded Your Invention?
- All day seminars, e.g., Understanding SBIR/STTR Programs: DARPA, NAVY, Air Force, NSF and NASA

The University of Arizona's Office of Instruction and Assessment (OIA) provides teaching and learning technology support under one roof. The web-site is: <http://oia.arizona.edu/>. The OIA offers support to the UA teaching community in course and curriculum design, online course development, program and classroom assessment and evaluation, instructional strategies, and learning technologies. They also offer numerous workshops through the year, for example:

- What is a #Tweetchat, How do I Do It, and Why Should I Care?
- Improving Student Writing
- Teaching Online Mini-Courses
- Applying the Quality Matters Rubric (APPQMR)
- D2L Support Team Workshop
- Course Level Assessment: An OIA Online Mini-Course
- Effective Online Discussions: An OIA Online Mini-Course
- Online Seminar: Evidence-Based Teaching in Higher Education: Strategies to Improve How Your Students Learn
- Brownbag: Active Participation with Clicker Technology
- Monitoring Teaching Effectiveness
- Active learning strategies: Resident rehearsal

The Office of the Provost offers a Faculty Career Discussion Series. The spring 2016 series included:

- Minority Faculty Career Discussions
 - Using your annual reviews to prepare for P&T
 - What do you want your heads, directors and deans to know?
 - Moving into leadership positions
 - Networking happy hour

- Women in STEM Career Discussions
 - Women in STEM Career Discussions Launch & Getting the Mentoring You Want
 - Women in STEM Career Discussion 2
 - Networking happy hour
 - Women in STEM Career Discussion 3

Department Heads have a special program – “HeadsUp” – where they have discussions with campus leaders and cover issues relevant to leading departments and dealing with students, faculty, and staff issues. The group’s website <http://headsup.arizona.edu/> shows the breadth of activities and aims of the group.

The Commission on the Status of Women's Faculty Affairs Workgroup organizes the First Friday Lunches. These lunches are being offered on the first Friday of the month, February through April, to facilitate the networking of faculty from across campus. These networking luncheons can potentially create self-sustaining interdisciplinary peer networks. In peer networks, faculty members discuss challenges, share information and brainstorm on how to address them. Peer networks also offer collaborative opportunities for both junior and midcareer faculty. Or these luncheons simply offer opportunities to create friendships.

For junior faculty, there are numerous additional development opportunities. Some of the seminars that were recently offered by UA Research Development Services are listed below:

- Early Career/Young Investigator Programs - This session will provide a brief overview of some of the federal and foundation opportunities available to Early Career and Young Investigators including DOD Young Investigator Programs (YIPs), NASA Early Career Faculty Awards, DARPA Young Faculty Awards as well as Cottrell Scholars and Bisgrove Scholars, among others.
- NSF CAREER Grant Preparation Program - The NSF CAREER Grant Preparation Program (“Program”) is offered by Research Development Services, a unit of the Office for Research & Discovery, to provide an overview of the NSF CAREER Grant program and provide proposal development assistance to UA Faculty that chose to submit a full proposal to NSF.
 - Phase I: Introductory Sessions - Includes two introductory sessions in January and February that are open to all potential applicants and interested parties.
 - NSF CAREER Program: An Overview - This session provides a synopsis, including how the CAREER program is different from other NSF programs. It includes advice on how to decide whether this program is a fit and when in their career applicants should apply. In addition, a general overview of the proposal requirements is presented.
 - NSF CAREER Recipients Panel - This session includes UA faculty members who have been recipients of the NSF CAREER award. Panel members discuss how/when they decided to apply for an NSF CAREER award and how they prepared to submit their proposal. They will also discuss their individual career development and educational plans.
 - Phase II: "Commit to Submit" Sessions - This section of the program runs from March through July 2016 and is open to researchers who have committed to the submission of an NSF CAREER application (due in late July 2016). Participants

will be assigned to small mentored proposal development writing groups based on their research areas. Each group will work with a faculty CAREER coach (a prior CAREER recipient) and a Research Development Services Associate. Once groups are assigned, individual group meeting times will be scheduled to coordinate with the participant's availability. The mentored writing group activities will include:

- Introductory Session: short presentations on research concept and education plan
 - Proposal Development: timeline and proposal requirements for the CAREER proposal
 - DC Visit with NSF Program Officers: coordinated by Lewis Burke Associates
 - Proposal Preparation: iterative sessions for proposal preparation
 - Concept Review (Pink Team): review by campus CAREER experts and external discipline experts
 - Final Review (Red Team): final proposal review by CAREER experts
- NIH K Award Grant Preparation Program - The Mentored K Program provides a series of workshops for early career faculty interested in applying to the NIH K funding opportunities. The workshops will include the following topics: overview session, mentor/collaborator statements, environment/institutional commitment session, research plan: specific aims session, as well as individual coaching.

The UA Office of Academic Affairs, in coordination with the Faculty Senate, offers a series of workshops/seminars that are geared towards faculty that are going up for promotion, e.g.,

- Going Up for Full
- Making Your Candidate Statement
- Annual Workshop on Preparing the Promotion Dossier
- Preparing Teaching and Outreach Portfolios

The UA Academic Leadership Institute, established in 2010, aims to enhance and diversify the University's leadership capacity. The Institute provides a yearlong professional development program for 25 faculty and campus leaders, including academic and administrative department heads, associate and assistant deans, and individuals identified as emerging leaders. The program serves both to strengthen the skills of those who are already in leadership positions and to provide a venue for career development for those who are seeking opportunities to lead.

D.2. Professional Development Activities at the College Level

The College of Engineering offers a one-day orientation for new faculty titled "Engineering Overview - New Faculty Orientation". The topics for this event include:

- Ice Breaker and Intro to the College
- Doing Business at UA and in the College
- IT Services
- Marketing and Communication
- Research Development
- Academic Affairs – undergrad/grad
- Tech Transfer and Tech Launch Arizona

The College of Engineering also provides a mentoring program for junior faculty - In an effort to increase faculty success and to enhance the faculty, department, and college cultures the College of Engineering has designed a formal college mentoring program for assistant and associate professors. The program will run approximately 40 hours over 2 years (2 hours per month) and at times we will split the group based on individual needs. This program does not eliminate the need for department mentoring and instead enhances the informal mentoring typically done in our departments. The topics covered include strategies for making you more effective in teaching, research, and your personal life, e.g.,

- Introduction to the College of Engineering
- Issues involving money and the budget at the UA
- Research mechanics before writing a proposal
- Research proposals
- Rest of the University helping with research
- How is it going?
- Teaching and classroom management – syllabus to final grades
- Managing graduate students
- Teaming – finding partners and being found! On and off Campus
- Appreciating and improving diversity – unconscious biases
- IP and tech transfer
- Working with companies on research
- Consulting and conflict of commitment
- Conflict of interest
- Going to conferences and other Universities – How to make the most of the trip
- How to be a compelling person

The college also offered an (Engineering Research Administration Services) ERAS Workshop on Proposals that was open to all faculty.

Another development activity that is offered through the College of Engineering is a travel program to Washington DC to visit NSF and other agencies. This activity is focused mainly on junior faculty, but the College has also supported visits by senior faculty. The main idea behind this program is that the grant writing and award process consists of a technical part and a relationship building part.

The College of Engineering provides support for the National Effective Teaching Institute (NETI) associated with ASEE. The College nominates and supports up to 2 faculty members to go each year to this workshop. We also support sending faculty to the NAE teaching institutes. The College offers to pay the for ASEE initial membership year dues

D.3. Professional Development Activities at the Department Level

Finally, there are also opportunities for faculty professional development at the departmental level. Some these include:

- Seminar series and presentations by invited speakers from industry, government agencies, and universities.
- Controlled Environment Agriculture Center Friday Seminar Series presentations by invited speakers from the UA, other universities and industry.
- Controlled Environment Agriculture Center Summer Research Retreat where faculty discuss about research activities and information exchange, including graduate and undergraduate students involved in research.

Our senior faculty also mentor the junior faculty. Some examples of mentoring include:

- Sharing syllabi and/or course materials for a class that a faculty member hasn't previously taught.
- Guidance and mentoring on the tenure process.
- Collaboration on research proposals and research projects.
- Critique of research proposals or publications prior to submission.

Our departmental business center provides regular sessions, either as part of faculty meetings or separately about financial management, project proposal routing processes, and budget related questions.

The following provides details of professional development activities of our faculty in the department for the current ABET review period.

An, Lingling: Attended American Statistical Association Annual Meetings (2010 -2016); Attended Annual Conference of Institute Biological Engineering (2012); Attended the annual meeting of The Western North American Region of The International Biometric Society (2010, 2013, 2016).

Andrade-Sanchez, Pedro: Attended ASABE Annual Meetings (2009, 2010, 2012, 2013).

Cuello, Joel: Visiting Professor (Short-Term), U.S. Agency for International Development (USAID) Science, Technology, Research and Innovation for Development (STRIDE), De La Salle University, Philippines, 2015; Fulbright Senior Specialist (Short-Term), Center for Antarctic Programs, Universidad de Magallanes, Chile (2010); Visiting Professor (Short-Term), Philippine Department of Science and Technology (DOST) Engineering Research and Development for Technology (ERDT) Program, Ateneo de Manila University, Philippines (2010), University of the Philippines at Los Banos (2009); Knowledge Partner, Global Forum for Innovations in Agriculture (GFIA), United Arab Emirates (2014-present).

Farrell-Poe, Kitt: Attended ASABE Annual Meetings (2009, 2010, 2012, 2013, 2014); Program Assessment and Outcomes Workshop, UA Office of Instruction and Assessment (2015); Attended UA Teaching Academies (2009, 2010, 2011, 2012, 2013); UA College of Agriculture & Life Sciences Leadership Development, Spring 2012; UA Academic Leadership Institute (AY 2015); Battlefield Leadership training (2014); FastTrack Leadership training (2015); Western Regional Teaching Symposium (2010).

Giacomelli, Gene: Videography for Promotion & Awareness – worked with producer/videographer, Cody Sheehy, to create documentary of Lunar Greenhouse NASA project (2014); Technology for Outreach & Promotion – invited to participate in the Global Food & Nutrition XPRIZE Expert Visioneering event, Las Vegas, NV (2016); University & Industry Consortium Conference (UIC), Yuma, AZ, invited presentation for food industry focus on CEA in the Food, Energy, Water Nexus for future of production ag.

Hurwitz, Bonnie: Attended two NSF CAREER award lecture series (at UA in 2015 and at NSF Headquarters 2016); Attended grant writing Workshop by the UA Office of Research; Attended instruction workshops by the UA Office of Instruction and Assessment (2015); Attended and gave invited talks: Diabetic Limb Salvage Conference, Washington, D.C. (2016); University of Michigan Institute for Data Science Distinguished Lecture Series (2016); Ocean Sciences Meeting, Townhall, New Orleans, LA. (2016); Plant Animal Genome Conference, San Diego, CA. (2016); University of Hawaii, Dept. of Oceanography, Honolulu Hawaii (2015); ASM ICAAC, San Diego, CA. (2015); Woods Hole Oceanographic Institute, Woods Hole, MA. (2015); 7th International Symposium on the Diabetic Foot, The Hague, Netherlands (2015); Diabetic Limb Salvage Conference, Washington, D.C. (2014); DFCon, Los Angeles, CA (2014); Plant Animal Genome Conference, San Diego, CA (2014); American Society for Microbiology, Viromics Workshop (2014).

Kacira, Murat: Attended ASABE Annual Meetings (2009, 2010, 2012, 2013, 2014); Attended ISHS GreenSys Int. Symposiums (2009, 2011, 2013, 2015); Program Assessment and Outcomes Workshop, UA Office of Instruction and Assessment (2015); Executive Comm. Meeting of Int. Soc. of Hort. Sci. (ISHS) (Turkey, 2015); Online Course Development, UA CALS Summer Institute (2015); High-level International Forum on Protected Horticulture, China (2015).

Livingston, Peter: Attended Thai Society of Agricultural Engineering Annual Meeting (2013), Kaun Keen University International Engineering Conference (2014); Attended Cornell Aquaculture Short Course, 2013; Attended Southwest Indian Agriculture Assn Meeting (2013).

Poe, Stephen: Attended ASABE Annual Meetings (2009, 2010, 2012, 2013, 2014); Program Assessment and Outcomes Workshop, UA Office of Instruction and Assessment (2015); Attended UA Teaching Academies (2009, 2010, 2011, 2012, 2013); Western Regional Teaching Symposium (2010).

Siemens, Mark: ASABE Annual Meetings (2009-2015); ASABE CPD Developing Native Apps for Android Devices (20015); CALS Effective Workplace Communication (2012); UNM-MTEC Solid Modeling Design Short course (2012); ASABE CPD Hydraulic System Design (2010); CALS Drupal Training (2009); ASABE CPD Hyperspectral and Multispectral Imaging (2008).

Slack, Donald: Attended ASABE Annual International Meetings (2011-2015); Attended International Engineering Conference-KKUIENC in Khon Kaen, Thailand,(2010, 2012, 2014); Attended International Meeting of the Thai Society of Agricultural Engineers (2013, 2015). Attended ABET Symposium, 2016.

Waller, Peter: Attended Algal Biofuel, Biomass, and Bioproducts meeting in San Diego, 2016;

Attended ASABE meeting Kansas City (2012, 2013); Attended National Alliance for Advanced Biofuels and Bioproducts meetings (2012, 2013, 2014); Research collaboration at Pacific Northwest National Laboratory, Sequim Washington (2012, 2014, 2016).

Yitayew, Muluneh: Attend the annual African Climate Change and Development Conferences Since 2011; Attend Brown Bag Seminars Water Resources Research Center UA.

Yoon, Jeong-Yeol: Attended numerous conferences, including IBE Annual Conference, ASABE Annual International Meeting, Biosensors World Congress, MicroTAS, KSBB International Meeting, In Vitro Biology. Made numerous seminar presentations throughout US and worldwide.

E. Authority and Responsibility of Faculty

The ABE Department faculty have responsibility for developing, revising, and assessing the biosystems engineering curriculum. We maintain an active undergraduate program committee which performs the major oversight functions and reports to the department head and the department faculty. All changes to the curriculum are discussed in the undergraduate program committee and then brought before the faculty for vote. Dr. Peter Livingston serves as chair of this committee and due to that role also sits on the College of Engineering (CoE) Undergraduate Studies Committee (USC). The CoE USC provides oversight and coordination of all undergraduate curricula within the college. A similar committee exists in the College of Agriculture and Life Sciences. Major changes in the biosystems engineering curricula are sent to the College of Engineering committee for evaluation; these are also sent to the CALS committee as a matter of courtesy.

Table 6-1. Faculty qualifications of the Biosystems Engineering Program in the Agricultural & Biosystems Engineering Department.

Faculty Name	Highest Degree Earned- Field and Year	Rank ¹	Type of Academic Appointment ² T, TT, NTT	FT or PT ³	Years of Experience			Professional Registration/ Certification	Level of Activity ⁴ H, M, or L		
					Govt./Ind. Practice	Teaching	This Institution		Professional Organizations	Professional Development	Consulting/summer work in industry
An, Lingling	PhD, Statistics, 2008	ASC	T	FT	0	8	8	none	L	M	L
Andrade-Sanchez, Pedro	PhD, ABE, 2004	ASC	CS	FT	0	1	8	none	H	H	L
Cuello, Joel	PhD, ABE, 1994	P	T	FT	0	24	21	none	H	H	L
Farrell-Poe, Kitt	PhD, Civil Engr, 1990	P	CS	FT	0	25	18	NAWT Certified Inspector, EIT	M	H	L
Giacomelli, Gene	PhD, Plant Science/ABE, 1983	P	T	FT	0	36	16	none	M	M	L
Hurwitz, Bonnie	PhD, Ecology & Evol Biol, 2012	AST	TT	FT	12	2	4	none	L	H	M
Kacira, Murat	PhD, Food, Ag. and Biological Engr., 2000	P	T	FT	0	16	9	none	H	H	L
Livingston, Peter	PhD, BE, 2013	ASC	NTT	PT	34	3	3	PE	M	H	M
Poe, Stephen	PhD, Ag. Engr., 1987	P	T	FT	1	30	17	NAWT Certified Inspector	H	H	L
Siemens, Mark	PhD, ABE, 1996	ASC	CS	FT	11	1	8	EIT	H	M	L
Slack, Donald	PhD, Ag. Engr., 1975	P	T	PT	1	46	32	PE	H	H	M
Waller, Peter	PhD, Ag. Engr., 1992	ASC	T	FT	3	23	23	none	L	H	M
Yitayew, Muluneh	PhD, Civil Engr., 1982	P	T	FT	2	32	32	EIT	M	M	L
Yoon, Jeong-Yeol	PhD, BME, 2004	P	T	FT	0	12	12	EIT	H	M	M

1. Code: P = Professor ASC = Associate Professor AST = Assistant Professor I = Instructor A = Adjunct O = Other

2. Code: TT = Tenure Track T = Tenured CS = Continuing Status NTT = Non Tenure Track

3. At the institution

4. The level of activity--high, medium or low--should reflect an average over the year prior to the visit plus the two previous years.

Table 6-2. Faculty workload summary of the Biosystems Engineering Program in the Agricultural & Biosystems Engineering Department.

Faculty Member (name)	PT or FT ¹	Classes Taught (Course No./Credit Hrs.) Term and Year ²	Program Activity Distribution ³			% of Time Devoted to the Program ⁵
			Teaching	Research or Scholarship	Other ⁴	
An, Lingling	FT	ABE 516A (3), ABE571B (3) both Spring 2016	30%	70%		100
Andrade-Sanchez, Pedro	FT	No teaching appointment		70%	30%	100
Cuello, Joel	FT	ABE 452/552 (3) Spring 2016; ABE 482/582 (3) Fall 2015	30%			100
Farrell-Poe, Kitt	FT	ABE 459/559 (3) Spring 2016; ABE 496A (1) Fall 2015	10%	18%	72%	100
Giacomelli, Gene	FT	ABE 483/583 (3) Fall 2015	20%	50%	20%	100
Hurwitz, Bonnie	FT	ABE 487/587 (3) Fall 2015	20%	80%		100
Kacira, Murat	FT	ABE 284 (3) Fall 2015; ABE 479/579 (3) Spring 2016	30%	70%		100
Livingston, Peter	PT	ABE 201 (2) Fall 2015, ABE 455/555 (3) Fall 2015, ABE 458/558 (3) Spring 2016, ABE 456/556 (3) Spring 2015, ABE 498A (3) Fall 2015, ABE 498B (3) Spring 2016, ENGR 102 (3) Fall 15 and Spring 2016	75%	20%		90
Poe, Stephen	FT	ABE 170A1 (3) Fall 2015 & Spring 2016; ASM 301 (3) Spring 2016; ASM 404 (3) Fall 2015	80%		20%	100
Siemens, Mark	FT	No teaching appointment	25%		75%	100
Slack, Donald	PT	ABE 426/526 (3) Fall 2015, ABE 455/555 (3) Fall 2015, ABE 696A (1) Fall 2015 and Spring 2016	27%	63%		80
Waller, Peter	FT	ABE 170A2 (3) Fall 2015, Spring 2016, Summer 2016, ABE 205 (3) Spring 2016, Summer 2016, ABE 423/523 (3) Spring 2016, ABE 456/556 (3) Spring 2015	30%	70%		100
Yitayew, Muluneh	FT	ABE 120 (3) Fall 2015 & Spring 2016; ABE 221 (3) Fall 2015 & Spring 2016	50%	50%		100
Yoon, Jeong-Yeol	FT	ABE 447/547 (3) Fall 2015, ABE 481B/581B (3) Spring 2016, ABE 486/586 (3) Spring 2016	30%	70%		100

1. FT = Full Time Faculty or PT = Part Time Faculty, at the institution
2. For the academic year for which the Self-Study Report is being prepared.
3. Program activity distribution should be in percent of effort in the program and should total 100%.
4. Indicate sabbatical leave, etc., under "Other." The % activity indicated on the table refer to Extension appointment of the faculty.
5. Out of the total time employed at the institution

CRITERION 7. FACILITIES

A. Offices, Classrooms, and Laboratories

A.1. Offices

The Department facilities include office space, classrooms, teaching and research laboratories. Available facilities are in general adequate to accomplish the instructional objectives of the Biosystems Engineering courses and curriculum, and support the attainment of the student outcomes and to provide an atmosphere conducive to learning.

All but four of the on-campus faculty have individual offices in the Shantz Building; Drs. Slack and Yoon have offices in the Forbes and Marley buildings, respectively. Drs. Giacomelli and Kacira share an office in Shantz building, but they also have individual offices at the Controlled Environment Agriculture Center (CEAC), located off-campus.

The administrative assistant, under graduate and graduate coordinator, and department front office student assistants have individual offices. In 2014, the Business Office of the ABE department was combined with the Business Office of the department of Nutritional Sciences creating a Business Center.

We need some office space for visiting faculty. Space for administrative offices for the department head and staff is adequate. However, the space is limited for storage, so files and cabinets are packed into these offices, making them crowded and less usable. The reception area for the department was updated recently with its furniture and also an LED TV was installed for promotional video presentations about the department.

The space for teaching assistants is limited in the department. The office space is usually used as available in various labs and space available in the graduate student offices.

ABE faculty have laboratory and office spaces in the Shantz and Marley building on main campus of the University of Arizona. ABE also has laboratory and office space of the CEAC, and a workshop at the University of Arizona farm to support senior design projects. In addition, the Department also has greenhouse facilities at the UA-CEAC. Research labs also exist at the Yuma and Maricopa Agriculture Centers for field agriculture mechanization and precision farming. Space is currently under review in the department as a result of the recent shift to the Responsibility Centered Management (RCM) financial model. As a result, unused space is being released and required space is being designated. Some faculty members are currently in need of space with growing research labs, while others report adequate space. Our off-campus research centers (MAC, YAC and CEAC) offer new facilities for research and outreach.

Maricopa Agricultural Center (MAC)

The Maricopa Agricultural Center provides office, laboratory, and shop space to support the research and extension activities of ABE faculty stationed in this center. Additional support available to faculty is MAC's IT infrastructure and a state-of-the-art meeting/conference center with 190 people capacity. The instrumentation laboratory and fabrication shop provide a combined area of 1550 sq. ft. of space dedicated to design, and development and testing of electronic instrumentation for precision agriculture research program directed by Dr. Pedro Andrade-Sanchez. Perhaps the most important contribution of MAC to ABE programs is in the form of agricultural fields to run experimental work to test new production technology and field-based high-throughput phenotyping capturing the low desert ambient conditions of high heat and long growing season. Moreover, MAC has provided to ABE faculty 1 ha of field space for a permanent installation of a rail-mounted plant scanner and a phenotyping system. This system is the first of its kind in the United States.



Figure 7-1. Field based high throughput phenotyping at MAC.

Yuma Agricultural Center (YAC)

Ag Mechanization Shop at the Yuma Agricultural Center (YAC): The Ag Mechanization Shop at YAC, Yuma, AZ is directed by Dr. Mark Siemens. The 3,200 sq. ft. facility is equipped with CNC lathes, milling machines, welders and other general-purpose machine shop tools necessary for the design and fabrication of specialized equipment. Electronic test equipment, sensors, data acquisition hardware and electronic equipment are housed in the building's clean room. Office space for technicians and students is also provided. The Ag Mechanization Shop is located adjacent to YAC's Glen G. Curtis Research Building. The 19,000 sq. ft. facility is equipped with state of the art laboratories and meeting and conference rooms. Dr. Mark Siemens has office space in this facility.



Figure 7-2. ABE shop at YAC.

Controlled Environment Agriculture Laboratory

The Controlled Environment Agriculture Center (CEAC) facilities are located within the Campus Agricultural Center (CAC) at Campbell Avenue and Roger Road, approximately 3 miles north of the main University of Arizona campus. CEAC facilities include an office building, state-of-the-art classroom, greenhouses, growth chambers, temperature controlled rooms, and three faculty laboratories (Drs. Giacomelli, Kacira, and Kubota). All facilities were designed and constructed since August 2000. Construction and operation costs were primarily provided by CEAC annual state budget funds; although several specialized greenhouse labs were developed with industry and competitive grant funding. Infrastructure, maintenance and construction support was provided by Campus Agricultural Center personnel, which also includes 24/7 operations support. Staff support

includes one 0.5 FTE office manager (Albertson) and one 0.5 FTE program coordinator (Tevik), plus one FTE staff engineer (Barto), and one 0.5 FTE technician (Kroggel for Dr. Kubota).

The CEAC main building (#2088) is a 5000 square foot, Spanish style, single story building. It contains the Directors office and 4 faculty/staff offices, state of the art classroom, two laboratories, a multi-purpose room, reception area, and kitchen facilities. One laboratory is for Plant Physiology and is directed by Dr. Chieri Kubota, faculty from the Plant Sciences Department and with joint appointment with ABE. The Plant Physiology laboratory has capability for plant photosynthesis and transpiration measurement; nutrient and plant constituent analysis; LED research applications, and general laboratory functions. The other laboratory is directed by Dr. Murat Kacira, engineer and faculty in ABE, and is for teaching and research on advanced sensing, monitoring, climate control, and alternative energy integrated CEA systems.



Figure 7-3. The Controlled Environment Agriculture Center (CEAC) facilities.

The multi-purpose room has 70-seat state-of-the art classroom lecture or conference room. The quality and reach of the audio, video and other visual systems have been significantly updated since the last visit. The room has web-casting capabilities. The classroom includes large screen projection equipment with connection for overhead projection, a PC, double screen monitor, internet, video/DVD, audio system, and remote control for audio and video systems. This room is not only used for teaching (i.e. ABE/PLS 483/583, ABE/PLS 475/575, ABE/PLS 479/579) but also for seminars, faculty and staff meetings, ABE departmental retreats, CEAC summer research retreat, and for industry and stakeholder outreach events.

The greenhouse teaching facilities include a 5200 square foot, multi-bay educational laboratory (GH#2078) for teaching controlled environment greenhouse systems operations and crop production system procedures. This facility is used for ABE/PLS 483/583, ABE/PLS 475/575, ABE/PLS 479/579 and the other CEAC supported courses including Plant Sciences Greenhouse and Hydroponic Crop Production classes (PLS217 & PLS394), and Entomology for Greenhouse Crop Production (497C/597C).

The Mars-Lunar Greenhouse Lab located within the ARC Building at the Campus Agriculture Center is also used as an education and outreach lab. It is supported by Dr. Giacomelli through CEAC funds (since 2001) and with the NASA Steckler Space Grant (since 2008 thru 2017), and consists of 1950 square foot room containing one operational Mars-Lunar Greenhouse unit and 3 incomplete units, plus various artificially lighted plant growing devices.

A.2. Classrooms and Associated Equipment

Overview: Common teaching facilities used for ABE class instruction are the ABE Teaching Laboratory, Shantz Room 440. The Department has also updated multi-media equipment in this room for effective instruction, and as well as for meetings with collaborators and faculty offsite. The principal facilities used for laboratory instruction in the various ABE specialization areas are the Marley Teaching Lab (218) for ABE 447/547, Sensors and Controls and ABE 481B/581B Cell and Tissue Engineering, the Irrigation/Hydraulics Laboratories at the Campus Agricultural Center, and the Biosystems Engineering Laboratory and Bioprocess Engineering Laboratory in Shantz 427 and 512, respectively. The Advanced Sensing and Climate Control Lab for Sustainable CEA Systems for ABE/PLS Applied Instrumentation for CEA, and the CEA state-of-art Teaching and Outreach Classroom and Greenhouse Laboratory are both located at the CEAC Building at the Campus Agricultural Center (located 3 miles north of main campus). These CEA-based Labs infrastructure are currently fully supported and maintained by CEAC funds and technical staff.

Centralized Resources for Instruction: The University of Arizona provides a number of centralized resources that support instruction at both the undergraduate and graduate level. The Office of Instruction and Assessment (OIA) is a campus resource that helps all faculty, instructional personnel, and researchers to integrate technology into academic activities. OIA employs 35 full time and part time staff who offer support to the UA teaching community in course and curriculum design, online course development, program and classroom assessment and evaluation, instructional strategies and learning technologies. OIA also provides workshops, training, and ongoing support for learning management systems and web based tools, including D2L, that supplement classroom instruction, and provides for fully distance-delivered courses and programs. Most of the ABE faculty take advantage of aspects of the services provided through OIA, and have a favorable appraisal of many of the resources. In particular, new faculty have attended the “D2L just in time workshops” to learn how to manage their classes and materials using D2L.

UA Classrooms and classroom support: Over the past decade, the university has made a concerted effort to outfit classrooms with technical equipment including computer projectors and wireless internet connections that facilitate classroom technology utilization, and the support has been very good. Classroom technology services (operated through the University Information Technology Services) are readily available by phone call that typically results in prompt assistance.

The **ABE Teaching Classroom**, Room 440 in Shantz Building (1,000 sq. ft.), with its multi-media teaching equipment used for most of the departmental lecture instruction, for laboratory exercises requiring dry laboratory facilities, for graduate student seminars and sometimes for committee and faculty meetings. Since the last visit the new upgrades to this room have included: updated the computer and presentation equipment, new audio and video system and software updates.

The current system includes a ceiling mounted projector and a computer linked to the University computer network with AutoCAD and other software are available to create presentation materials. These pieces of equipment may all be connected to the projector and hence, provide ready access to multiple modes of presentation. There is a wireless hub located in this room. Addition of the multimedia system has improved classroom instruction considerably as electronic materials from

the World-Wide-Web, from graphic software, and from video may be easily disseminated to the students. Instructors are able to utilize any of the media to deliver materials. Student presentations, particularly senior design project presentations have changed dramatically as a result of the updated systems in the room. The room has large tables with ready access to electric power, chalkboard, overhead projector and screen. In addition, the room contains substantial wall and cupboard storage for equipment, both lockable and non-lockable, sink with hot and cold water, and hood.

Instructional Computing Classroom Facilities available to ABE students include the CCIT Microcomputer Laboratory in Shantz 338 and the ABE student computing room in Shantz 425. Computer instruction now principally involves microcomputers, though the University maintains and provides access to modern, high capacity main frame computers for large computational needs in the CCIT buildings. A number of CCIT microcomputer laboratories, most equipped with Pentium 4 computers, but two with MAC computers, are maintained at convenient sites around campus, including two located in dormitories. All of these labs are open for extended time periods each day and are staffed by student assistants.

Instruction in Computer Aided Design (ABE/ENGR 221) was expanded in Spring 2007 to include SOLIDWORKS as well as AutoCAD. The Shantz 338 computer laboratory equipped with 30 workstations provides the capability for CAD instruction. In addition all libraries and Office of Student Computing Resources (OSCR) labs throughout the campus have installed SOLIDWORKS in their computers to make it available to students almost 24/7 throughout the semester.

Shantz 531 is upgraded with two big screen TV monitors, a one gig data line, 3D printers and computers for use for face-to-face help session for both Microcomputer Application courses (ABE 120) and ABE/ENGR 221. The room and the computing facilities are also used to hold online office hour using Citrix GoToMeeting collaboration software. The 3D printers are for use in ABE/ENGR 221 class to prototype the design that is developed using SOLIDWORKS.

Student laboratory monitors provide security and assistance with equipment problems and some application questions during all open hours. Equipment maintenance and upgrades are provided by CCIT in CCIT labs and by the CALS. ABE and CCIT faculty and staff, with CALS funding, manage and maintain the computer lab.

The **Marley Teaching Laboratory** (2500 sq. ft.): This lab, since fall 2006, has been utilized to teach ABE 447/547 Sensors and Controls and ABE 481B/581B Cell and Tissue Engineering. This teaching lab is controlled by Department of Plant Science. Current enrollment ranges from 50 (for 481B/581B) to 80 (for 447/547), so we divide the entire class into three to four sections. The lab accommodates up to 20 people and we had no space problems in teaching this class. All necessary small equipment and supplies are stored in a secured and locked cabinet within the teaching laboratory, while more expensive equipment are stored in a secured and locked cabinet in Dr. Yoon's lab (Biosensors Lab, Marley 503 and 509). Laboratory topics in 447/547 class includes: resistors, diodes, transistors, temperature sensors, op-amps, light sensors, spectrophotometry, fluorescence, electrochemical sensors, glucose sensors, immunosensors, lab-on-a-chip, microcontrollers, etc. Laboratory topics in 481B/581B class includes: bacterial culture,

mammalian culture, cell/cytoskeleton imaging, biomaterial surfaces, cytotoxicity, focal adhesion, contact guidance, organ-on-a-chip, etc.

A.3. Laboratory Facilities

The Irrigation/Hydraulics Laboratory

This lab is located at the Campus Agricultural Center provides a fairly large roofed area to shade experiments, pumps, experimental channels and water storage tank. A long throat flume for open channel flow measurement equipped with pressure transducers and data acquisition system has been installed since the last accreditation visit with funding from the USDA Water Conservation Laboratory in Phoenix. Adjacent test plots are available for conducting irrigation tests; a well and pump for pumping tests. Equipment is available for obtaining climatic data, measuring soil properties, measuring flow and evaluating irrigation system performance. The facility also includes a small enclosed room to store equipment. There are plans to upgrade the laboratory by providing an instrumented manifold for conducting pipe flow measurement laboratory exercises. The lab was too small and inappropriate for lab analysis and office work, so a small temporary office was added to accommodate desk and computer. At some point, a more permanent or larger structure will be needed to house this office.

Soil and Water Resources Engineering Laboratory, Shantz 436 (300 sq ft)

The laboratory has four primary emphases. (1) Soil analysis and irrigation research, (2) algae growth research, (3) computer modeling of algae growth systems, and (4) aquaponics demonstration for ABE423 and ABE170A2. Soil measurement capabilities include pressure plate measurement of water characteristic curves for soils and other porous media, oven drying of soils and plants. We are also setting up an aquaponics demonstration for the ABE423 and ABE170A2 classes. The lab has lighted shelves for algae and contaminant growth experiments. The main focus of the laboratory is modeling algae growth in the algae raceways at the ARID Raceway Research Facility, and the graduate students have desks where they conduct this research. The computer modeling efforts use data from the ARID Raceway Research Facility.

Remote sensing equipment includes unmanned aerial vehicles with an autonomous guidance system, cameras, GPS receivers, sensors for measurement of remote sensing indices from the plane, and temperature and humidity sensors. This research is performed in collaboration with the Center for Applied Spatial Analysis for GIS applications. Field and greenhouse research associated with the laboratory includes biochar incorporation in soils, greenhouse growing media, and remote sensing of agricultural fields; this research is conducted at the 6th Street Garage Greenhouses, at Red Rock Agricultural Center, and at Maricopa Agricultural Center, and at the Controlled Environment Agriculture Center.

ARID Raceway Research Facility

(Office/lab, 300 sq ft; working area, 1800 sq ft; harvesting area, 500 sq ft., cultivation area, 36000 sq ft; storage room with chain link sides, 520 sq ft.). This facility is located at the Campus Agricultural Center. This facility was primarily constructed by the College of Agriculture but is shared with Chemical Engineering as the primary research location for the Regional Algae Feedstock Testbed grant from the Department of Energy. The office includes a spectrophotometer, chemical cabinet, microscope with camera, growth chamber, two computers, freezer, printer, and radio connection to outdoor dataloggers. The open air, partially roofed, concrete work area includes CO₂ tanks, inoculum tanks, and centrifuge for harvesting, pipes from raceways to deliver algae water, work tables, hand and power tools, and radial grinder. The harvesting area includes a settling tank but is being converted to a raceway. The cultivation area includes four raceways of various sizes with remote control of raceway pumps, air bag berms, carbon dioxide, and oxygen injection. Control sheds in the cultivation area include Campbell Scientific dataloggers and computers, which provide control for the raceway and monitor dissolved oxygen, salinity, pH, and temperature in raceways. A weather station provides atmospheric and light measurements.



Figure 7-4. ARID Raceway Research Facility.

Geographic Information Systems Laboratory, Shantz 531 (300 sq. ft.).

This laboratory contains two SUN System microcomputers which implement an ARC INFO GIS program. The laboratory is used primarily for geospatial analysis and remote data sensing of natural resources for graduate student research although it also provides GIS demonstrations for undergraduates. The laboratory has been maintained by research grants and contracts. Presently it is being transformed to a distance learning center with multimedia equipment for international project.

Controlled Environment Agriculture Laboratory

The CEAC (<http://ceac.arizona.edu/>) greenhouse facilities include 2 research/demonstration greenhouses (GH#2091A & C) (2700 square foot each), 2 small high tunnel greenhouses (1500 sq. ft. each) for PV integrated greenhouse research (Dr. Kacira), 11,000 square foot retractable roof greenhouse (Schuch, School of Plant Sciences), and with SWES department, a 2500 sq. ft. greenhouse/headhouse facility containing 3, 625 sq. ft. aquaponic plant and fish research facilities. A small (100 sq. ft.) vertical farm system (Dr. Kubota) and a larger vertical farm research and teaching facility (750 sq. ft.) (Drs. Kacira, Giacomelli and Kubota) is also located at the CEAC. These facilities offer experiential activities for students, including design and operations of



Figure 7-5. CEAC greenhouse facilities.

computer environmental controllers, drip irrigation and fertigation systems, and general greenhouse actuators for environmental control by heating, fan or natural ventilation, pad or fog evaporative cooling, shading, and carbon dioxide enrichment, plus various hydroponic and aquaponic hardware systems.

Other greenhouses available for rent from the Campus Agricultural Center have been renovated and used for specialty or specific project purposes, and include: (1) a 25 by 75 foot single bay aquaponics research facility (GH#3018), with multiple, computer-controlled environmental zones for fish culture and for hydroponic plant culture (Drs. Giacomelli and Fitzsimmons (SWES)); (2) a 1000 square foot single bay greenhouse (GH#2078-1) with an ebb & flood table system and trough systems for production of specialty crops (Kubota); (3) a 1000 square foot single bay greenhouse (GH#2078-3) for testing and demonstrating crop production in hydroponic systems (Dr. Giacomelli); and (4) a 1000 square foot single bay greenhouse (GH#2078-2&3) for PV integrated greenhouse systems project (Dr. Kacira).

The controlled environment chamber facilities include a 900 square foot metal building which houses 3, 9 square foot reach-in growth chambers, a 150 square foot walk-in growth chamber, and one 150 square foot walk-in cooler. There are also 2, 150 square foot walk-in low temperature storage rooms adjacent to building #2075.

The Bioprocess Engineering Laboratory, Shantz 512 (637 sq. ft.)

This lab was under the direction of Dr. Mark Riley until he left for University of Nebraska in fall of 2012. The lab included equipment such as a fluorescence microscope, uv-vis 96-well plate reader, Nicolet Magna 560 Fourier Transform Infrared (FTIR) spectrometer with InSb and MCT infrared detectors, portable Enwave Raman spectrometer, a uv-vis spectrophotometer, a temperature controlled high speed centrifuge, freezer, analytical balance, two controlled temperature water baths, a Silicon Graphics O₂ workstation, two biological safety cabinets, microscope for cell enumeration, liquid nitrogen facilities for cell storage, two CO₂ incubators, one atmospheric incubator, several liquid and vapor pumps, MilliQ water purification, a pH meter, and many other pieces of small equipment. It is currently being used by multiple faculty members for various research including growing algae and using microbubbles for disinfecting cut lettuce leaves.

Biosensors Laboratory

Biosensors Laboratory, under the direction of Dr. Jeong-Yeol Yoon, was originally located in Forbes 132 has been recently moved to its new location in Marley building (rooms 503 and 509). This lab is currently approved for Biosafety Level 2 (BSL-2) and Chemical Safety Level 2 (CSL-2). Equipment in Biosensors Laboratory include: gas chromatograph with auto sampler (Shimadzu); liquid chromatograph with diode array detector, refractive index detector, and auto sampler (Shimadzu); 3D printer (Dimension uPrint); ball-bearing linear and rotational positioning stages; inverted fluorescent microscope (Nikon) with digital image/movie capturing; dynamic



Figure 7-6. Biosensors lab.

contact angle/surface tension analyzer (First Ten Ångstroms); flow-cell quartz crystal microbalance (Stanford Research Systems); two PCR thermocyclers (MJ Research); two gel electrophoresis systems (Fisher); gel documentation system (Bio-Rad); electrochemical DNA sensor (AndCare); 18 MΩ-cm water purification systems (Millipore); -40°C deep freezer (Thermo); autoclave (Tuttnauer-Brinkmann); two CO₂ incubators (Thermo); incubator (Fisher); oven (VWR); chemical hood (Hamilton); class II biosafety cabinet (NuAire); two UV/visible spectrometers (Ocean Optics); two optical fiber spectrometers (Ocean Optics); Qubit fluorometer (Invitrogen); two electronic balances (Ohaus); digital multimeters; breadboards; power supplies; two centrifuges; two vortex mixers; rock shaker; heating block; shaking incubator; water bath; refrigerator/freezer.

Water Distribution Laboratory at the Water Village

The Water Village was a state-of-the-art facility established at a University of Arizona off-campus research center (The Environmental Research Lab, ERL) and directed by Dr. Christopher Choi. The ERL was decommissioned by the University in fall 2015. When the ABE department was doing research at the ERL, until fall 2012, the Water Distribution Network Laboratory at the Water Village consisted of various pipe networks. These were constructed with flexible modular units, and thus the network geometry was readily modified based on simulation models. It was also possible to change the water quality at various points in the distribution system and remove selection of piping for testing and observation. The distribution system contained sensors for water hydraulics and quality (e.g., flow meters, pressure gages, salinity, pH, temperature, dissolved solids, etc.) throughout the network for continuous monitoring. The laboratory was also equipped with data loggers, a high-speed camera, and various sensors for real-time, remote (using RF and cell phone modem) monitoring in aquatic systems for laboratory and field scale experiments. The laboratory was designed to test various control devices, pumps, and testing and data acquisition units. Two high speed workstations were dedicated to running Fluent, MATLAB, and EPANET. There were four additional workstations and laptops for data acquisition and processing.

Water Sensing Laboratory

In the water sensing laboratory, also located at Environmental Research Laboratory (ERL), there was a variety of equipment for monitoring biological contaminants in water. This lab was directed by Dr. Christopher Choi who left the department in fall 2012. The lab included a water purification system to permit delivery of water of varying quality ranging from drinking water to deionized to reverse osmosis. On-line sensors included those for electrical conductivity, total organic carbon, ultraviolet light scattering, turbidity, and flow. More sophisticated sensors included a JMar Biosentry system to quantify bacteria, protozoa, and spores; a system for quantifying bacteria, TOC, DOC, and others; and a Hach event monitor system which included individual sensors for pH, TOC, turbidity, free chlorine, and a pattern-matching expert system to predict and classify water intrusion events. The water sensing laboratory was officially decommissioned the fall of 2015 with the rest of the ERL.

Biosystems Engineering Laboratory

This laboratory is under the direction of Dr. Joel Cuello. The laboratory, located in Shantz 427 (800 sq. ft.), is used for conducting research studies on cell and algae cultures for biofuel and biochemical production as well as plant tissue cultures and hydroponics. It includes cell and algae culture photobioreactors, a controlled-environment growth chamber, UV/VIS and FTIR spectrophotometers, an HPLC, centrifuge, several desktop computers, laminar flow hoods, orbital shakers, microscopes, CO₂ incubator, light meters, water purification systems and instrumentation and data acquisition equipment for cell growth and evaluation. This laboratory has been renting a greenhouse unit located on top of the campus 6th street garage for conducting large-scale operation and piloting of algae photobioreactors.



Figure 7-7. Biosystems engineering lab.

The Lunar Greenhouse (LGH) Lab

The LGH lab is directed by Dr. Gene Giacomelli. The lab (1950sq. ft.) is located within the Animal Research Center Building (#2019). The lab houses the single operational Mars/Moon Inflatable Greenhouse and 3 incomplete units, plus various artificially lighted plant growing devices.



Figure 7-8. Lunar greenhouse lab.

The Mars-Lunar Greenhouse is a lightweight, 18 foot long by 7.8 foot diameter climate controlled flexible film, collapsible structure.

It is fully instrumented to monitor and control by computer the basic plant aerial and root zone environmental conditions, including light by high intensity discharge lamps or LED lamps, air temperature and relative humidity, and root zone nutrition, and specifically to monitor carbon, hydrogen and oxygen as biomass, water and carbon dioxide, respectively, within a semi-closed bioregenerative life support system prototype. A web connection for remote monitoring and control of web cameras and data monitoring is operable.

Sensing and Control Lab for Controlled Environment Agriculture (SCL-CEA)

This lab is directed by Dr. Murat Kacira. The mission of the lab is to establish resource use efficient controlled environment agriculture systems with novel sensing and monitoring and climate control technology applications. The lab has machine vision system components including research grade cameras (visible, NIR and IR), frame grabbers, single and two axis positioning robotic system for automated crop diagnostics research. The lab has 4xCR1000 and 2xCR3000, 1xCR6 Campbell Scientific dataloggers, a wireless and a wired climate station and computers (5 PC work stations, 4 Notebooks and 4 Laptops). A multi-monitor and Intel Quad core work station with AnSys Fluent software package for CFD analysis studies. The lab is equipped with programmable automation

controller (Compact FieldPoint) composed of rugged I/O modules and intelligent communication interfaces for real-time monitoring and control applications. The lab equipment also includes a FLIR A325 machine vision thermal camera, an NIR range digital camera for UAV applications (TetraCam ADC Air), a HACH DR-3800 spectrophotometer, Hanna photometer, a HukseFlux I-V400 tester for photovoltaic panels, Spectroradiometer (300-1100 nm), porometer, optical density

measurement and flow cells for algae growth monitoring, and chlorophyll content sensor. The lab has various sensors including pyranometers, quantum sensors, hot wire and sonic anemometers, CO₂ analyzer, solid state temperature sensors, soil moisture probes, psychrometers, electrical conductivity and pH probes for inline measurements. A fully instrumented and autonomous photobioreactor test-bed for novel sensor and climate control strategy development studies for microalgae. The laboratory is also used in part for teaching Dr. Kacira's dual listed course "ABE/PLS 479/579, Applied Instrumentation for Controlled Environment Agriculture." Computers in the lab include software: Microsoft Office 2016, Solid Works 2016, Matlab 2016, AnSys Fluent 12.1.4., and LoggerNet. Sensors, instrumentation, computer software are periodically updated.

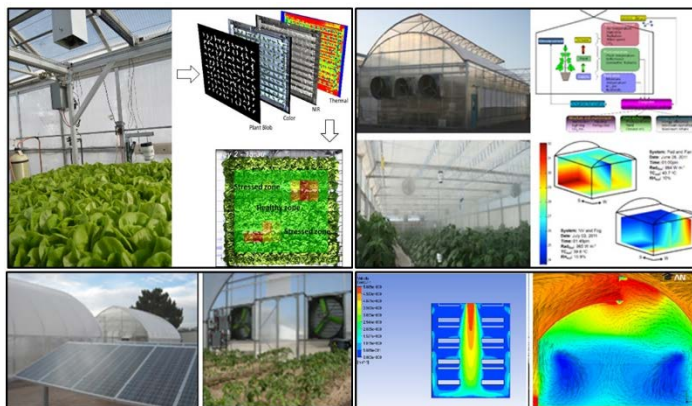


Figure 7-9. Sensors and control lab for controlled environment agriculture.

Controlled Environment Plant Physiology & Technology Lab (Kubota Lab)

Dr. Chieri Kubota, with joint appointment with ABE, directs this lab. The mission of the Lab is to serve in the development of science and technology in the area of controlled environment agriculture. The projects focus on interdisciplinary area that encompasses plant physiology and horticultural engineering to enhance understanding and efficiency of CEA plant production systems such as greenhouses and growth chambers as well as vertical farming/warehouses. Kubota Lab owns growth chambers, LED lightings, a leaf photosynthesis measurement system, HPLC, environmental sensors and dataloggers in the standard wet and dry lab facilities located at CEAC building as well as main campus (Marley).

Crop Production Small Business Studies Lab

A 2500 sq. ft. Greenhouse #3918, located at the Roger Road area of University of Arizona has been utilized for education and training of students along with small businesses. Currently Sonoran Hydroponics, a local Tucson hydroponic food producer is teamed with CEAC as part of the Organic Hydroponic Tomato Education Demonstration. Previous small business collaborations have included Arizona Vegetable Company, whose focus was for lettuce and greens production. The small businesses financially support the greenhouse operations, and the student paid internships.

Statistical Bioinformatics Lab

This is a dry lab and directed by Dr. Lingling An. The lab, located in the Shantz 519 (200 sq. ft.), is used for conducting research studies on statistical and computational research in bioinformatics, genomics and metagenomics, and other related areas. It includes three desktop computers, three laptop computers, and three printers/copiers/scanners. It usually holds 5~6 students/postdocs working in this lab.

Biological Big Data Laboratory (BBD)

Dr. Hurwitz directs the biological big data laboratory (BBD) to develop algorithms and computational systems for analyzing large-scale-omics datasets. Offices are located on the 4th floor of the Bio5 Keating Building (4- cubicles, 1 office) and 6th floor of the Shantz building (3-120 sq. ft. offices). Offices are comprehensively equipped with personal computers, scanners, software and various color and black-and-white printers. Currently, offices house two graduate students, one postdoc, two software developers, one community outreach coordinator, and four undergraduates. The BBD partners with high-performance computing centers both locally and nationally to develop next-generation data analysis platforms for integrating and analyzing biological big data.

University Spectroscopy and Imaging Facilities

Housed in Marley building. Equipment includes: SEM, cold-cathode FE-SEM, TEM, dynamic light scattering, etc.

Micro/Nanofabrication Center

Housed in ECE building. Micromachining equipments are available in class 1/10/100 clean lab environments. Equipments include: mask alignment/exposure, spin coating, profilometer, oxygen plasma machine, LPCVD, DRIE, etc.

StatLab: Several ABE faculty participate in and collaborate with statistics faculty and staff in the StatLab. The StatLab partners with researchers and faculty by (i) providing statistical expertise and computing resources, (ii) designing studies which are statistically efficient and scientifically practical, (iii) conducting data analysis and interpreting results, (iv) providing assistance with grant applications and preparation of manuscripts, (v) developing new statistical methods to address emerging problems in science, and (vi) connecting researchers with specialized statistical expertise.

Appendix C provides a details listing and description of the major pieces of equipment used by the program in support of instruction.

B. Computing Resources

The College of Engineering has a wide variety of computing resources available for students, faculty, and staff. There is a single university-wide authentication system (UA NetID) that allows access to a variety of university systems from any internet connection. For some resources a secure VPN connection is required and this can be obtained using free software provided by the University information Technology Services (UITS). There is a student IT/Library fee of \$240

per semester for full time students (7 or more credits). The split per semester is \$139 to IT and \$101 to Library and with more than 30,000 students paying the fee, this generates more than \$8M for IT support annually. A complete report on how the dollars were spent from FY 12, 13 and 14 is given at <http://cio.arizona.edu/it-student-fee-overview>.

The following types of services are provided at the University level:

- Desktop computers in a variety of locations all over campus (library, student union, various buildings on campus including old engineering and electrical and computer engineering). <http://uits.arizona.edu/locations> contains a map with links to hours and equipment available. Typically these facilities are open late and on weekends and have support staff while open
- 24/7 IT Support Center - The 24/7 IT Support Center is the first point of contact for many IT applications and services at the University of Arizona. UITS staff are available seven days a week (excluding University holidays) and help address any computer or technical concerns students or staff have. This is free to all students and staff and is funded by the Student IT fee.
- Catmail - University email system available with NetID - <http://uits.arizona.edu/services/catmail>
- D2L – Campus wide course management system and is typically used as a repository of all information for a class. d2l.arizona.edu
- Anti-virus support using Sophos
- 2 high speed wireless networks that cover all of campus – UAWifi (secure access with NetID) and UAPublic (anyone can get on this network).
- UAccess Student and UAccess Employee are the University information sites. Students have the ability to register and change courses, see grades, make payments, view academic records, and more. Employees have access to all the tools that are needed to do jobs such as entering grades, filling out and approving time cards, accessing student records, using dashboard tools to manage the operation, and much more.
- Campus site licensing - <http://softwarelicense.arizona.edu/> is a repository of all software where the university has campus-wide licenses. Students can download from here using NetID and most packages are free. This is funded through student fees, tuition, state appropriations funds, and philanthropy. The College strongly participates and contributes funds fairly when asked. For many of these packages, the College was the driving force in the decision to add to the collection:
 - Student software includes - <http://softwarelicense.arizona.edu/students> MSOffice 365, AutoDesk, SOLIDWORKS, LabVIEW, MATLAB, Mathematica (fee), Adobe (various), Sophos, VPN, Qualtrics (survey software)
 - Faculty and Staff software includes - Adobe (various), MSOffice and other MS products, SOLIDWORKS, Panopto (classroom capture), Turning Technology Clickers, D2L, Adobe Connect, Sophos, ESRI, Qualtrics, various statistics/data packages

Overall, there is strong student computing support and the College is quite happy with the partnership that we have with UITS. They listen to our needs and propose solutions. The College of Engineering (COE) work together to support students, staff and faculty. The network, hardware

and software provided help us achieve our educational mission. Note that we did not list the University Research computing support and this is extensive as well.

In addition to the University resources, the College provides significant support. The College of Engineering (ENGR-IT) provides computing resources and other services for research, instruction and administration. Common services for all three missions are to manage 28 Subnets with over 7,000 IP addresses. Services include MPLS and firewall management. Static IP and DHCP assignments. Border firewall management. Cabling in CPE locations. DNS services for the Engineering subnets. Switch configurations and port connection management. ENGR-IT participates in the UA CatNet Active Directory Architecture and we manage servers, desktops and laptops in the Engineering (ENGR) organizational unit (OU) on behalf of the three missions. The COE e provide consultation, purchasing and setup support of computing resources. All three missions benefit from the College of Engineering storage management and home directory backup services. The COE also manage college print servers and have limited support for poster printing. The COE is also the primary web host provided for the main college website and department sites as well as around 500 faculty, student and club websites.

The COE's major hub of operation for support is the College Help Desk located in the AME building, Room 319A. The College Help Desk partners with the UITS 24/7 to provide students with support on installing and using College specific software. In particular, the College Help Desk provides a distribution and management service for the highly popular Microsoft Academic Alliance, which allows engineering students and researchers to get a wide range of Microsoft development software. ENGR-IT provides license servers for the various software titles. Other Engineering software that the COE supports for Researchers and Students include: AutoCAD, Abaqus, Ansys, SOLIDWORKS, Matlab, Mathametica, Spim, MPLAB X, Xilinx, Cadence SPB, LabView, nVidia CUDA, PTV Vissim, Xming, ChemCAD, Comsol Multiphysics, Bentely Microstation, Minesight, Rocsicence Suite, Smath Studio, AGI STK, Texnic Center, Enterprise Architech.

The College Help Desk provides management of 14 undergraduate labs with about 230 computers joined to the University CatNet domain, so students have easy access from their standard university accounts. The College Help Desk also works directly with UITS in support of the lab in ENGR 213 and AME S314, where all undergraduate students have access to another 50 computers with both The UA and Engineering specific software titles. In addition the ENGR-IT group provides support for class capture for both University provided classroom and a few dedicated college provided spaces. ENGR-IT has also created a specific engineering student account management system to provide access and resources to only the college undergraduates who are allowed resources in specific courses. College classrooms are managed by creating an image of the required setup for each semesters classes and pushing out these images as changes are necessary throughout the semester. Scripted software installations are also possible as necessary.

ENGR-IT provides Researchers with some special services such as HPC cluster server management, large storage array management, specialized security configurations for managing CUI and ITAR research goals and specialized wireless configurations. The COE creates video conferencing spaces as requested and we support multiple off-campus research locations such as West, AML, and the SX Mine.

The College IT support team website is <http://www.engineering.arizona.edu/IT/ITsupport> and there is a strong FAQ page – <https://account.engr.arizona.edu/account-faq.php?&ticket=ST-4957223-lbQxA0NI4jOXggLccK0F-buddy.uits.arizona.edu> (behind UANnetID authentication).

The COE has currently 9.5 FTE staff budgeted with a total expense of \$758K annually. In addition we have 5 FTE of student labor (10 students) costing \$108K annually, \$70K in operations, \$9K in training and professional development and \$110K in equipment including desktop refresh and infrastructure refresh. Anyone in the college can get desktop support by filling out a ticket at <https://account.engr.arizona.edu/index.php>.

Overall the COE invests more than \$1M annually from College central funds and it is possible that the Departments invest additional funds for special initiatives. The College has moved from a completely decentralized system where we had some departments serviced by one staff member, to a centralized system where we have significantly less infrastructure and backup/support system that enables everyone to get better service. The COE would certainly like to better support research computing needs however the CEO is at the limit in what can be spent on general IT support.

University of Arizona Information Technology Service (UITS) High Performance Computing Center: Computational algorithms are developed on data on resources from the UITS High Performance Computing Center (HPC). The UA Research Computing includes state-of-the-art High Performance Computing (HPC) and High Throughput Computing (HTC) systems, dense high capacity data storage, a 3D immersive visualization facility, and consulting services for HPC/HTC, visualization and statistics through UITS Research Computing Support (RCS) services. The UITS Research Computing service is staffed by six full-time, fully trained personnel that have expertise in HPC, statistics and visualization. The HPC Facility is equipped with long-term, fail-over building generators, high-speed gigabit networking, and state-of-the-art facilities.

University of Arizona Hadoop Cluster: The ABE has exclusive access to the UITS hadoop cluster. This cluster consists of 10 physical nodes (9 MapReduce computation nodes), where each node contains 12 CPUs, 128 GB of RAM and 100TB total configured HDFS capacity. Each node runs a maximum of 7 YARN containers simultaneously with 10 GB of RAM per container. Other memory space is reserved for the operating system and other Hadoop services such as Hive or Hbase. The Hadoop cluster was preinstalled with HDP (Hortonworks Data Platform) Version 2.2 (Hadoop 2.6.0).

Wrangler Cluster at the Texas Advanced Computing Center at the University of Texas, Austin: Students in ABE also use NSF-supported compute resources at Texas Advanced Computing Center on the Wrangler cluster. Wrangler boasts (i) 10PB of geographically replicated storage, (ii) flash storage for analytics with 1TB/S and 250 IOPS, (iii) more than 3,000 embedded processor cores, (iv) flexible support for Hadoop, (v) integration with Globus ONline for fast data transfer, and (vi) scalable design to grow with increased users and data.

The iPlantCollaborative (<http://www.iplantcollaborative.org/>): The NSF-funded IPlantCollaborative Cyberinfrastructure is headquartered at the University of Arizona. IPlantCollaborative provides capabilities for data management & sharing, tool development, and computation.

IPlantCollaborative makes bioinformatics tools, data, and computation for scientific research freely available to the community. The following resources are available in IPlantCollaborative (i) A Data Commons: a federated source of datasets consisting of projects, -omics data, assemblies, standardized metadata, and other associated files, (ii) Discovery Environment: Simple web portal for managing data, bioinformatics analyses, and workflows, (iii) Data Store: scalable, secure, and reliable storage for terabyte-scale data, and (iv) Atmosphere: 1-click, on-demand cloud computing for accessing software contained in virtual machines. IPlantCollaborative compute resources include multiple servers in the Bio5 Keating Building, a large cluster system at the Texas Advanced Computing Center, and other large clusters available through the Teragrid (through a partnership with TACC). IPlantCollaborative personnel are available to help with computing needs. ABE faculty members use these resources and contribute to their development as part of funded research.

C. Guidance

UA Computing and Technology Services: The University of Arizona offers a 24/7 IT Support Center that provides administrative and instructional support for services offered through UITS. Engineering students can call or go to the walk-in help desk located in the Martin Luther King, Jr. Building, room 207, and receive one-on-one support with their personal computers or software provided by the UA. Faculty can also call the 24/7 in support of their undergraduate courses.

College Help Desk: One major hub of operation for undergraduate support is the College Help Desk located in the AME building, Room 319A. The Help Desk provides students with support on installing and using College specific software and provides a distribution and management of the highly popular Microsoft Academic Alliance that allows students to get a wide range of Microsoft development software.

The College Help Desk provides management of 6 undergraduate labs with about 50 computers joined to the University CatNet domain so students have easy access from their standard university accounts. The College helpdesk also works directly with OSCR in support of the lab in ENGR 213 and AME S438 where all undergraduate students have access to another 50 computers with both University and Engineering specific software titles.

The Computer Systems Group (CSG) operating from Electrical and Computer Engineering provides license servers for the various software titles used in both the engrnet and CatNet domains. The CSG has a help desk primarily to assist students with creating and managing their engrnet accounts. The CSG provide access to undergraduates for high performance computing resources and advanced computing requests such as providing project Wiki or other non-standard service.

Systems and Industrial Engineering (SIE) and Chemical and Environmental Engineering (CHEE) each have an undergraduate lab with a person dedicated to support of the facilities. There are 2 dedicated Distance Learning installations in the College.

ABE IT Support: The day-to-day IT support is provided to the Department through a single IT staff person (Mr. Brian Little). This staff person provides technology support for desktop support, software installations, printer problems, meeting room/WebEx support for faculty, staff, and students. This person also develops the departmental website that contains information for students on degree requirements and ABE courses.

ABE Fabrication Laboratory and Shop (2,500 sq. ft.). The ABE Department supports its research and senior design fabrication projects with a fully- equipped shop facility. This facility is located at the Campus Agricultural Center and is staffed by a senior instrument maker. By the end of their time at the UA all of our students are proficient using metal, wood, and plastic fabrication tools. Many learn how to weld, including steel, stainless steel, and aluminum material. The shop is equipped with a variety of fabrication tools, including computer controlled metal lathes. Surplus equipment and material is stored in a secure 30-ft by 40-ft metal “Butler” building. The students also have access to plasma cutting equipment located in an adjacent teaching shop operated by agricultural education. All students are supervised by the shop supervisor (Mr. Charlie DeFer). In addition, there is also an engineer, Mr. Neal Barto, who helps install, maintain, and manage laboratory equipment at CEAC, and work with students in the lab and research setting.

D. Maintenance and Upgrading of Facilities

D.1. College of Engineering

The College has no formal policy for maintenance and upgrade of facilities. In fact, the entire University struggles with this issue and we are 100’s of \$M behind in building renovation and repair. We have done renovations as needed and we have built/outfitted special rooms and labs for teaching. ENGR 214 was converted from a student lounge area to our ENGR 102 classroom space and we run all 15 or so sections per year in that room. We have converted classrooms to “distance education” rooms by installing mics, cameras, and capture software. We have also used philanthropic dollars to support the conversion of “lecture-type” classrooms to “active-learning-type” classrooms. This is an ongoing priority for the University and we have participated by helping to raise funds for this purpose (Proctor and Gamble Foundation grant for example).

As we mentioned in the IT section, desktop computers and College computing Infrastructure is on a 3 to 4 year refresh cycle and this generally corresponds to the warranty cycle of new machines. If there is tools and equipment used in College-managed classes, then the refresh is funded out of college level differential tuition funds or a course fee specifically for annual expendables. For example ENGR 498 – Cross-Disciplinary Design, has a course fee to support the shop requirements for fabricating prototypes. Also, we often get philanthropy of used (almost new) tooling and equipment to use in student labs – for example, see <http://news.engr.arizona.edu/news/practical-gift-injects-new-power-engineering-machine-shop> The lab or course directors take stock of what is needed and we budget funds to satisfy needs.

Each department is in charge of their own Department-managed labs and classes. Again, we use a combination of differential tuition (this expense was one of the reasons we were able to justify adding on a differential tuition) and course fees. These upgrades occur as needed and the instructor

in charge of the lab/course is responsible for recognizing the need, working with the Department Head to ensure that the required funds are budgeted, and managing the upgrade process. Some departments have lab managers that take on such a role for the entire group of labs within the department.

D.2. ABE Department

We have been continuously updating equipment and instrumentation in the teaching and research laboratories, with newer and more up-to-date sensors and instrumentation and broaden laboratory capabilities. These improvements address the needs to continue to provide the best opportunities to use modern engineering tools. The upgrading of the tools, equipment, computing resources, and laboratory equipment in individual research labs are evaluated and decided by the faculty lab director. We use differential tuition to update the tools, equipment, and computing resources used in the ABE computer lab (Shantz 425). There are about eight desktop computers connected to both the University internet hub and a common printer. We schedule to replace two computers each year with differential tuition. The University provides upgrades for our operating system and other software applications. We are responsible for the hardware updates.

The Facilities Management unit at the University of Arizona also provides support for effective and efficient maintenance, operational services, and utilities services that support the faculty, staff, and students. The upgrading of facilities are conducted based on the guidelines of the Facilities and Management.

E. Library Services

Our Department takes advantage of support offered through the main library, the science library, and the University Health Sciences Center Library. Electronic resources at the library enable faculty and students to order books or subscriptions and locate and obtain electronic information. Material that is unavailable at the University of Arizona can be requested via the University's Interlibrary Loan process.

The Main Library, open practically 24/7, offers flexible spaces, friendly experts, a wide range of technology, and in-depth research collections that encourage new ideas and help to build new connections. It houses extensive collections in the social sciences, humanities, fine arts, education and business as well as media, maps and government documents. The complete holdings of the University Libraries are accessible through the library's online catalog.

The Science and Engineering Library hosts a number of technology-rich collaborative spaces, including group study rooms, the University's first collaborative learning classroom, and a makerspace with 3D printing. The library's collection includes print and online materials on life and physical sciences, engineering and technology, and military sciences, including selected government publications from NASA, DOE, USGS, FAO and other agencies. The library also houses collections in photography and the fine arts, including visual arts, architecture, sculpture, illustration, design, drawing, painting, printing and decorative arts.

The Arizona Health Sciences Library

The Health Sciences Library is active statewide, working with health professionals and public libraries, health departments, and community groups to improve the access to high-quality health information. Equipping Arizonans with effective health information seeking skills is important to improve the health of everyone in our community. The Health Sciences Library is a member of the National Network of Libraries of Medicine and the National Library of Medicine, serving as the designated resource library for Arizona. The Health Sciences Library is also a founding member of the Arizona Health Information Network (AZHIN), a consortium of the major hospitals in Arizona, rural clinics, telemedicine sites, state and local health departments, and health-related educational institutions. Through AZHIN, member institutions are able to receive large discounts on electronic resources, making more high-quality online resources available to everyone, even the smallest and most remote organizations in our state. The Health Sciences Library is the largest, most comprehensive health sciences library in Arizona, providing electronic access to vast stores of biomedical literature and participating as instructors in the curriculum of the colleges. It also works with researchers and clinicians on projects to improve access to essential information and provides comfortable spaces for small group collaborations and quiet studying in a collegial atmosphere. The Health Sciences Library's primary clientele are the UA colleges associated with the Arizona Health Sciences Center, including University Medical Center.

Current UA libraries initiatives include, but not limited to, are to: (i) partner with faculty teaching research-intensive classes; (ii) Incorporate tools in campus learning management systems; (iii) collaborate with Office of Research & Discovery (ORD) and University Information Technology Services (UITs) on an integrated approach to support researchers; (iv) provide just-in-time expertise and tools in areas like data management planning and copyright law; (v) Partner with regional libraries; (vi) partner with early recruitment efforts to attract underserved and first generation students to the University; (vii) expand relationships with consortia; (viii) design virtual library environments that optimize content delivery for a wide range of device platforms and that ensure ADA accessibility; (viii) Library research awards for students utilizing library resources;

Detailed and more complete information on the UA libraries (most recently ranked 33rd by the Association of Research Libraries), including the Science and Engineering Library, and the extensive services provided by the UA libraries are available online at <http://www.library.arizona.edu/>.

F. Overall Comments on Facilities

The ABE department ensures that the facilities, tools, and equipment are safe and up to specification through examination by the faculty and departmental staff and administration. Thus, the ABE facilities comply with all applicable rules or regulations pertaining to: fire, safety, building, and health codes, and consensus standards and follow best practices for safety.

CRITERION 8. INSTITUTIONAL SUPPORT

A. Leadership

The department is administered by a Department Head, who is appointed by the Dean of the College of Agriculture and Life Sciences (with recommendation from faculty vote). The Department Head is responsible for implementing and managing the programs and policies of the Department, providing leadership, and representing the faculty to higher administration. Department policies are developed at departmental meetings and retreats and are generally established by consensus. However, when consensus is not achievable, a vote of the majority prevails. The Department Head is the final authority in Departmental matters. However, the Head follows the general policies agreed upon by the department faculty and also considers the input from the Advisory Council who generally meet annually. The members of the Advisory Council consist of representative members of the industry (based on the department focus areas), faculty, and students (graduate and undergraduate).

An organizational chart for the department is provided in Figure 8-1. All faculty and staff report to the Department Head. The shared staff of the Business Center (Manager of Finance and Administration, Accountant, and Program Coordinator) also report to the Head of the Nutritional Sciences Department.

Nine standing committees oversee important aspects of the Department: Academic Programs Assessment Committee, Branding and Marketing Committee, Faculty and Staff Awards Committee, Forward Planning Committee, Graduate Committee, Promotion and Tenure/Continuing Status Committee, Social Committee, Student Club Advisors, and an Undergraduate Program Committee. Committees are comprised of both faculty and staff members. Committees meet on a regular basis or as needed throughout the year. They act on business brought before the committee and may make recommendations to the faculty and/or the Department Head for final action. All committees, chairs, and members are appointed by the Department Head. The Department Head is an ex-officio member of all Department standing and ad hoc committees. The Department Head works closely with the chairs of the committees.

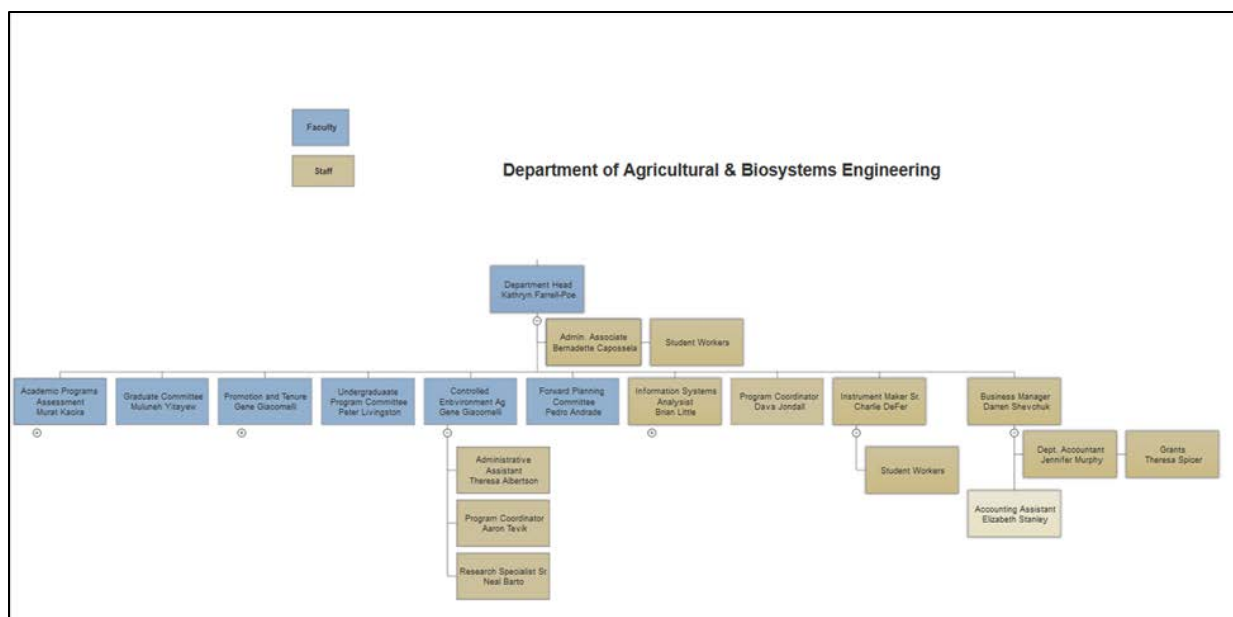


Figure 8-1. Organization chart for Agricultural and Biosystems Engineering Department.

Departmental meetings (includes both faculty and staff) are held semi-monthly during the academic year. Periodically, guest speakers are invited to present updates on university and college matters that are of pertinent interest to the department. Multi-day departmental retreats occur once or twice a year to address broad issues related to strategic planning, curriculum review/revision, and the like. At least once per semester, the Department Head meets with staff as a group to answer questions, and to seek input on departmental issues. The standing committee chairs are also given opportunity in the departmental meetings to provide updates on committee activities.

B. Program Budget and Financial Support

B.1. The Responsibility Centered Management (RCM) – UNIVERSITY LEVEL

The Responsibility Centered Management (RCM) Budget Model was designed with the input of the University community to 1) encourage revenue generation and cost effectiveness, 2) align authority and accountability at the local level, 3) provide transparency and flexibility in financial operations, and 4) enhance the ability for units and the institution as a whole to plan.

RCM provides a methodology for allocating both University revenues and costs to Responsibility Center Units to provide a transparent budget process that is based on the level of activity within an RCU. In layman's terms Colleges (RCU's) will receive revenue based on what they do – tuition from teaching/advising undergraduates, tuition teaching/advising graduate students, and obtaining indirect cost recovery for research. The methodology also has to support the UA central structures that provide service to all.

The following chart illustrates how funds flow in RCM (Figure 8-2).

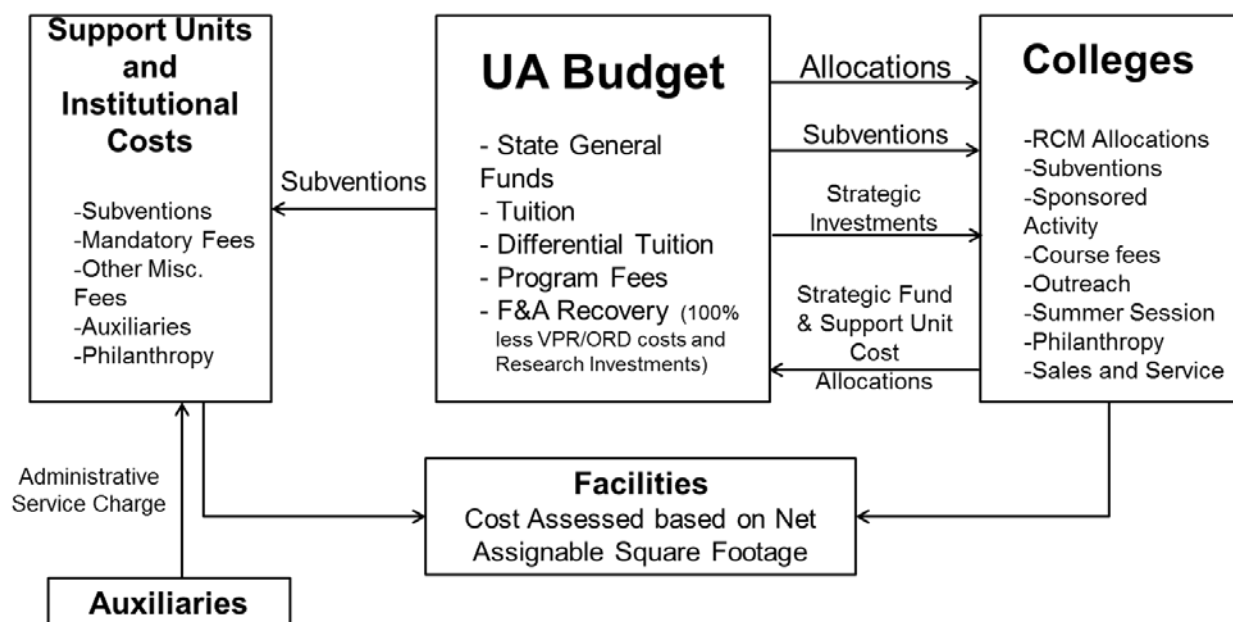


Figure 8-2. The funding flow in RCM model.

There are two types of Responsibility Center Units (RCUs) within RCM, Revenue RCUs and Support RCUs. Revenues RCUs include the colleges (like Engineering) that are allocated funds based on their activity and large auxiliaries (Student Union, Residence Life, Athletics, etc.) which are mostly self-supported units. Support centers consist of the units that support the primary missions of the university including institutional administration, business services, student support, research support, public service and facilities.

At the outset of RCM, the overall level of funding did not change within any of the RCUs as historical budgets were maintained at previous levels (this was known as the “held harmless” principle). Revenues were attributed to each of the college RCUs along with a calculated share of the support and facility costs. State funds (subventions) were provided to each of the Revenue RCUs, that, when combined with the allocated revenue, was sufficient to cover the RCU’s historical budget and their share of the allocated support and facility costs. However, the system setup clearly favors some strategies over others moving forward. If a college is not growing then the only increases in revenue would be from subvention increases (likely to decrease along with state appropriations), temporary strategic investments, and tuition increases placed on the students.

The FY16 budget was the first year that RCM affected the level of spending in the RCU’s budgets based on changes in instructional and research activity. Based on the results of the RCM model, budget allocations were implemented as part of the FY16 Budget. As we move forward each year budget will be adjusted based on the activity that occurred in the prior year. Fluctuations in annual activity have financial implications which require Revenue RCU’s to monitor activity on a regular basis.

B.2. University of Arizona RCM Model Overview

Revenue Steams

Undergraduate Tuition Allocation - Undergraduate tuition revenues are pooled together and reduced by the institutional aid that has been allocated to students. The undergraduate tuition pool is split into two amounts; 75% allocated based on the number of student credit hours (SCH) produced and 25% allocated based on where students majors reside.

Generally, if a college teaches more credit hours and they have more majors the college budget allocation will increase given that the overall size of the student population (and associated revenue) grows. If the college teaches fewer credit hours the college allocation would decrease. It is important to remember that the pie needs to grow for there to be more money overall to allocate or we would just be dividing up the same size pie into different size pieces among the colleges.

Graduate Tuition Allocation - Graduate tuition will be allocated based on the funding each student brings in (could be paid by a variety of sources – sponsored projects, the student, companies, governments), with 75% being allocated to the college of enrollment and 25% to the college teaching the credit hours. Interdisciplinary and Non-degree Seeking students will be allocated 100% based on the college teaching the courses.

If a college teaches more graduate students where the tuition isn't waived, the college allocation will increase. If a college waives more of the tuition the allocation would decrease. This differs from undergraduate since the funds are not pooled together so the amount a college receives is entirely based on the graduate activity within their college.

Program Fees and Differential Tuition Allocation - Program Fees and Differential Tuition will be allocated 100% based on the college who owns the program fee or differential tuition.

If a college has a program fee the allocation of the program fee goes to the college less any attributed waivers. This is a major revenue stream for Engineering as we have had differential tuition for over 10 years.

Facilities and Administration (F&A) Cost Recovery from Grants - F&A will be allocated 100% to the college RCUs based on the F&A distribution associated with the sponsored award. 25% of the F&A allocation will continue to flow through the colleges and departments as it has historically, with the remaining 75% allocated during the RCM budget process. Support RCUs will no longer receive F&A allocations based on sponsored activity but instead have been provided a base budget based on historical sponsored activity.

A college will now receive the entire benefit of increases in F&A recovery but will also need to cover 100% of the decline in activity. Please note that this change did not create a windfall of funds for Engineering as our initial budget was held constant during the setting of subvention.

Subvention - Subvention is essentially the state funds and other institutional earnings that cover the shortfall between the revenues distributed and all costs. If you earned \$60 in revenues and all

costs totaled \$100, a subvention of \$40 was provided to the college. A budget reallocation between colleges or a state budget cut would change the amount of subvention a college. **The RCM model does not change subvention as the result of changes in revenue distribution.**

Cost Streams

Facilities Rate - Facilities cost which includes operations, maintenance, utilities, and debt payments associated with facilities and grounds are recovered by charging a flat rate charged per square foot on all space that is assigned to a unit. At the outset of RCM these costs have been initially funded through subvention funds provided to the Revenue RCUs. The cost of facilities is also a component of Support RCU total cost. These facilities costs do not include services which have previously been billed back to units. These billable services will continue to be billed to units separately.

Facilities are being charged based on the space that has been assigned to units. The rate is calculated by taking the total overall cost of facilities for the university and dividing it by the amount of square feet that are assigned to units.

Strategic Investment Assessment – A tax is charged to RCM Allocations to fund a Strategic Investment Fund that will allow the institution to invest in strategic initiatives and collaborative activities. The assessment will start out at a rate of just under 1.7% growing to 5% over a four-year span. In addition, colleges allocate a portion of their RCM allocation for strategic investments within the college.

Support Center Expense Recovery - The recovery of support RCU expenses are funded through “taxes” to the revenue allocated to Revenue RCUs and the amount of subvention received by the Revenue RCUs. An assessment rate has been determined using the FY15 base budget that is applied to Revenue and Subvention within the model that will recover the support RCU costs. The support unit expense recovery rate will stay stable for 3 years and is scheduled to be reviewed on a 3-5 year cycle. The tax rates differ by revenue stream and are listed in the following table (Table 8-1) along with other key rates:

Table 8-1. The tax rates by revenue stream.

Facilities Rate per assigned sq ft.	\$25.19
Support Center Expense Recovery (Tax on Revenue)	
• Undergraduate	30.96%
• Subvention	30.96%
• Graduate	12.38%
• Differential Tuition/Program Fees	12.38%
• Sponsored F&A Expense Recovery	12.38%
Strategic Investment FY17 Rate (Tax on Revenue streams)	2.00%
Strategic Investment Rate Planned Increases	
• FY18	2.75%
• FY19	3.50%
• FY20	5.00%

RCM Budget Allocation

The model takes into the account the all revenues earned, facilities cost, and support costs to determine a funding change that will be applied to the overall college budget. The amount is a lump sum that is posted directly at the college level. The distribution of funds within the college is the responsibility of the college Dean. Colleges have been directed to allocate funds within their college in a manner which is consistent with the principles of RCM. In addition to allocating funds based on levels of activity, it is important that the college provide subventions between departments and maintain the flexibility to provide for strategic investments within the college.

Summer and Winter session distributions of revenue are similar to those found in the RCM model for Undergraduate, Graduate, Program Fees and Differential Tuition. The main difference is that the distribution of Summer and Winter session tuition is based entirely on Student Credit Hours. Like other revenue distributions, these allocations are assessed for Support Center Cost Recovery. Online and Distance Programs as well as philanthropy are not included in the model and these revenues are at the discretion of the colleges (along with the attending costs).

Table 8-2 lists our FY16 base budget for the college and our estimates for FY17. One can see that we have over \$20M in revenue from our undergraduate programs (Tuition + Differential Tuition) and around \$12M from our research and graduate education. We also have an extra \$3.5M for the recognition that ENGR is a more expensive program to run. This type of “weighting” is common for ENGR programs in universities that have RCM budget models.

Table 8-2. FY16 base budget for the college and our estimates for FY17.

	RCM FY 16	RCM Est. FY 17 From Spring Census
Undergraduate Tuition	17,833,366	18,848,765
Graduate Tuition	6,494,010	6,311,058
Differential Tuition and Program Fees	2,802,476	2,967,000
F&A Recovery After Research Costs	5,564,154	5,014,228
Sum RCM Revenue Allocations	32,694,006	33,141,052
Reallocation for more expensive programs	3,591,829	3,802,733
Subvention	12,723,912	12,723,912
TOTAL SOURCES	49,009,746	49,667,697
Operational Base Budget from previous year	25,598,712	27,738,659
Facilities NASF Cost	8,359,100	8,359,100
Support Units and Institutional Costs	12,205,993	12,526,285
Strategic Institutional Investment Pool	705,994	861,514
Total Institutional Overhead Assessment	21,271,087	21,746,899
TOTAL USES	46,869,799	49,485,558
RCM Allocation Change	2,139,947	182,138
Revised Operational Budget Authority	27,738,659	27,920,798

In FY16, the College's budget increased approximately \$2.1M, however some \$986,400 went towards a permanent budget cut due to decrease in the state allocation. In FY17, we are not expecting a budget cut, and are projecting an increase in revenue of \$180,000. Our undergraduate program revenues are strong, as our recruiting efforts are robust and retention has been strong, however our graduate tuition and research activity are both down.

B.3. College of Engineering RCM Model Overview

In FY16, the University of Arizona implemented a RCM budget model. In turn, the College of Engineering implemented an activity-based model for College budget allocation that followed similar ideas. We allocate dollars based on activity levels of the academic departments and use internal taxes on revenue streams to support College central operations. We held back approximately \$1.3M for a College investment pool, which is to be used for special projects and initiatives (faculty startup packages, short term labor costs for new programs, capital investment, space renovation).

Like the university model, the overall level of funding did not change within any of the academic departments as historical budgets were maintained at previous levels. Revenues were attributed to each of the academic departments, along with a calculated share of the College support costs. State funds (subventions) were provided to each of the academic departments, that, when combined with the allocated revenue, was sufficient to cover the academic department's historical budget and their share of the allocated College support costs. Table 8-3 lists the revenue breakdown by our individual departments:

Table 8-3. Department revenue for computing initial FY16 College RCM.

Academic Depts	FY16 Net Lower Division Differential Tuition Revenue	FY16 Net Upper Division Differential Tuition Revenue	FY15 Net Grad Revenue	FY15 Net Undergrad Major Revenue	FY15 Net Undergrad Student Credit Hour Revenue	FY15 Est F&A Cost Recovery Revenue	Total Revenue
AME	48,536	351,576	682,864	779,630	1,625,228	1,154,655	4,642,489
ABE	3,704	40,543	220,646	40,523	834,674	222,217	1,362,307
BME	33,917	114,973	92,977	336,518	135,618	260,606	974,610
CEEM	11,890	98,030	390,323	204,378	876,119	204,334	1,785,074
CHEE	32,162	137,363	703,599	357,661	732,628	572,061	2,535,474
ECE	39,959	244,469	2,537,603	563,800	1,671,540	1,404,185	6,461,557
MGE	9,356	79,876	189,732	162,974	361,480	94,314	897,732
MSE	9,161	68,379	344,415	143,593	575,852	579,616	1,721,016
SIE	27,484	160,357	742,604	380,565	1,036,905	170,036	2,517,953

Note that the College has no budget authority over the programs Optical Sciences and Engineering and Agriculture and Biosystems Engineering (ABE). These are in different colleges. Any differential tuition from these programs goes directly to the programs. The College has central costs that support both programs, however our initial intention was to have subvention adjusted and simply return 100% of all costs back to these units. This did not materialize so we receive some revenue from both but are still working on our original approach.

College Support Expense Recovery - The recovery of central College support expenses is funded through assessments to the revenue allocated to academic departments and revenue directly generated by College support units, e.g., Engineering No Major Selected enrollment. In order to incentivize growth, the College model minimizes cost allocations to departments. Per this principle, the College model does not assess any support recovery for the following revenue streams: undergraduate enrollment, graduate enrollment, graduate SCH, and undergraduate differential tuition. **The College central recovery percentages are: 25.25% assessment on undergraduate SCH revenue, 17.5% assessment on sponsored F&A expense recovery.**

Initial Allocation – Using the “held harmless” principle, initial subvention was set. Note that subvention for programs is expected and a large subvention simply means that the College is investing dollars above RCM revenue. This is common for smaller programs. However over time, all departments are going to have to grow simply to support things like salary increases and general cost increases. Natural tuition rate growth will cover some of this, but there is little defense other than growth if there is a state budget cut or some other overall decrease in subvention at the University level. Table 8-4 lists the department allocations and this table includes the FY16 budget cut apportioned to departments.

Table 8-4. Department allocations FY16.

	FY16 Net Revenue	Subvention	Allocation Prior to Budget Cut	Budget Cut	Total FY16 Allocation
AME	4,030,055	351,390	4,381,445	(91,050)	4,290,395
BME	894,760	20,503	915,263	-	915,263
CEEM	1,528,095	300,580	1,828,675	(44,384)	1,784,291
CHEE	2,250,375	596,561	2,846,936	(71,481)	2,775,455
ECE	5,793,761	194,155	5,987,916	(144,330)	5,843,585
MGE	789,953	479,811	1,269,764	(30,308)	1,239,456
MSE	1,474,181	856,781	2,330,962	(56,489)	2,274,473
SIE	2,226,378	(274,788)	1,951,590	-	1,951,590

Note that in the above table SIE was subventing the programs of the College on the order of \$275,000. This is a temporary situation as SIE was in the process of hiring 3 faculty members and these will easily bring the department to positive subvention. We held back some subvention dollars in anticipation of the need to balance in FY17. Also, we did not give SIE a budget cut in FY16. We did not cut BME as this is an investment area in partnership with the College of Medicine.

We followed a similar budget allocation process with our central College units and we allocated a portion of the budget cut centrally as well (380,000 central, 438,043 departments, \$168,357 College strategic investment – total FY16 budget cut \$986,400). The Central allocation is funded approximately from \$2.85M in RCM revenue (College level classes and no major selected students mainly), \$1.7M in subvention, and \$2.5M from the central recovery method on Indirect Cost Recovery and Undergraduate Credit hours (Table 8-5).

Table 8-5. College-level allocations FY 16.

	ENGR Central Unit Expenses	Budget Cut	Total FY16 Allocation
ACAD	1,881,368	(50,000)	1,831,368
ADM	2,071,381	(250,000)	1,821,381
ERAS	433,527	-	433,527
DEV	633,761	(30,000)	603,761
IT	1,040,589	(30,000)	1,010,589
MKT	409,810	(20,000)	389,810
RD	297,254	-	297,254
GRAD	213,957	-	213,957

Note that \$1.3M of ADM expense is the initial strategic investment pool and these dollars are spent across the College and the University. If one computes the total subvention used for expenses, you get $1.7M + 2.5M = \$4.2M$ and this represents our total investment pool potential at this time (assuming that tuition and ICR are used to cover normal operating expenses).

Moving Forward – We are in the process of making FY17 allocations using the discussed model. Some departments are growing and others are not, so we will have some winners and losers for next year. Each department has some cash reserves (recall that philanthropy and external revenue streams are not part of the RCM model) so these can be used to fill temporary shortfalls.

To ensure that the strategic plan of the College is adequately addressed, a central pool of investment funds is maintained in the College RCM model (currently about \$1.3M recurring annually). In the future, the investment pool is also funded through reductions to academic department subvention that occur when an academic department earns revenue above the historical base of activity. **New growth revenue is distributed 85% to the academic department and 15% as a reduction to historic subvention which becomes part of the strategic investment fund.** As stated, this pool is used for temporary investments in new initiatives, faculty startup commitments, and to respond to unforeseen expenses, e.g., significant increases in employee related expenses. RCM best practice recommends that the RCM units (colleges) target 5% of revenue as the size of their strategic investment pool, the College pool is currently approximately 2.2% of revenue, the subvention recovery method will allow this pool to grow over time to recommended levels. We believe that the approach in the College model encourages academic units to grow and to develop cash reserves in order to sustain budget adjustments based on year-to-year fluctuations in activity. We do not sweep allocated funds remaining in departments at the end of each fiscal year and we are not changing subvention investment (other than growth pull-back) even if costs decrease.

B.4. ABE Department

Program Budget

Although the Biosystems Engineering degree program is offered in the College of Engineering, the Department and the program are budgeted almost entirely within the College of Agriculture and Life Sciences. The Departmental budget is divided into three general categories of Instruction, Research, and Extension, and faculty appointments are also defined in these three categories. However, the Department Head has relatively wide latitude to expend the Departmental budget in

support of Departmental programs so long as the expenditure does support the specific budget from which it came. Many of the research expenditures also benefit instructional programs of the Department. We have had significant budget cuts over the past six years which have resulted in loss of staff, operating funds, and graduate-student assistants. However, we have managed to recover staffing positions to support our instructional programs.

Budgeting occurs in an annual planning process between the Department and the College. The Department Head prepares an Annual Departmental Report which is submitted to the Executive Council of the College in early February of each year. Included in this report is a plan for the next year's activities and initiatives and any required changes in budget to accommodate those plans. The Department Head then meets with the Executive Council to discuss the report, the plans, and the budget. Since state and federal funding for the College, the Agricultural Experiment Station, and Cooperative Extension has been flat or declining over the past five years, budget changes usually require internal reallocation (within the College) or come about in the form of "temporary" funds which come from vacant faculty positions which are retained by the College. Since, the state budget is generally not approved until late May or early June, the budget discussion with the Executive Council result in a tentative understanding which is subject to modification pending finalization of the state budget.

Financial Support

The Department generally receives notice of its final budget allocations for the three main budget categories in early June. Operating funds for Instruction are retained at the Department level, and faculty expend their instructional operation requirements against this budget, generally only requiring approval of the Department Business Center Manager.

There is no re-occurring budget line for capital in Departmental budgets. Request for capital items are considered under the "temporary commitment/strategic investment" category at the time of the planning meetings. Small amounts for capital expenditures are generally approved in this way each year. We also make capital purchases using indirect cost return funds, other non-state funds generated by faculty, and differential tuition when needed to improve teaching facilities.

The ABE department receives its budget for teaching programs from the College of Agriculture and Life Sciences. The College of Engineering, at times, has been able to provide partial support for teaching assistants to assist with courses taught by ABE faculty to a broader engineering student clientele.

In 2008, the Arizona Board of Regents (ABOR) permitted colleges to charge a differential tuition to students in their majors. COE charges all students matriculating into engineering at the rate of \$600/semester for lower-division students (freshmen and sophomores) and \$900/semester for upper-division students (juniors or seniors). The Biosystems Engineering program receives 100% of these funds which must be utilized for student activities (hiring teaching assistants, graders, purchasing teaching laboratory equipment, student computer laboratory refresh, and other teaching investments).

Another source of cash for the department that is used to support our Academic programs is Summer/Winter and Outreach tuition return. Funds from tuition by students taking classes that are

not taught during the regular academic year or from students taking courses through the outreach college have a heavy tax, but the resulting revenue is used to support the academic programs.

The department primarily uses differential tuition to cover graders and teaching assistants. In addition, CALS provides \$1500/semester for graders for ABE 120-Microcomputing Applications (a CALS service course) and \$6000/semester for graders/TA for ABE 170A1-Basic Concepts in Water-related Applications and ABE 170A2-Science, Technology, and Environment (general education classes with large enrollments (over 70)). COE provides a 0.25 FTE graduate teaching assistant for ABE 447-Sensor & Controls.

RCM has structured how resources are provided to acquire, maintain, and upgrade the infrastructures, facilities, and equipment used in the program. Prior to 2015, resources were provided by CALS and differential tuition. With the institution of RCM in FY 16, undergraduate tuition is primary revenue to the department with a student's tuition being distributed to the RCM unit by 75% student credit hours (SCHs) and 25% major. ABE splits its majors evenly between CALS and COE, and all SCH's going to CALS. ABE uses state instruction, differential tuition, summer/winter and Outreach tuition return, grants, and gifts for maintaining and improving our academic programs

The ABE Undergraduate Curriculum Committee periodically reviews the curriculum and course content. Any significant proposed changes to required courses are reviewed by this committee so as to evaluate how such changes impact achievement of the program objectives. Any suggested changes are taken to the faculty as a whole for a vote.

The ABE Industrial Advisory Committee (IAC) meets a minimum of once per year to review program objectives and to provide suggestions for new developments to better prepare students for future employment. A recent suggestion of this committee was to address concerns that students were not adequately prepared in the area of global issues, the engineering profession, and communications. The IAC recommended the introduction of a seminar course to address these issues. The ABE Department instituted two seminars, one at the sophomore level and one at the senior level to address this.

C. Staffing

C.1. University of Arizona

- Key institutional services supported at the University level include:
- The UA library (most recently ranked 33rd by the Association of Research Libraries), including the Science and Engineering Library
- The Integrated Learning Center (ILC), 119,000 ft² of instructional space in the center of campus that provides freshmen students with a resources-rich learning environment and a home-base for the delivery of general education curricula
- The Office of Instruction and Assessment, housed in the ILC and newly-formed to better support teaching and learning technologies
- The Financial Service Office (FSO), including the Bursar's Office

- University Information and Technology Services (UITs)
- Office of Student Computing Resources (OSCR)
- Office of Early Academic Outreach, including the MESA (Mathematics, Engineering Science Achievement) program.
- Office of Student Affairs, which includes:
 - Office of the Registrar, including Graduation Services
 - Office of Admissions
 - Office of Scholarships and Financial Aid
 - New Student and Transfer Student Orientation
 - Residence Life
 - The Think Tank, including the Writing Center; tutoring in math, science, and Tier 1 Gen Ed; and peer mentoring
 - UA BookStores
 - Career Services
 - Disability Resources Center
 - Campus Health Services

C.2. College of Engineering

Academic programs are supported by the College of Engineering Academic Affairs Office (AAO). We support the following key functions at the College level in the AAO:

- Recruiting high school students – including our ENGR 102 in high school program
- Admission evaluation for new freshman and transfer students
- Advising no-major selected students (some of these have been termed “pre-engineering” students)
- Initial advising of all transfer students
- Monitoring student records and verifying graduation requirements are met (called the “senior degree check”)
- Allocation of College non-department designated undergraduate scholarships
- Advising of College level student organizations and clubs – including a semi-annual granting program for approximately \$12,000 per year of funds
- Tutoring for math (Math Study Groups that meet weekly)
- E-Zone – Engineering living learning community in the UA residence life program
- Success classes for freshman that are predicted to struggle – ENGR 197a
- Freshman design class - ENGR 102 (Introduction to Engineering)
- Multi-Cultural Engineering programs
- University level processes such as academic integrity cases, general petitions, probation and disqualification, honors convocation, dean’s list, pre-commencement

The AAO Staff are supervised by the Associate Dean for Academic Affairs and include:

- two full-time personnel for recruiting/admissions
- a full time advisor for freshmen and transfer engineering students
- a full time program coordinator for student records
- a full time senior program coordinator for academic administration
- the course coordinator for the required freshman engineering course ENGR 102, Introduction to Engineering

- a full time coordinator for ENGR 102 in Arizona HS
- the Director of the Multicultural Engineering Program
- an administrative assistant for student services

C.3. ABE Department

Table 8-6 summarizes department staff, position, FTEs, and funding source. Our current classified staff (10.77 FTE) support the administrative and financial needs of the department in general (4.5 FTE), of the Controlled Environment Agriculture Center (3.75 FTE), and specific research-related functions (2.52 FTE). Our staff includes a Manager of Finance and Administration (ABE), Accountant (ABE), Administrative Associate (ABE), Administrative Assistant (CEAC), Academic Program Coordinator (ABE), 3 Program Coordinators (1 with CEAC, 2 with research grants), Systems Administrator (ABE), Instrument Shop Supervisor (ABE), 3 Research Specialists (CEAC), and a Programmer (ABE). Table 8.1 lists all the ABE staff with their titles, FTE, and source(s) of funding. Several of these are shared with the Department of Nutritional Sciences. There are also staff (2.49 FTE) who support faculty working at the Yuma and Maricopa Agricultural Centers. Overall, state funds cover about half of the staff salaries (3.03 FTE-ABE; 2 FTE-CEAC) with the rest provided by grant-related funds, IDC recovery funds, differential tuition, summer or outreach tuition return funds, and/or produce sales.

Table 8-6. Department staff, position, FTEs, and funding source.

Staff Name	UA Title		Funding Source
Albertson, Theresa*	Administrative Assistant	0.5	State, CEAC
Barto, Neal*	Research Specialist, Sr.	1.0	State, CEAC, Grants
Capossela, Bernadette	Administrative Associate	1.0	1.0 State
Defer, Charles	Instrument Shop Supervisor, Sr.	1.0	0.96 State, 0.04 Other
Jondall, Dava	Program Coordinator	1.0	0.55 State, 0.45 Other
Little, Brian	Systems Administrator, Sr.	1.0	0.52 State, 0.48 Other
Murphy, Jennifer†	Accountant, Sr.	(1.0)	NSc Dept.
Shevchuk, Darren†	Manager, Finance and Admin.	(1.0)	NSc Dept.
Spicer, Theresa†	Program Coordinator, Sr.	(1.0)	NSc Dept.
Stanley, Elizabeth	Accounting Specialist	0.50	0.50 State
Tevik, Aaron*	Program Coordinator	0.50	State, CEAC
*denotes CEAC exclusive employee			
†denotes staff of ABE/NSc Business Center that are paid from NSc funds			

We have four main areas where increased staff support would make us more efficient:

1. Three of our four main staff positions are partially funded with “soft” funds. Currently, we use our entire summer tuition return funds to backfill these salaries. If all of our four main staff positions were fully funded by state dollars, then the department could invest in graders, assistantships, lab equipment, course improvements, and marketing and recruiting materials.

2. 0.5 FTE Internship Coordinator. Given that we require internships for all our undergrads and encourage them for our graduate students, both programs would benefit from someone who coordinated efforts to find internships and place students in them. This person might also serve as an undergraduate recruiter and placement person. Essentially, this position could help find students, then help them find jobs as they graduate. Currently, these functions are being handled by both the Academic Program Coordinator and the Undergraduate Program Committee Chair.
3. 0.48 FTE Instructional Technologist. Currently, our IT position is funded at 0.52 FTE. We have enlarged the position responsibility to not only support decisions related to computer hardware and software purchases and maintenance, internet access, and ABE classroom and computer room support, but to also support research and senior design projects. We would like to increase this position to a fully-paid 1.0 FTE position.
4. 0.5 FTE Accounting Specialist. Currently, we have 0.5 FTE Accounting Specialist in the Business Center. Another half-time person would help with all the paperwork associated with the Business Center, particularly tracking purchase card transactions.

Staff are encouraged to seek professional development opportunities through UA offerings. They are also encouraged to complete post-secondary degrees. New staff members are provided with appropriate training to help them with their new responsibilities.

D. Faculty Hiring and Retention

D.1. Strategies for Hiring New Faculty: College of Engineering

Each July 1, a hiring plan for the College is due in the Provost Office. This plan has a prioritized list of hiring positions along with an estimate of needed salary, start-up funding, space, and topical area. The plan is created by the Dean's office after discussion with department heads. The Provost is looking for

- how will hires contribute to engaging students,
- how will hires contribute to innovating in research,
- how will hires help us to expand partnering with community and business,
- how will hires help us to foster interdisciplinary synergies across colleges/units,

as well as sufficient financial means to support the hires. In some cases, the positions are jointly supported by Department, College, and University resources so there has to be an agreement between the parties before the plan is approved.

Once the plan (or part of the plan) is approved, the hiring group – this could be multiple departments or a single department – a search committee is formed. At least one person on the search committee must have completed The Faculty Hiring Workshops offered by UA Faculty Affairs (covering topics like unconscious bias, developing diverse pools of candidates, and

understanding that hiring is a multi-criteria problem and the term “best candidate” can have many solutions). At least one member of the search committee has to be from another unit when the position is envisioned for a single department. The tasks of the search committee include:

- Construct an ad for the position as well as a search plan that includes a list of venues for posting. The search plan can be reviewed by HR if so desired.
- Submit the ad for posting based on the plan.
- Make calls or connections to prospective candidates.
- Evaluate applications submitted and possibly do phone interviews.
- Communicate to selected candidates and set up on-campus interviews. Alert non-selected candidates of decisions.
- Manage the campus visit process and collect evaluations from the various constituents.
- Make a recommendation to the affiliated faculty and department heads.

Once an offer is ready to be made, usually one department head will negotiate with the candidate as to the specifics of the offer. This is then assembled into an offer letter (composed largely with the UA offer letter template software) and this letter is reviewed by all parties with a financial commitment for the hire and the Provost Office. If there is an issue with a spousal/partner hire/placement, then there could be additional efforts to satisfy needs before the offer letter is generated.

Usually we allow two weeks for consideration of the offer. Upon acceptance, the candidate simply signs the letter in the appropriate place and faxes or emails a copy back to campus. When the candidate next comes to campus, we have them sign an original of the offer letter.

D.2. Strategies for Hiring New Faculty: ABE Department

ABE uses strategic planning and Logic Models as tools for creating our hiring plans. Since February 2014, the department uses the CALS Unit Metrics-Projections-Investments Needed spreadsheet to indicate what faculty will be needed to meet Arizona Board of Regents (ABOR) metrics and when. Every fiscal year when a position is indicated, a position description is created and discussed at departmental meetings. The position may be ranked by other unit heads in CALS and may or may not move forward that fiscal year.

D.3. Strategies Used to Retain Current Qualified Faculty: College of Engineering

Retention of faculty is a difficult issue – especially in times where finances do not easily permit broad-based salary increases. Our approach has been to anticipate retention issues and try to get ahead of these by making:

- pre-emptive raises,
- title changes and early promotions,
- investments in research and teaching programs (support for graduate students, post-docs, technicians, equipment, operations),
- investments in facility upgrades,

- reallocation of duties including additional research time and leadership opportunities, and
- positions/connections for spouses and partners.

One of the strongest retention ideas is to make it difficult for a person to leave and improve their ability to do strong research. Retention is not always about salary. We make a strong effort to integrate faculty into research and teaching teams on the campus and in the community. We support faculty with research development services and make it easier to compete for grants. We recruit outstanding students, and we try to have an enjoyable work place.

We know that our strategies are on target. In 2015, the UA did a survey of “leaving” tenure track faculty and the results of that survey are found in Table 8-7 (sample of approximately 50).

Table 8-7. 2015 survey results regarding reasons for leaving the UA. (n=50)

Items	Impact on Decision to Leave			
	N/A	No Impact	Some Impact	Major Impact
Value placed on scholarly area in unit/university	2	17	9	22
Other resources to support research/creative work	5	13	15	17
Department/Unit leadership	3	20	10	17
College-level leadership	5	19	9	17
Participation and influence in decision making	2	22	10	16
Opportunities for advancement/prof development	6	21	8	15
Upper admin and/or University leadership	7	13	17	13
Job opportunities for spouse/partner	17	15	6	12
Collegiality	1	26	12	11
Salary	1	15	25	9

These surveys were not engineering faculty largely (our 2015 sample was quite small), however these issues are what we deal with regularly. We have lost faculty to strong offers where we could not compete on resources, but we have lost far more to spouse/partner/ family issues, value placed on a particular area (the target school wanted to focus in an area that we used only for support), and struggles with department/college/university leadership. Note that the survey results are a bit skewed in that given one has a spouse/partner, it is 50% likely that leaving faculty have an issue with positions for spouses.

D.4. Strategies Used to Retain Current Qualified Faculty: ABE Department

The department head meets with faculty annually for performance reviews. At this time, the faculty member and department head are able to discuss challenges, opportunities, and needed resources for continued or improved performance. If it is determined that a faculty member is unhappy with his/her situation, the department head starts to explore what is needed to retain that faculty member. Methods of increasing salary are explored, and opportunities for professional development or advancement likewise are explored. The current department head has not had to submit a retention package, but it is possible to work with CALS administration to try to keep qualified faculty at the institution.

E. Support of Faculty Professional Development

All ABE faculty belong to and are active in one or more professional societies. Faculty are encouraged to participate in professional meetings both to present professional papers and to participate in workshops. Departmental funds are not sufficient to cover the costs of participation in professional meetings. However, most faculty have sufficient grant funding to allow them to fully cover expenses associated with participation in professional development activities. CALS has travel funds to attend multi-state research meetings and professional development opportunities. CoE also supports a limited number of professional development opportunities for ABE faculty. Several faculty members have served as instructors for continuing education programs or short courses associated with professional meetings and such participation often provides funding to cover travel and expenses of participation. Faculty are also active in the American Society for Engineering Education and have presented papers at meeting of that society.

In the past, at least one faculty member participates in the Western Regional Teaching workshop sponsored by Western Regional Colleges of Agriculture. CALS pays travel and registration expenses and the Department pays hotel and miscellaneous expenses. There are also several in-state workshops each year for faculty from the three Arizona Universities and at least one of the ABE faculty participates in these workshops with expenses paid by the Department and CALS. Several faculty members participate in the UA Teaching Academies offered at the beginning of every semester.

We have also presented detailed descriptions of professional development activities for each faculty member in the ABE department in Criterion 6.D. section in this report.

PROGRAM CRITERIA

Criteria for Accrediting Engineering Programs, 2016-2017 “Biological and Similarly Named Engineering Programs”

Lead Society: American Society of Agricultural and Biological Engineers

Cooperating Societies: American Ceramic Society American Academy of Environmental Engineers and Scientists, American Institute of Chemical Engineers, American Society of Civil Engineers, American Society of Mechanical Engineers, Biomedical Engineering Society, CSAB, Institute of Electrical and Electronics Engineers, Institute of Industrial Engineers, Minerals, Metals, and Materials Society.

These program criteria apply to engineering programs that include “biological,” “biological systems,” “food,” or similar modifiers in their titles with the exception of bioengineering and biomedical engineering programs.

1. Curriculum

The curriculum must include mathematics through differential equations, a thorough grounding in chemistry and biology and a working knowledge of advanced biological sciences consistent with the program educational objectives. The curriculum must prepare graduates to apply engineering to biological systems.

2. Faculty

The program shall demonstrate that those faculty members teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of education and experience or professional licensure.

The UA Biosystems engineering B.S. degree program meets or exceeds all of the ABET criteria for “biological” engineering programs.

Mathematics through differential equations.

Students take four semesters of calculus, with the last course being MATH 254 Differential Equations. The total number of credits is 13 if MATH 125 Calculus I is chosen in the first semester or 15 if MATH 122A Functions for Calculus and MATH 122B First Semester Calculus are selected. These courses are pre-requisites for the more advanced science and engineering courses.

A thorough grounding in chemistry and biology.

Students take two 4-credit courses of inorganic chemistry, each including laboratory, namely CHEM 151 and CHEM 152, which had previously been numbered CHEM 103a,b and CHEM 104a,b, respectively. Students also take two 4-credit courses of introductory biology, each including laboratory, namely MCB 181R,L Introduction to Cell Biology (or MCB 184 Introductory Biology I or PLS 240 Plant Biology) and ECOL 182R,L Introductory Biology II (or MIC 205A,L General Microbiology or PSIO 201 Human Anatomy and Physiology).

A working knowledge of advanced biological sciences consistent with the program educational objectives.

Students obtain advanced biological science training through a number of paths. The required course ABE 447 Sensors and Controls provides extensive theory and applications of molecular chemical recognition methods to detect nucleic acids, proteins, and cells in a variety of complex environments. In the required course ABE 423 Biosystems Analysis and Design students learn in-depth methods to model and analyze metabolic pathways and metabolic fluxes, population growth models (including predator-prey and virus transmission). Student-selected projects are completed in both of these courses. Additionally, students gain more depth in advanced biological sciences through their technical and design electives. These can include courses such as ABE 481a, ABE 481b, ABE 475, ABE 479, ABE 483, ABE486, ABE 489a, ABE 489b, BIOC 460, BIOC 461, BIOC 473, MSE 461, and others.

Many biosystems students perform laboratory research as a means to fulfill the required 1-credit internship (ABE 393) which amounts to at least 70 hours of activities. Students can choose the type of internship and so this may or may not necessarily include advanced biological skills. Note that this requirement was added to the Biosystems Engineering curriculum in 2008 and was grandfathered so that few of the 2010 graduates were required to meet the requirement. However, many of the 2010 graduates did work in biological science laboratories in the ABE department or across campus. Faculty advisors identify students with interest and skills for laboratory projects and facilitate connecting the students with appropriate research mentors.

A quantitative measure of this component was developed by evaluating student performance on projects, homework, and exam questions that specifically address the use of advanced biological sciences. The working knowledge of advanced biological science was assessed by 1) course outcome assessment and 2) projects. The course outcome assessment was conducted based on the outcome assessment scores of select classes, including ABE 423, 447, 486 (see Criterion 4 section and assessment findings).

Competence must be demonstrated in the application of engineering to biological systems.

This criterion is achieved in a number of ways. All students must perform a senior design project (ABE 498a,b or ENGR 498a,b) as part of their curriculum. Each project is developed either with an industrial sponsor or with a strong industrial perspective with the ultimate goal of providing the students with experience in applying engineering analyses to biological systems or systems which interact with living systems. Competence is verified by successful completion of the required curriculum and by successful performance as judged by the faculty and industrial partners on the design project.

The program shall demonstrate that those faculty members teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of education and experience or professional licensure.

Faculty involved with teaching ABE engineering courses all have accredited degrees in engineering at the B.S. and then Ph.D. levels. Note that several ABE faculty do not have Ph.D.'s in engineering; however these faculty have either primarily extension appointments or teach courses to students in the College of Agriculture and Life Sciences. Faculty without a Ph.D. in engineering do not teach core courses which are a part of the B.S. Biosystems Engineering degree.

Faculty primarily involved in the senior design sequence (Dr. Muluneh Yitayew, Dr. Donald Slack, Dr. Peter Livingston and others) have extensive experience in applying engineering design to living systems. While Dr. Yitayew and others have passed the FE, Dr. Slack and Dr. Livingston are the only faculty members with a PE license. Dr. Livingston has been teaching the ABE 498a,b senior-design sequence since 2013.

Level of Achievement of Competencies and Proficiencies

The level of achievement of the proficiencies and competencies related to the Program Specific Criteria were evaluated using the metric criteria defined in Table 4-1. Achievement levels were rated on a scale of 1-5 with 5 denoting very high achievement and 1 very low achievement. Achievement level 2 is the minimally acceptable level of achievement and requires corrective action. Performance of Biosystems Engineering graduates on the FE exam provides one measure of achievement of the outcomes relating to proficiency in math, physical sciences and engineering sciences. As can be seen from table below, the achievement level for Biosystems Engineering graduates was between 3.3 and 4.0 in all categories of the exam, implying high achievement of these outcomes. The levels of achievement can also be evaluated from the results of the senior exit surveys and the alumni surveys. The mean of these results over the past seven years are summarized below. The metric used for this table follows that presented in Table 3-5 above. Thus, the level of achievement in all competency/proficiency areas ranges from medium to very high. Other assessment results can also be seen in various tables and figures presented in Criterion 4 Continuous Improvement section of the report. Continuous improvement will be applied on a regular basis to ensure that these scores are consistently high and are increased where possible.

Assessment of achievement of program criteria.

Relevant Competency / Proficiency	Level of Achievement as gauged by specific tools				
	Senior Exit Survey	Alumni Survey	FE exam	SR design	Course outcome assessment
mathematics through differential equations	5	4.1	3.5		4.2
a thorough grounding in chemistry			3.3		
a thorough grounding in biology			4		4.2
working knowledge of advanced biological sciences					4.2
application of engineering to biological systems	5	4.1		4	4.2
Scores: 5 Very High (Exemplary), 4 High (More than acceptable), 3 Medium (Fully Acceptable), 2 Low (Barely acceptable), 1 Very low (Not acceptable)					

Appendix A – Course Syllabi

Course syllabi are presented below for the required curriculum and the most common electives taken by biosystems engineering students. These are organized here in the following way:

Foundation courses

MATH 125	Calculus I
MATH 129	Calculus II
MATH 223	Vector Calculus
MATH 254	Introduction to Ordinary Differential Equations
CHEM 151	General Chemistry I
CHEM 152	General Chemistry II
MCB/Biology 181	Introductory Biology I (biological science elective)
ECOL 182	Introductory Biology II (biological science elective)
PHYS 141	Introductory Mechanics
PHYS 241	Introductory Electricity and Magnetism
ENGL 101	First-Year Composition
ENGL 102	First-Year Composition
ENGL 308	Technical Writing
AGTM 422	Communication Knowledge in Agriculture and the Life Sciences
PLS 240	Plant Biology

Foundational engineering

ENGR 102	Introduction to Engineering
CE 214	Statics
CE 218	Mechanics of Fluids
AME 331	Introduction to Fluid Mechanics
AME 324A	Mechanical Behavior of Engineering Materials
SIE 265	Engineering Management
SIE 305	Introduction to Engineering Probability and Statistics
AME 431	Numerical Methods in Fluid Mechanics and Heat Transfer
AME 432	Heat Transfer

Required courses with ABE prefix

ABE 201	Introduction to Biosystems Engineering
ABE 205	Engineering Analytic Computer Skills
ABE 221	Introduction to Computer Aided Design
ABE 284	Biosystems Thermal Engineering
ABE 393	Internship
ABE 423	Biosystems Analysis and Design
ABE 447	Sensors and Controls
ABE 496a	Seminar in Engineering Careers and Professionalism
ABE 498A	Biosystems Engineering Design I
ABE 498B	Biosystems Engineering Design II

Elective courses

ABE 426	Watershed Engineering
ABE 452	Globalization, Sustainability and Innovation
ABE 455	Soil and Water Resources Engineering
ABE 456	Irrigation Systems Design
ABE 458	Soils, Wetlands and Wastewater Reuse
ABE 459	Design of Onsite Wastewater Treatment and Dispersal Systems
ABE 479	Applied Instrumentation for Controlled Environment Agriculture
ABE 481a	Engineering of Biological Processes
ABE 481b	Cell and Tissue Engineering
ABE 482	Simulation of Biological Systems
ABE 483	Controlled Environment Systems
ABE 486	Biomaterial-Tissue Interactions
ABE 489A	Fabrication Techniques for Micro- and Nanodevices
CHEM 241A	Organic Chemistry I Lecture
CHEM 241B	Organic Chemistry II Lecture
Chemistry 243A	Organic Chemistry I Lab
Chemistry 243B	Organic Chemistry II Lab

English 101, First Year Composition

Credits and contact hours:	3 units and 45 contact hours.
Instructor's or course coordinator's name:	Various sections and instructors
Textbook, title, author and year:	<p>Alvarado, Beth, and Barbara Cully, eds. <i>Writing as Revision</i>, 4th edition. Needham Heights: Pearson Custom, 2011. Print.</p> <p>Hacker, Diana, and Nancy Sommers. <i>Rules for Writers, The University of Arizona Edition</i>, 7th edition. New York: Bedford/St. Martin's, 2014. Print.</p> <p>Jacobson, Brad, Madelyn Tucker Pawlowski, and Emma Miller, eds. <i>A Student's Guide to First-Year Writing</i>, 36th edition. Plymouth: Hayden-McNeil Publishing, 2015. Print.</p>
Other Supplemental materials:	None
2015-2016 catalog description:	Exposition, emphasis on essays.
Prerequisites:	ENGL 100 completed/passed with grade C or higher. (English placement 101).
Co-requisites:	
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	<p>Upon successful completion of English 101, the student will be able to:</p> <ul style="list-style-type: none">• Rhetorical Awareness: Learn strategies for analyzing texts' audiences, purposes, and contexts as a means of developing facility in reading and writing.• Critical Thinking and Composing: Use reading and writing for purposes of critical thinking, research, problem solving, action, and participation in conversations within and across different communities.• Reflection and Revision: Understand composing processes as flexible and collaborative, drawing upon multiple strategies and informed by reflection.• Conventions: Understand conventions as related to purpose, audience, and genre, including such areas as

mechanics, usage, citation practices, as well as structure, style, graphics, and design.

**Student Outcomes –
Listed in Criterion 3 or
any other outcomes are
addressed by the course:**

Learning Outcome (g) can communicate effectively

Topics covered:

- Essay 1: Textual Analysis
- Essay 2: Textual Analysis
- Essay 3: Contextual Analysis
- Final Project: Reflection and Revision

English 102, First Year Composition

Credits and contact hours:	3 credits and 45 contact hours.
Instructor's or course coordinator's name:	Various sections and instructors
Textbook, title, author, and year:	<p>Hacker, Diana, and Nancy Sommers. <i>Rules for Writers, The University of Arizona Edition, 7th edition</i>. New York: Bedford/St. Martin's, 2014. Print.</p> <p>Minnix, Christopher, and Carol Nowotny-Young. <i>Writing Public Lives</i>. 3rd ed. Plymouth, MI: Hayden McNeil, 2012.</p> <p>Winet, Kristin, Brad Jacobson, and Madelyn Tucker, eds. <i>A Student's Guide to First-Year Writing</i>, 35th ed. Plymouth: Hayden McNeil Publishing, 2014.</p>
Other Supplemental materials:	None
2015-2016 catalog description:	Critical papers on selected subjects.
Prerequisites:	ENGL 101 or 101A
Co-requisites:	None
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	<p>Upon successful completion of English 102, the student will be able to:</p> <ul style="list-style-type: none">• Read texts to assess how writers achieve their purposes with their intended audiences• Devise writing strategies suited to various rhetorical situations• Develop an argument with persuasive appeals to your audience• Locate and analyze evidence to develop an argument• Develop ideas with observations and reflections on your experience• Revise in response to feedback from readers to improve drafts

- Use the conventions of scholarly research, analysis, and documentation
- Use the conventions of academic writing, including clear, convincing prose.

**Student Outcomes –
Listed in Criterion 3 or
any other outcomes are
addressed by the course:**

Learning Outcome (g) can communicate effectively

Topics covered:

- Essay 1: Rhetorical Analysis Report
- Essay 2: Controversy Analysis
- Essay 3: Public Argument
- Final Project: Revision and Reflection

CHEM 151, General Chemistry I

Credits and contact hours:	4 credits and 60 contact hours.
Instructor's or course coordinator's name:	Various sections and instructors
Textbook, title, author and year:	The "Chemical Thinking, Volume 1" is the current required electronic textbook for this course. You will need to go to the bookstore to get your individualized access code for the book to allow you to access the text on your computer, tablet, or smartphone. Once purchased, technical support can be found at help@redshelf.com . You may also want to acquire a used General Chemistry textbook to support your work during the course.
Other Supplemental materials:	The use of a scientific calculator is essential for chemistry examinations and assignments. All students must own and be able to use a calculator with the capability for basic arithmetic functions, exponentials, and logarithms. They will also need a periodic table to be used in the different class sessions, and goggles and a cotton lab coat for the experimental activities. Students will be asked to bring a laptop computer to the lecture and lab on a regular basis.
2015-2016 catalog description:	Integrated lecture-lab course designed to develop a basic understanding of the central principles of chemistry that are useful to explain and predict the properties of chemical substances based on their atomic and molecular structure. Additionally, students will be introduced to modern laboratory techniques and participate in experimental activities that promote the development of basic and advanced science-process skills. The course is designed for students who require a strong foundation in general chemistry, such as science and engineering majors, and pre-medical and pre-pharmacy students.
Prerequisites:	MATH 110 or an equivalent level of proficiency as demonstrated by the Math Readiness Test score.
Co-requisites:	None
Required, Elective, or Selected Elective:	Required

Instruction Outcomes:

Upon successful completion of Chem 151, the student will be able to:

- Fundamental understanding of how the structure of matter on the molecular level relates to the observable properties on the macro scale;
- Be able to make predictions and build explanations for the behavior of substances using the appropriate models;
- Understand fundamentally how chemical thinking can be utilized to distinguish, detect and isolate individual substances in a mixture;
- Utilize basic and advanced science-process skills to design an experiment, organize results and make conclusions based on data.

**Student Outcomes –
Listed in Criterion 3 or
any other outcomes are
addressed by the course:**

Learning Outcome (a) can apply mathematics, science and engineering principles to solve problems

Learning Outcome (b) can design and conduct experiments and analyze and interpret data.

Topics covered:

- Distinguish substances by searching for differences, modeling matter, comparing masses and determining composition
- Determine structure by analyzing light-matter interactions, looking for patterns, predicting geometry and inferring charge distribution
- Predict properties by analyzing molecular structure, considering different scales and characterizing ionic networks
- Characterize chemical processes by modeling chemical reactions, understanding proportions and tracking chemical energy

CHEM 152, General Chemistry II

Credits and contact hours:	4 credits and 60 contact hours.
Instructor's or course coordinator's name:	Various sections and instructors
Textbook, title, author and year:	The "Chemical Thinking, Volume 2" is the required electronic textbook for this course. You will need to go to the bookstore to get your individualized access code for the book to allow you to access the text on your computer, tablet, or smartphone. Once purchased, technical support can be found at help@redshelf.com . You may also want to acquire a used General Chemistry textbook to support your work during the course.
Other Supplemental materials:	The use of a scientific calculator is essential for chemistry examinations and assignments. All students must own and be able to use a calculator with the capability for basic arithmetic functions, exponentials, and logarithms. They will also need a periodic table to be used in the different class sessions, and a lab notebook, goggles, and a 100% cotton lab coat for the experimental activities. Students will be asked to bring a laptop computer and/or an internet connected "device" to the lecture and lab sessions on a regular basis.
2015-2016 catalog description:	Integrated lecture-lab course designed to develop a basic understanding of the central principles of chemistry that can be used to explain and predict the extent and rate of chemical reactions based on the physical and chemical properties of reacting substances. Additionally, students will be introduced to modern laboratory techniques and participate in experimental activities that promote the development of basic and advanced science-process skills. The course is designed for students who require a strong foundation in general chemistry, such as science and engineering majors, and pre-medical and pre-pharmacy students.
Prerequisites:	CHEM 151, MATH 110 or an equivalent level of proficiency as demonstrated by the Math Readiness Test score.
Co-requisites:	None

**Required, Elective, or
Selected Elective:**

Required

Instruction Outcomes:

Upon successful completion of Chem 152, the student will be able to:

- Fundamental understanding of how the structure of matter on the molecular level relates to chemical reactivity
- Be able to make predictions and build explanations for the chemical behavior of substances using the appropriate models
- Understand fundamentally how chemical thinking can be utilized to explain and predict the directionality, extent and rate of chemical reactions
- Utilize basic and advanced science-process skills to design an experiment, organize results and make conclusions based on data

**Student Outcomes –
Listed in Criterion 3 or
any other outcomes are
addressed by the course:**

Learning Outcome (a) can apply mathematics, science and engineering principles to solve problems

Learning Outcome (b) can design and conduct experiments and analyze and interpret data.

Topics covered:

- Predict chemical changes by analyzing structure, comparing free energies, understanding mechanism and measuring rates
- Control chemical processes by characterizing interactions, analyzing chemical stability and influencing chemical equilibrium
- Synthesize substances by analyzing processes
- Harness chemical energy by controlling electron transfer

MCB 181L, Introductory Biology Laboratory I

Credits and Contact Hours:	1 credit
Instructor's or course coordinator's name:	Emily Dykstra
Textbook, title, author and year:	MCB 181L Lab Manual, B. Patterson & E. Dykstra, 2016
Other Supplemental materials:	On-line tutorials via the Hayden McNeil website: https://courses.hayden-mcneil.com/local/ecologin/?errorcode=4
2015-2016 Catalog Description:	Laboratory exercises presenting techniques and fundamental principles of modern biology. Designed to complement the information concurrently presented in MCB 181R.
Prerequisites:	MCB 181R or concurrent registration.
Co-requisites:	None
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	<ul style="list-style-type: none">• Work collaboratively to understand foundational molecular and cellular biology concepts• Understand and be proficient in the cyclical nature of the scientific process: hypothesis-model-test-refine-repeat• Use active learning strategies to deepen an understanding of experimental design• Distinguish between understanding a process or concept and merely knowing the labels associated with it; be able to clearly communicate this understanding both verbally and in written format• Understand how genetic information is stored, accessed, and distributed• Understand a protein in depth (how amino acids drive its structure and properties, how its properties generate its function, how its function allows life/health, and how changes in structure cause changes in health). Examples: hemoglobin, opsin• Understand the nature, flow and storage of energy within and between molecules

- Use computer representations of molecules in order to understand inter and intra molecular interactions and the biological implications of these interactions (examples: hydrogen bonding between water molecules, hydrophobic affect and protein folding, how a mutation in hemoglobin leads to the formation of long chains of hemoglobin which ultimately results in sickle cell anemia)
- Evaluate the validity of various published sources of scientific information (i.e. using Wikipedia vs. NIH's Genetics Home Reference page, etc. – this does not apply to evaluating primary literature)
- Use models to generate hypotheses, predictions and experiments (Understand that models can be used to both understand a system/phenomena and generate predictions about that system)
- Distinguish between a hypothesis (a testable proposed explanation that is based on previous knowledge) and a 'guess'
- Understand the roll of controls in experimentation and apply this understanding to the design of controls for specific experiments
- Use argumentation to defend positions and generate consensus understanding
- Understand the relative merits of graphs and tables and apply this understanding to appropriately representing data in lab reports
- Apply an understanding of the difference between direct and indirect evidence in the designing of experiments and the interpretation of data

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

Outcome a: Can apply mathematics, science and engineering principles to solve problems

Outcome b: Can design and conduct experiments and analyze and interpret data

Topics covered:

- The scientific approach
- The nature of the molecular world
- The structure and function of key macromolecules
- The Central Dogma
- Detection of macromolecules and their state
- Basic molecular genetics
- Experimental Design

MCB 181R, Introductory Biology I

Credits and Contact Hours:	3 credit hours. 3 hours of contact time/week
Instructor's or course coordinator's name:	Lisa Elfring
Textbook, title, author and year:	Through Summer 2015: Scott Freeman, Kim Quillin, Lizbeth Allison's <i>Biological Science</i> , 5 th edition, Volume 1
Other Supplemental materials:	Mastering Biology (online homework system)
2015-2016 Catalog Description:	Introduction to biology covers fundamental principles in molecular and cellular biology and basic genetics. Emphasis is placed on biological function at the molecular level, with a focus on the structure and regulation of genes, the structure and synthesis of proteins, how these molecular are integrated into cells, and how these cells are integrated into multicellular systems. Examples stem from current research in bacteria, plants, and animals (including humans) in the areas of cell biology, genetics, molecular medicine, and immunology.
Prerequisites:	Appropriate Math Placement Level or Math 109C, 110, 112, 113,115, 120, 120R, 122B, 124, 125, 129, 223, or Proctored/Prep for Calculus 45+ or Proctored/Prep for College Algebra 55+.
Co-requisites:	None
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	<p>In terms of biology content students will:</p> <ul style="list-style-type: none">• Demonstrate understanding of the ways that chemical principles govern the ability of biological molecules to form cellular structures, tissues, organs, and organisms, and the energy transformations that make these steps possible.• Explain mechanisms and outcomes of the ability of cells to sense and respond to internal and external cues.• Explain the role of and mechanisms by which the genome and its products generate biological structures and phenotypes, including human disease, including:

- Differentiate among replication, transcription, and translation with regard to mechanisms and biological roles.
- Analyze mechanisms of inheritance and their consequences for phenotypes.
- Differentiate among various types of mutations and predict their outcomes at the molecular, cellular, and organismal level.
- Describe ways that research in different experimental organisms sheds light on the important biological processes described above.

In terms of skills, students will:

- Apply analytical thinking to biological problems:, including applying quantitative strategies to analyze and understand biological processes.

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

Outcome a: Can apply mathematics, science and engineering principles to solve problems

Outcome b: Can design and conduct experiments and analyze and interpret data

Topics covered:

- Biological molecules, structure and function (Proteins, nucleic acids, carbohydrates, and lipids)
- Biological membrane structure and function, focusing on transport
- Prokaryotic and eukaryotic cell structure and organelle functions
- Cellular respiration
- Photosynthesis
- Gene structure, genetic code, and mutations
- Transcription and translation
- Control of differential gene expression, focusing mostly on transcriptional regulation
- Meiosis
- Mendelian inheritance of traits
- Cell-cell interactions: Extracellular matrix and cell signaling
- The eukaryotic cell cycle and its regulation
- DNA synthesis and repair

ENGR 102, Introduction to Engineering – Main Lecture

Credits and contact hours:	3 credits and 45 contact hours.
Instructor's or course coordinator's name:	Various sections and instructors
Textbook, title, author and year:	Students are not required to purchase a textbook for this class. The required resources will be available on D2L or on the worldwide web. Therefore, students must have access to the internet.
Other Supplemental materials:	Students must have a Turning Technologies Response Card (NXT or XR) "clickers" for the Main Lecture. Please see the Main lecture D2L site for instruction on how to register your clicker.
2015-2016 catalog description:	Engineering design, effective team participation and career preparation. Students are expected to participate in hands-on design projects, develop education/career plans and initiate development of the personal and management skills necessary for life-long learning.
Prerequisites:	College of Engineering major. Appropriate Math Placement Level or Proctored/Prep for Calculus 75+, Concurrent enrollment in, or successful completion of, MATH 122B, 124, 125, 129, 223, 250A, 250B or 254.
Co-requisites:	None
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	<p>Upon successful completion of Engr 102, the student will be able to:</p> <ul style="list-style-type: none">• Introduce students to the fundamental principles of engineering design through project-based learning.• Teach students how teamwork, communication and design techniques can be applied to a variety of engineering problems.• Provide important information to help students make informed decisions regarding their academic and professional careers in engineering.

- Help students develop useful skills that will enable them to be successful in the UA College of Engineering and as engineering professionals.
- Provide students an opportunity to explore a topic of particular interest for a 4-week period in an online environment.

**Student Outcomes –
Listed in Criterion 3 or
any other outcomes are
addressed by the course:**

Learning Outcome (a) can apply mathematics, science and engineering principles to solve problems.

Learning Outcome (d) can function on multidisciplinary teams.

Topics covered:

- Learn assigned materials in D2L and submit homework assignments.
- Solar Oven team design project – develop two oven models, give oral progress reports, perform demonstrations, perform analysis and write report.
- Grand Challenges unit
- Design of experiments unit
- Midterm/Final Exams

MATH 125, Calculus I

Credits and contact hours:	3 credits and 45 contact hours.
Instructor's or course coordinator's name:	Various sections and instructors
Textbook, title, author and year:	Math 125 covers chapters 1 - 6 and section 7.1 of <i>Calculus, Single Variable</i> ; 6th edition; Hughes-Hallett, et al.; Wiley.
Other Supplemental materials:	None
2015-2016 catalog description:	<p>An accelerated version of MATH 122B. Introduction to calculus with an emphasis on understanding and problem solving. Concepts are presented graphically and numerically as well as algebraically. Elementary functions, their properties and uses in modeling; the key concepts of derivative and definite integral; techniques of differentiation, using the derivative to understand the behavior of functions; applications to optimization problems in physics, biology and economics. A graphing calculator is required for this course. We recommend the TI-83 or TI-84 models. Calculators that perform symbolic manipulations, such as the TI-89, NSpire CAS, or HP50g, cannot be used. Except as per University policy on repeating a course, credit will not be given for this course if the student has credit in a higher level math course. Such students may be dropped from the course. Examinations are proctored.</p>
Prerequisites:	Appropriate Math Placement Level or Proctored/Prep for Calculus 90+ or MATH 125.
Co-requisites:	None
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	<p>Upon successful completion of Math 125, the student will be able to:</p> <ul style="list-style-type: none">• Compute limits and derivatives of algebraic and transcendental functions;• Determine the differentiability of functions;• Use the Rule of Four to interpret and express derivatives and definite integrals;

- Use derivatives to determine properties of graphs of functions, solve optimization problems, and evaluate related rates;
- Recognize and apply L'Hopital's Rule.
- Apply the Fundamental Theorem of Calculus;
- Evaluate indefinite integrals, including the method of substitution

**Student Outcomes –
Listed in Criterion 3 or
any other outcomes are
addressed by the course:**

Learning Outcome (a) can apply mathematics, science and engineering principles to solve problems

Topics covered:

- Basic review of exponential, logarithmic, trigonometric, power, polynomial and rational functions and transformations of these functions
- Limits, continuity
- The derivative: the derivative function, interpretations of the derivative, second derivative, differentiability, short-cuts to differentiation, product rule, quotient rule, chain rule, implicit functions, hyperbolic functions, linear approximations, theorems about differentiable functions,
- Derivative applications: using first and second derivatives, families of functions, optimization, modeling, rates, related rates, L'Hopital's rule, parametric equations
- The definite integral: the fundamental theorem and interpretations, theorems about definite integrals
- Antiderivatives: graphically and numerically, constructing analytically, differential equations, second fundamental theorem of calculus, equations of motion
- Integration by substitution

MATH 129, Calculus II

Credits and contact hours:	3 credits and 45 contact hours.
Instructor's or course coordinator's name:	Various sections and instructors
Textbook, title, author and year:	Math 129 covers chapters 7 through 11 of <i>Calculus Single Variable</i> , Sixth Edition by Hughes-Hallett et al. published by Wiley.
Other Supplemental materials:	None
2015-16 catalog description:	Continuation of MATH 122B or MATH 125. Techniques of symbolic and numerical integration, applications of the definite integral to geometry, physics, economics, and probability; differential equations from a numerical, graphical, and algebraic point of view; modeling using differential equations, approximations by Taylor series. A graphing calculator is required for this course. We recommend the TI-83 or TI-84 models. Calculators that perform symbolic manipulations, such as the TI-89, NSpire CAS, or HP50g, cannot be used. Examinations are proctored.
Prerequisites:	MATH 122B or MATH 125 with a grade of C or higher.
Co-requisites:	None
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	<p>Upon successful completion of Math 129, the student will be able to:</p> <p>Use techniques of analytical and numerical integration; be able to apply the definite integral to problems arising in geometry and physics; be able to work with the concept of infinite series and be able to calculate and use Taylor series; be able to analyze differential equations from a numerical, graphical, and algebraic point of view and model physical and biological situations by differential equations.</p>

**Student Outcomes –
Listed in Criterion 3 or
any other outcomes are
addressed by the course:**

Learning Outcome (a) can apply mathematics, science and engineering principles to solve problems

Topics covered:

- Integration: by substitution, by parts, table of integrals, algebraic identities, trig substitutions, approximating definite integrals, approximating errors, Simpson's rule, improper integrals, comparison of improper integrals
- Applications of the Definite Integral: areas, volumes, geometric applications, density and center of Mass, distributions functions, probability, mean, median
- Sequences and series, geometric series, convergence of series, tests for convergence, power series, interval of convergence
- Approximating functions using series: Taylor polynomials, Taylor series, error in Taylor polynomial approximations
- Differential equations: slope fields, Euler's method, separation of variables, growth and decay, applications and modeling

MATH 223, Vector Calculus

Credits and contact hours:	4 credits and 60 contact hours.
Instructor's or course coordinator's name:	Various sections and instructors
Textbook, title, author and year:	Math 223 covers chapters 12 through 20 of <i>Calculus Single Variable</i> , Sixth Edition by Hughes-Hallett et al. published by Wiley.
Other Supplemental materials:	None
2015-16 catalog description:	Vectors, differential and integral calculus of several variables. Examinations are proctored.
Prerequisites:	MATH 129 or 250A with a grade of C or higher.
Co-requisites:	None
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	<p>Upon successful completion of MATH 223, the student will be able to:</p> <ul style="list-style-type: none">• Recognize and sketch surfaces in three-dimensional space;• Recognize and apply the algebraic and geometric properties of vectors and vector functions in two and three dimensions;• Compute dot products and cross products and interpret their geometric meaning;• Compute partial derivatives of functions of several variables and explain their meaning;• Compute directional derivatives and gradients of scalar functions and explain their meaning;• Compute and classify the critical points;• Parameterize curves in 2- and 3-space;• Set up and evaluate double and triple integrals using a variety of coordinate systems;• Evaluate integrals through scalar or vector fields and explain some physical interpretation of these integrals;

- Recognize and apply Fundamental theorem of line integrals, Green's theorem, Divergence Theorem, and Stokes' theorem correctly.

**Student Outcomes –
Listed in Criterion 3 or
any other outcomes are
addressed by the course:**

Learning Outcome (a) can apply mathematics, science and engineering principles to solve problems

Topics covered:

- Vectors: displacement vectors, vectors in general, dot product, cross product
- Functions of several variables: functions of two variables and their graphs, contour diagrams, linear functions, functions of three variables
- Differentiating functions of several variables: partial derivative, computing partial derivatives algebraically, local linearity and the differential, gradients and directional derivatives in the plane and in space, the chain rule, second order partial derivatives, optimization, local extrema
- Integrating functions of several variables: the definite integral of a function of two variables, iterated integrals, triple integrals, double integrals in polar coordinates, integrals in cylindrical and spherical coordinates
- Parameterizations and vector fields: parameterized curves, motion, velocity, acceleration, vector fields
- Line integrals: computing line integrals over parameterized curves, gradient and path-dependent fields, path-dependent vector fields, Green's theorem
- Flux Integrals: flux integrals for graphs, cylinders, and spheres
- Calculus of vector fields: divergence of a vector field, divergence theorem, curl of a vector field, Stokes' theorem

MATH 254, Introduction to Ordinary Differential Equations

Credits and contact hours:	3 credits and 45 contact hours.
Instructor's or course coordinator's name:	Various sections and instructors
Textbook, title, author and year:	Fundamentals of Differential Equations by R. Kent Nagle et al., Pearson, 8th edition.
Other Supplemental materials:	None
2015-16 catalog description:	Solution methods for ordinary differential equations, qualitative techniques; includes matrix methods approach to systems of linear equations and series solutions. Examinations are proctored.
Prerequisites:	MATH 129 or 250A with a grade of C or higher.
Co-requisites:	None
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	<p>Upon successful completion of Math 254, the student will be able to:</p> <ul style="list-style-type: none">• Recognize and solve first order linear differential equations.• Recognize and solve constant coefficient differential equations of degree 2 and above.• Use method of undetermined coefficients and variation of parameters apply to mechanical and electrical driven damped oscillators.• Apply phase plan analysis to simple systems of differential equations• Solve small systems of linear first order differential equations

**Student Outcomes –
Listed in Criterion 3 or
any other outcomes are
addressed by the course:**

Topics covered:

Learning Outcome (a) can apply mathematics, science and engineering principles to solve problems

- Introduction: Verifying solutions, initial value problems, direction fields, approximate solutions
- First-order differential equations: motion of a falling body, separable equations, linear equations, exact equations, special integrating factors
- Linear second-order equations: the mass-spring oscillator, the general solution to homogeneous linear equations, auxiliary equations with complete roots, variation of parameters, variable-coefficient equations, qualitative considerations for variable-coefficient and nonlinear equations
- Introduction to systems and phase plan analysis: Introduction of the phase plane, applications to biomathematics, coupled mass-spring systems, electrical systems
- Series solutions of differential equations: the Taylor polynomial approximation, power series and analytic functions, power series solutions to linear differential equations, equations with analytic coefficients, method of Frobenius
- Matrix methods for linear systems: linear and algebraic equations, matrices and vectors, linear systems in normal form, homogeneous linear systems with constant coefficients, complex eigenvalues, nonhomogeneous linear systems

Physics 141, Introductory Mechanics

Credits and contact hours:	4 units and 60 credit hours.
Instructor's or course coordinator's name:	Various sections and instructors
Textbook, title, author and year:	Young, Hugh D. & Freedman, Roger A., <i>University Physics</i> – 14 th Edition.
Other Supplemental materials:	Physics 141 Lab Manual, available as “class notes” from the UA bookstore.
2015-2016 Catalog description:	A first course in Newtonian mechanics; introduces freshman-level students to the statics and dynamics of point particles, rigid bodies, and fluids. Topics include vector algebra, projectile and circular motion, Newton's Laws, conservation of energy, collisions and conservation of momentum, rotational dynamics and conservation of angular momentum, statics, harmonic oscillators and pendulums, gravitation and Kepler's Laws, fluid statics and dynamics.
Prerequisites:	Math 122B or MATH 124, Math 125 or appropriate Math Placement Level. Also, if you plan on continuing with physics next semester you should be concurrently enrolled in MATH 129.
Co-requisites:	None
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	Upon successful completion of PHYS 141, the student will be able to: Learn the principles of mechanics: Newton's laws, conservation of energy/momentum, simple harmonic motion, and Newton's theory of gravity.
Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:	Learning Outcome (a) can apply mathematics, science and engineering principles to solve problems Learning Outcome (b) can design and conduct experiments and analyze and interpret data

Topics covered:

- Vectors; two-dimensional motion; projectile motion
- Dimensional analysis: one dimensional motion and acceleration
- Newton's Laws and applications
- Circular motion (kinematics); moving reference frames.
- Circular motion (dynamics)
- Work; kinetic energy; potential energy
- Conservation of momentum
- One and two dimensional collisions: center of mass
- Motion of a system of particles
- Angular velocity and acceleration
- Moments of inertia; torque; rotational energy and rolling motion
- Angular momentum; conservation of angular momentum
- Statics
- Simple harmonic oscillator; pendulums.
- Damped and forced oscillators
- Newton's Law of Gravity
- Kepler's Law
- Gravitational energy
- Fluid statics; fluid dynamics
- Traveling waves; standing waves; sound

Physics 241, Introductory Electricity and Magnesium

Credits and contact hours:	4 credits and 60 contact hours.
Instructor's or course coordinator's name:	Various sections and instructors
Textbook, title, author and year:	<i>University Physics with Modern Physics</i> , Young and Freedman, 13th ed., Pearson/Addison Wesley Publishing 2012. Homework will be assigned out of the 13th ed.
Other Supplemental materials:	None
2015-2016 Catalog description:	A first course in electromagnetic fields and their applications. Coulomb's and Gauss' Law, electric fields and potentials, electrical and magnetic properties of matter, Ampere's and Faraday's laws, elementary DC and AC circuits, Maxwell's equations.
Prerequisites:	Course Requisites: PHYS 141 or 140 or 161H, (including transfer and AP credit) and MATH 129 or 250A or appropriate Math Placement Level (including transfer and AP credit); Concurrent registration: MATH 223 is recommended but not required. Some elementary vector calculus will be taught in class.
Co-requisites:	None
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	Upon successful completion of PHYS 241, the student will be able: <ul style="list-style-type: none">• To survey classical electricity and magnetism; in particular to study how charged objects move and how interactions between charged objects influence motion.• To study electromagnetic waves.
Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:	Learning Outcome (a) can apply mathematics, science and engineering principles to solve problems Learning Outcome (b) can design and conduct experiments and analyze and interpret data

Topics covered:

- Electrostatics
- Gauss' Law
- Electric Potential and Potential Energy
- Conductors, Insulators and Capacitors
- DC Circuits
- Magnetism and Magnetic Fields
- Biot-Savart and Ampere's Law
- Faraday's Law
- Inductance and AC Circuits and Magnetism in Matter
- Electromagnetic Waves

CE 214, Statics

Credits and Contact Hours:	3 (3 lecture hours)
Instructor's name	Dean Papajohn
Textbook, title, author and year	Engineering Mechanics: Statics by R.C. Hibbeler, 14th Edition, Pearson. (ISBN 978-0-13-391892-2).
Other supplemental materials 2015-2016 Catalog Description	Equilibrium of a particle, equivalent and resultant force systems, equilibrium, geometric properties of areas and solids, trusses, frames and machines, shear force and bending moments, friction. Honors section is available.
Prerequisites	PHYS 141 or PHYS 161H; and MATH 129 or MATH 250B or concurrently enrolled in MATH 250B
Co-requisites	None
Required, Elective, or Selected Elective	Required
Instructional Outcomes	Students should be able to: <ol style="list-style-type: none">1. Draw Free Body Diagrams. (A, G)2. Calculate forces on rigid bodies by using fundamental laws (such as Newton's laws) and concepts. (A,E)3. Demonstrate an understanding of the principles of mechanics. (A, G, M)4. Apply engineering principles to analyze physical systems. (E, L, M)5. Demonstrate problem-solving skills. (E)
Student Outcomes	Primary – A, E, L Secondary – G, M

AGTM 422, Communication Knowledge in Agriculture and the Life Sciences

Credits and Contact Hours:	3 credits, 2.5 hrs/week lecture, Office hours: Open and by appointment
Instructor's or course coordinator's name:	Matthew M. Mars, Assistant Professor, Agricultural Leadership and Innovation
Textbook, title, author and year:	The Gregg Reference Manual , 11 th Ed., Sabin, W.A. Selected readings and course notes will be posted on D2L course site
Other Supplemental materials:	N/A
2015-2016 Catalog Description:	Principles and processes of knowledge diffusion and methods of transferring appropriate technology to user/clientele groups. Communicating effectively within organizations.
Prerequisites:	N/A
Co-requisites:	N/A
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	Upon completing the course students should be able to: <ol style="list-style-type: none">1. Synthesize technical knowledge from the program/major area.2. Create business documents.3. Create career readiness documents.4. Engage in career readiness activities.5. Possess basic knowledge of communication theory.6. Develop an organized method to approach communication issues.7. Create context appropriate communication media.8. Outline a plan of work for future job related projects.
Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:	Outcome (g):) Can communicate effectively
Topics covered:	<ol style="list-style-type: none">1. Communication in the Career Development Context: <i>Oral Communication (Interviews) and Written Communication (Resume, Cover Letter, Email)</i>2. The Fundamentals of Professional and Strategic Communication: <i>Grammar, Organization, and Structure; Technical Report Writing; Research Manuscript Writing; Social Media Utilization</i>

3. **Strategic Communication Planning and Execution:**
Development of Mission, Goals, and Objectives during the Strategic Communication Process, Target Audience Analysis, Press Release Development, Expert Interview and Feature Article, Public Service Announcement Development and Posting, Podcast Development, Blog Design and Management, Campaign Performance Assessment

CE 218, Fundamentals of Fluid Mechanics

Credits and Contact Hours:	3 (3 lecture hours)
Instructor's name	Jennifer G. Duan
Textbook, title, author and year	Fundamentals of Fluid Mechanics, Muson, Young, and Okiishi, 5th, 6th, or 7th edition
Other supplemental materials	N/A
2015-2016 Catalog Description	Hydrostatics, continuity, irrotational flow, pressure distributions, weirs and gates, momentum and energy, surface drag, pipe friction, form drag, pipe fitting losses.
Prerequisites	CE 214
Co-requisites	N/A
Required, Elective, or Selected Instruction Outcomes	Required <ul style="list-style-type: none">• Understand the definition of a fluid• Understand the concepts of viscosity, surface tension, caterpillar, the difference of Newtonian and non-Newtonian fluids• Understand the assumptions for ideal flow• Understand the difference between laminar and turbulent flow and the transition between them, and know how to determine these flow regime• Able to calculate hydrostatic pressure on a plate or curved surface and locate the centre of pressure• Understand the principles of manometer and know about its applications• Derive and apply the Bernoulli equation• Derive and apply the one-dimensional momentum equation• Understand major losses and minor losses, and know how to quantify them using the Moody diagram in pipe flow analysis
Student Outcomes – Listed in Criterion 3 or any other outcomes are Contribution to criterion 5	<i>Primary:</i> A, E, L <i>Secondary:</i> G, J, M

Topics covered

- Characteristics of Fluids (Chapter 1)
- Fluid Statics (Chapter 2)
- Fluid Dynamics: Bernoulli Equation (Chapter 3.1; 3.2; 3.3)
- Applications of Bernoulli Equation (Chapter 3.4; 3.5; 3.6; 3.7; 3.8)
- Flow Fields and Reynolds' Transport ☐ Theorem (Chapter 4.1; 4.2; 4.3; 4.4)
- Conservation of Mass (Chapter 5.1)
- Momentum and Moment of
- Momentum Equations (Chapter 5.2)
- First Law of Thermodynamics -
- Energy Equation (Chapter 5.3)
- Similitude and Dimensional Analysis (Chapter 7)
- Laminar Pipe Flow (Chapter 8.1; 8.2)
- Turbulent Pipe Flow (Chapter 8.3)
- Flow Resistance in Pipes, Flowrate
- Measurement (Chapter 8.4; 8.5)

PLS 240, Plant Biology

Credits and Contact Hours:	4 credits 6 contact hours per week (3 lecture and 3 lab)
Instructor's or course coordinator's name:	Dr. Steve Smith
Textbook, title, author and year:	<i>Biology of Plants</i> . Peter Raven, Ray Evert and Susan Eichhorn, 2012 (8th edition).
Other Supplemental materials:	
2015-2016 Catalog Description:	This course deals with plant form and function from an evolutionary point of view and is intended for majors in all fields of biology. Emphasis is placed on understanding basic processes of metabolism, evolution, reproduction, growth, development, and physiology of nonvascular and vascular plants. These processes are considered within the context of the environments plants inhabit and human activities that affect or depend upon plants.
Prerequisites:	none
Co-requisites:	none
Required, Elective, or Selected Elective:	
Instruction Outcomes:	Students completing PL S 240 will: <ol style="list-style-type: none">1. Understand the basic structures and processes involved in plant growth and development;2. Appreciate the diversity found among plants and understand the basis for and significance of this diversity;3. Understand how plants interact with their environment and the critical roles that plants play in all ecosystems;4. Use scientific terminology to communicate effectively about plants;5. Develop critical thinking skills by evaluating information from multiple perspectives, drawing reasonable conclusions, and defending them rationally; and6. Have assumed complete responsibility for their performance in the course and actively worked to improve their organizational and time management skills.

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

Outcome h: has the broad education necessary to understand the impact of engineering solutions in global, economic, environmental and societal context

Outcome i: Recognize the need for and the ability to engage in lifelong learning.

Topics covered:

I. Cells: Structure and energy

II. Form and function

III. Genetics and evolution

IV. Regulation of growth and development

V. Evolution of diversity

VI. Ecology and the human prospect

SIE 265, Engineering Management I

Credits and Contact Hours:	3 Credits – Three 50-minute lectures per week.
Instructor's or course coordinator's name:	Robert G. Lepore
Textbook, title, author and year:	There is no required textbook for this class. Material will be made available on the course website to support class lectures. Contemporary Engineering Economics, 5th Edition, by Chan S. Park is a recommended textbook. Microsoft Excel is required. Students must have either a financial calculator (e.g. HP -10B) or a calculator that includes financial functions (e.g. TI-89)
2015-2016 Catalog Description:	Fundamentals of economic analysis and the time value of money for engineers. Construction of financial models in Microsoft Excel including Income, Cash Flow, and Balance Sheet. Estimation of required capital and project acceptance criteria.
Prerequisites:	ENGR 102 and MATH 129. Students are expected to be reasonably proficient with Microsoft Excel.
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	<p>This course introduces students to concepts of economic analysis, profitability, and cost estimation. Specific outcomes include:</p> <ul style="list-style-type: none">• Increased proficiency with Excel.• Understanding concepts of the time value of money.• Understanding of Pro Forma Income Statements, Cash Flow Statements and Balance Sheets.• Ability to create financial statements for evaluating Engineering projects.• Ability to determine the economic viability of engineering projects.
Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:	<p>(b) An ability to design and conduct experiments, as well as to analyze and interpret data</p> <p>(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.</p>

Topics covered:

- Microsoft Excel
- Accounting
- Time Value of Money
- Financial Functions
- Financial Modeling
- Valuation
- Taxation
- Project Acceptance Criteria
- Replacement Cost Analysis
- Entrepreneurship

SIE 305, Introduction to Engineering Probability and Statistics

Credits and Contact Hours:	3 Credits – Three 50-minute lectures per week
Instructor's or course coordinator's name:	Don Bruyere
Textbook, title, author and year:	Devore, Jay L. Introduction to Engineering Probability and Statistic, CENGAGE Learning. (University of Arizona Specific)
2015-2016 Catalog Description:	Axioms of probability, discrete and continuous distributions, sampling distributions. Engineering applications of statistical estimation, hypothesis testing, confidence intervals.
Prerequisites:	MATH 129 Each student must be able to do: 1. Differentiate (derivatives of exp., log, and polynomial, etc.) 2. Integrate (single integrals, simple double integrals)
Required, Elective, or Selected Elective:	Required
Course Objectives:	<ul style="list-style-type: none">• Understand and apply basic probability correctly.• Understand when and how to use discrete and continuous probability models in univariate and multivariate contexts.• Application of probability to reliability.• Derive functions of random variables.• Learn the correct use point estimation techniques.• Develop confidence intervals, tolerance intervals, and prediction intervals.• Develop tests of hypotheses in single and two-sample scenarios. Collect and describe data.
Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:	b) An ability to design and conduct experiments, as well as to analyze and interpret data
Topics covered:	<ul style="list-style-type: none">• Combinatorics, Basic Probability• Discrete R.V, Continuous R.V.• Descriptive Stats., Function of R.V.• Joint R.V., Point Estimation• Sampling Dist., Stat. Intervals• Hypothesis Tests

AME 331, Introduction of Fluid Mechanics

Credits and contact hours:	3 credits, 3 contact hours
Instructor/coordinator's name:	Jesse Little
Textbook(s) and/or other supplemental materials:	<i>Fox and McDonald's Introduction to Fluid Mechanics</i> , 8th Edition Philip J. Pritchard, Wiley, 2011
Catalog description:	Fundamentals of fluid mechanics covering properties of fluids, fluid statics, dynamics of incompressible viscous and inviscid flows, control volume formulations of continuity, momentum and energy equations, dimensional analysis, viscous pipe flow, boundary layers and drag.
Prerequisites/Co-Requisites:	AME 230 (or ABE 284 for BME and BE majors only), AME 250 (or PHYS 141 for BME majors only), and MATH 254. Adv Stdg: Engineering.
Required, Elective, Selected Elective:	Required
Specific outcomes of instruction:	<ul style="list-style-type: none">• Use fluid-mechanic terminology and concepts appropriately.• Define appropriate system boundaries for analyzing a variety of fluidic components and systems.• Determine and calculate the appropriate mass, momentum and energy transfers and properties to solve system applications with any number of flows crossing the system boundary.• Determine and calculate appropriate mass and energy transfers and properties to solve stead-state open system applications.• Determine when and how to introduce simplifying assumptions for the analysis of complex fluid systems.• Appreciate the role of dimensional analysis in handling fluid problems for which no analytical solution is available.• Understand the physical interpretation of non-dimensional control parameters, and be proficient in applying them for the analysis of fluid systems.• Analyze fluid systems individually and as part of a team.

- 9. Communicate the results of a system analysis orally or in writing.

**Outcomes listed in
Criterion 3:**

- a. apply mathematics, science, and engineering principles
- e. identify, formulate, and solve engineering problems

Topics covered:

- Introductory Remarks
- Concepts & Definitions
- Fluid Statics
- Integral Analysis
- Fluid Kinematics
- Differential Analysis
- Dimensional Analysis
- Pipe Flow (internal flow)
- Boundary Layers (external flow)

AME 324A, Mechanical Behavior of Engineering Materials

Credits and contact hours:	3 credits, 3 contact hours
Instructor/coordinator's name:	John Turner
Textbook(s) and/or other supplemental materials:	<i>Mechanics of Materials</i> (T.A. Philpot), 3 rd Edition, Wiley Detailed class lecture notes
Catalog description:	Introduction to engineering mechanics of solid materials; concepts of stress and strain at a point; states of plane stress and plane strain, stress-strain constitutive relations; stress equilibrium; material/structural responses to applied loading/deflection; analysis of statically determinate and indeterminate engineering components, e.g., trusses, rods, beams, frames, thin-walled pressure vessels; failure theories; introduction to structural stability
Prerequisites/Co-Requisites:	CE 214 (Statics) and Adv Stdg: Engineering
Required, Elective, Selected Elective:	Required
Specific outcomes of instruction:	<ul style="list-style-type: none">• Equip students with skills to determine the structural integrity of common engineering components.• 2. Prepare students to develop further analytical skills for more complicated structures.
Outcomes listed in Criterion 3:	a. apply mathematics, science, and engineering principles e. identify, formulate, and solve engineering problems
Topics covered:	<ul style="list-style-type: none">• Stress and strain• Stress-Strain Constitutive Relations• Long Bars/Indeterminate Structures• Design Concepts & Axially Loaded Bars• Axial Loading/indeterminate Structures• Torsion of Circular Rods• Torsion & Indeterminate Members• Beam Shear/Moment Diagrams• Beam Stresses-Bending• Beam Stresses-Unsymmetrical Loading• Beam Stresses-Shear

- Combined loadings
- Beam Deflections
- Strain Energy & Failure Theories
- Stability, Column Buckling

AME 431, Numerical Methods in Fluid Mechanics and Heat Transfer

Credits and contact hours:	3 credits; 3 contact hours
Instructor/coordinator's name:	Hermann Fasel
Textbook(s) and/or other supplemental materials:	J. H. Ferziger, <i>Numerical Methods for Engineering Applications</i> , 2 nd Ed., Wiley, 1998
Catalog description:	Development of numerical techniques for the solution of ordinary and partial differential equations that arise in heat transfer and fluid mechanics; classification of equations, methods of solutions, examples.
Prerequisites/Co-Requisites:	AME 302 and AME 331 and Adv Stdg: Engineering
Required, Elective, Selected Elective:	Elective
Specific outcomes of instruction:	<ul style="list-style-type: none">• Understanding fundamental concepts such as stability, accuracy, consistency, systematic errors (phase/amplitude errors), artificial diffusion, etc.• Completion of several extensive computer projects as assigned that require development of algorithms, writing and testing of computer programs.• 3. Ability to present and analyze numerical results.
Outcomes listed in Criterion 3:	<ul style="list-style-type: none">a. Apply mathematics, science, and engineering principlese. Identify, formulate, and solve engineering problems
Topics covered:	<ul style="list-style-type: none">• Ordinary differential equations—initial value problems (numerical discretization, non-uniform grids, Euler explicit method, stability, backward implicit Euler, error estimation and accuracy improvement, predictor-corrector methods, Runge-Kutta methods, multistep methods, choice of method and automatic error control, system of equations—stiffness, inherent instability) and boundary value problems (shooting method, direct methods, higher-order direct methods, compact methods, non-uniform grids);• Partial differential equations—parabolic equations (classification of partial differential equations, explicit

- method, Crank-Nicholson method, Dufort-Frankel method, Keller box method, second-order backward method, high-order methods, two and three spatial dimensions, other coordinate systems and transformations, nonlinear problems)
- Elliptic equations (discretization, iterative methods and their properties, Jacobi method, Gauss-Seidel method, line relaxation, successive overrelaxation, alternating direction implicit methods).

AME 432, Heat Transfer

Credits and contact hours:	3 credits; 3 contact hours
Instructor/coordinator's name:	Cholik Chan
Textbook(s) and/or other supplemental materials:	<i>Introduction to Heat Transfer, 6th Ed.</i> John Wiley, by F. P. Incropera, D. P. DeWitt, T. L. Bergman, and A. S. Lavine. Classnotes uploaded onto D2L.
Catalog description:	Study of conduction, convection and radiation heat transfer, with applications to engineering problems.
Prerequisites/Co-Requisites:	AME 230 – Thermodynamics AME 331 – Introduction to Fluid Mechanics AME 302 – Numerical Method (very helpful) Matlab or other programming languages
Required, Elective, Selected Elective:	Required-MEE, Selected Elective-AEE
Specific outcomes of instruction:	<ul style="list-style-type: none">• Understand Fourier's law, energy balance, heat conduction equation and its solutions, Planck's blackbody radiation, surface properties, view factors, and radiation exchange, heat transfer coefficients and various correlations;• 2. Able to apply the basic principles to model and analyze the thermal systems for engineering design.
Outcomes listed in Criterion 3:	a. apply mathematics, science, and engineering principles e. identify, formulate, and solve engineering problems
Topics covered:	<ul style="list-style-type: none">• Conduction includes 1-D steady state, lumped capacitance, 1-D transient, 2-D steady state, and numerical methods;• Radiation includes blackbody radiation, grey body radiation, view factor, radiation exchange between black surface and radiation exchange between grey surface;• Convection includes internal pipe flow, external boundary layer, laminar and turbulent heat transfer coefficients, and free convection.

ABE 201, Introduction to Biosystems Engineering

Credits and Contact Hours:	2 Units, 2 hours per week
Instructor's or course coordinator's name:	Peter Livingston, PhD, PE
Textbook, title, author and year:	N/A
Other Supplemental materials:	N/A
2015-2016 Catalog Description:	<p>This course provides an introduction biosystems engineering with emphasis on biological laboratory skills and basic fabrication, foundations of modeling biological processes, team work and professional skills, and the societal and global context in which the profession is practiced. Discussion topics include internship opportunities, professionalism, engineering ethics, and the impact of engineering on society. Laboratory exercises include renewable energy production, device design and fabrication, and biological sensing. Presentations, discussions, and writing exercises will provide communication experiences.</p>
Prerequisites:	Math 124
Co-requisites:	N/A
Required, Elective, or Selected Elective:	Required course
Instruction Outcomes:	<p>Upon completion of this class, students are expected to:</p> <ol style="list-style-type: none">1) Understand the role of experiential learning by doing in engineering education and have knowledge of internship possibilities available to Biosystems Engineering students;2) Have a basic understanding of real world issues that influence the problems engineers face; and3) Have experience in giving formal and informal presentations. Students will gain experience in oral and written communications through leadership of group discussions and presentations of seminars and discussion reports.4) Learn about the basics of microcomputers, including execution of lab exorcises that include programing.

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

- (a) An ability to apply knowledge of mathematics, science, and engineering (4)
- (b) An ability to design and conduct experiments (1 & 4)
- (d) An ability to function on multidisciplinary teams (2 & 3)
- (f) Understanding of professional and ethical responsibility (2)
- (g) An ability to communicate effectively (2 & 3)
- (h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context (2)
- (i) A recognition of the need for, and an ability to engage in life-long learning (2 & 3)
- (j) A knowledge of contemporary issues (2)
- (k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. (4)

Topics covered:

- Unit Analysis
- Physics as it relates to Biosystems engineer's
- Alternative energy (solar, biodiesel, ethanol from sweet sorghum)
- Intro to microcomputers
- Career skills
- Contemporary Issues and Global Content
- Engineering in a flat world
- Ethics debate with ABE seniors
- Introduction to microfluidics lab

ABE 205, Computational Methods for Engineers

Credits and Contact Hours:	3 credits, 6 hrs/week laboratory, 1 hr/week online lecture, self-paced and 6 hrs contact time with instructor during labs.
Instructor's or course coordinator's name:	Peter Waller
Textbook, title, author and year:	A Concise Introduction to Matlab. By William Palm III (ISBN: 978-0-07338583-9)
Other Supplemental materials:	Course notes for Excel/VBA unit.
2015-2016 Catalog Description:	Introduction to Excel, Visual Basic in Excel, Access, and Matlab with an emphasis on flow charts, graphing, regression, if-then, do loops, statistics, functions and subroutines, and copying to and reporting results in Word; applications include biological energy, growth, and CO2 models.
Prerequisites:	College of Engineering Majors
Co-requisites:	
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	Upon completing the course, students should be able to:
Note: Excel/VBA skills have a parallel track in Google Sheets/JavaScript (students choose which track). Five out of 10 Excel/VBA chapters have been rewritten for Google Sheets/JavaScript. The rest will be finished before next semester.	<ol style="list-style-type: none">1. Use different iteration methods and Excel Solver to find roots, maxima, and minima.2. Carry out statistical analyses in Excel;3. Perform least squares regression with equations, with Excel Trendline in figures, with Solver (minimization of squared errors), and with the statistical algorithms in Excel Data Analysis Add on.4. Process the data in VBA or the worksheet.5. Perform simple matrix algebra calculations.6. Generate forms in Excel/VBA with buttons, comboboxes, textboxes, checkboxes, option buttons, and scrollbars.7. Develop programs in VBA modules.8. Set up finite difference models (Euler method) in time and space (two independent variables) in Excel worksheets and in VBA.9. Write scripts and functions and use the command window in Matlab.

10. Write arrays, manipulate arrays, use matrix algebra, and perform element by element operations in **Matlab**.
11. Use elementary functions and make user-defined functions in **Matlab**.
12. Use relational operators, logical operators, conditional statements and loops in **Matlab**.
13. Use advanced plotting and modeling methods in **Matlab**.
14. Carry out statistical analyses in **Matlab**.
15. Use numerical integration methods for calculus and differential equations in **Matlab**.

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

Outcome (a) an ability to apply knowledge of mathematics, science, and engineering: **1, 2, 3, 4, 7, 17, 20, 22**

Outcome (b) an ability to design and conduct experiments as well as to analyze and interpret data: **1, 2, 3, 6, 7, 10, 5, 13, 18-22**

Outcome (k) an ability to use techniques, skills, and modern engineering tools necessary for engineering practice: **2, 3, 4**

Topics covered:

Topics covered:

Iteration methods: *Solver, Newton-Raphson, and simple iteration.* **Statistics:** *random number generation, descriptive statistics, Monte Carlo analysis, least squares regression, multilinear regression, and Fourier series modeling.* **Data processing:** *data from internet, data from data loggers, string manipulation.* **Automated graphing:** *Use VLookup and VBA to show the selected variable and position in an Excel graph.* **Forms (dialog boxes):** *buttons, comboboxes, textboxes, checkboxes, option buttons, and scrollbars.* **VBA basics:** *subroutines, functions, "Record Macro," for-next loop, do loop-until, conditional statements.* **Arrays:** *array dimensioning, passing 2-D arrays to and from worksheet, manipulation and calculation in loops.* **Data types:** *strings, integers, Boolean, single, and double precision in VBA.* **Finite difference models.** *partial differential equation for mass and energy (time and space) in worksheets and VBA.* **Matlab basics:** *files, command window, scripts and functions.* **Matlab matrices:** *generate arrays, manipulate arrays, and use matrix algebra.* **Matlab functions.** *elementary functions and user-defined functions.* **Matlab decision-making:** *relational operators, logical operators, conditional statements and loops.* **Matlab plotting:** *advanced plotting and modeling methods* **Matlab statistics:** *statistics, probability, and interpolation.* **Matlab numerical methods:** *numerical integration and differentiation, ode45 (Runge Kutta method).* **Matlab symbolic processing:** *eval and diff.*

ABE 221, Introduction to Computer Aided Design

Credits and Contact Hours:	3 credits, Three 2-hours help session per week hybrid course Online office hour as needed using GoToMeeting
Instructor's or course coordinator's name:	Muluneh Yitayew
Textbook, title, author and year:	Engineering Design and Graphics with SOLIDWORKS 2014. James D. Bethune. Printice Hall, Pearson. 2015. Engineering Design with SOLIDWORKS 2014 and Video Instruction. David C. Planchard. SDC Publications.
Other Supplemental materials:	Instructional Videos
2015-2016 Catalog Description:	Introduction to computer aided design concepts and techniques. Two and three-dimensional drawing presentation, methods of graphical communications, data analysis, design synthesis and production methods.
Prerequisites:	None
Co-requisites:	None
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	<ol style="list-style-type: none">1. Understanding of parametric modeling2. Understanding of the use of sketch and features tools in SOLIDWORKS3. Ability to create and interpret orthographic views4. Ability to create assembly drawings and document assemblies.5. Ability to create and design with threads and fasteners.6. Understanding of dimensioning shapes and features.7. Understanding of both linear and geometric tolerances.8. Ability to create gears using SOLIDWORKS toolbox9. Understanding of printing the model created engineering drawing and design in to a prototype using 3D printing.

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

Learning outcome (c) Can design a system, component or process to meet desired needs within realistic constraints: 1,4,5,7,8

Learning outcome (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice: 1-9

Topics covered:

This course provides sophomores and juniors in ABE and other engineering disciplines with the ability to use parametric models in design and prototyping of systems..

1. Sketch Entities and Tools

Creating 2D sketches, Using the sketch tools, Creating complex shapes by combining individual sketch tools

2. Features

Feature tools, Drawing 3D objects, Using features to create objects.

3. Orthographic Views

Use two-dimensional views to define a three-dimensional model, ANSI standards and conventions, Drawing section and auxiliary views.

4. Assemblies

Creating assembly drawings, Create an exploded assembly drawings, Creating a part list, Animation of assembly, and Edit title block.

5. Threads and Fasteners

Thread terminology and conventions, Draw threads, Size both internal and external threads, Use standard-size threads, Use and size washers, nuts, and screws.

6. Dimensioning

Dimensioning objects, ANSI standards and conventions, Dimensioning different shapes and features, and Fundamentals of 3D dimensioning

7. Tolerancing

Tolerance conventions, Defining tolerances, Apply tolerances, Geometric tolerances, and Positional tolerances

8. Gears

Concept of power transmission, Fundamentals of gears, Drawing and animating gears.

9. 3D Printing

Developing a model for printing, Converting file format, Use the driver software, Filament types and use, Issues with 3D printing.

ABE 284, Biosystems Thermal Engineering

Credits and Contact Hours:	3 credits, 2.5 hrs/week lecture, 2hrs/week official office hours, open door policy for student office visit with appointments
Instructor's or course coordinator's name:	Murat Kacira
Textbook, title, author and year:	Moran, M. J., H. N. Shapiro, B. R. Munson and D. P. DeWitt. 2003. Introduction to Thermal Systems Engineering: Thermodynamics, Fluid Mechanics, and Heat Transfer. John Wiley & Sons Inc. ISBN: 978-0-471-20490-0.
Other Supplemental materials:	Interactive Thermodynamics and Heat Transfer Software
2015-2016 Catalog Description:	This course provides an integrated introduction to basic thermal engineering topics. A structured problem-solving approach emphasizes the interrelated roles of Thermodynamics, Fluid Mechanics, and Heat and Mass Transfer relevant to real-world engineering analyses.
Prerequisites:	MATH 129, PHYS141
Co-requisites:	
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	<p>Upon completing the course students should be able to:</p> <ol style="list-style-type: none">1. Understand the concepts of conservation of mass, conservation of energy, and the second law of thermodynamics.2. Understand the methods for determining thermodynamic properties of simple compressible substances.3. Identify, formulate and solve engineering problems in classical thermodynamics involving closed and open systems for both steady state and transient processes.4. Have ability to use thermodynamic property data, units, unit conversions and significant digits.5. Have ability to set up mass balance and energy balance equations for closed and control volume systems.6. Identify work interactions and heat transfer.7. Demonstrate the ability to determine accurately the thermodynamic properties of simple compressible substances.8. Apply the principles of conservation of mass and conservation of energy to the solution of problems.

9. Understanding of the concepts of Second Law analysis and an ability to apply them to closed and open systems for both steady and transient processes.
10. Analyze the performance of vapor and gas power cycles; identify methods for improving thermodynamic performance.
11. Understand engineering applications of Psychrometrics.
12. Understand fluid mechanics, dealing with the behavior of fluids at rest or in motion for analysis and design of systems engineering systems.
13. Analyze the internal flow of a viscous fluid through pipe systems and the external flow around familiar geometric shapes.
14. Develop appreciation for the fundamental concepts/principles underlining heat transfer processes, and apply heat transfer processes (conduction, convection and radiation) in conjunction with the first law of thermodynamics to solve problems in thermal systems engineering.

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

Outcome (a) an ability to apply knowledge of mathematics, science, and engineering: **1-14**

Outcome (e) an ability to identify, formulate, and solve engineering problems: **3-14**

Topics covered:

Introduction to Thermodynamics Units: *Force, energy, work, power.* **Basic Laws:** *First and second laws.* **Energy and the First Law:** *Energy balance, cycles, and efficiencies, properties and states.* **States of Simple Substances and Properties:** *Phase transitions, thermodynamic property data, perfect gas.* **Quantitative Energy Analysis:** *Set up mass/energy balance equations for control mass/control volume. Engines, turbines, heat pumps, boilers, refrigeration units, separators, nozzles.* **Entropy and the Second Law:** *Reversible and irreversible processes, entropy transfer and change, entropy as a function of state entropy, temperature, pressure.* **The Thermodynamics of State:** *Vapor power and refrigeration systems.* **Gas Power Cycles:** *Air-standard Otto and diesel cycles, gas turbine power plants.* **Power Cycles and Applications:** *Diesel engine and fuel consumption.* **Psychrometrics:** *Fundamentals and applications.* **Introduction to Fluid Mechanics:** *Fluid statics/fluid dynamics/internal and external flow/laminar and turbulent flow/pipe flow and head losses/boundary layer theory.* **Introduction to Heat & Mass Transfer:** *Conduction, radiation and convection/applications with the first law of thermodynamics*

ABE 423, Biosystems Analysis and Design

Credits and Contact Hours:	3 credits, 3 hrs/week lecture, open door policy and possible contact with instructor during 6 hr/week ABE205 labs.
Instructor's or course coordinator's name:	Peter Waller
Textbook, title, author and year:	<i>Numerical Methods in Biomedical Engineering</i> , SM Dunn, A. Constantinides, and P.V. Moghe, Academic Press, 2006. ISBN 10: 0121860310 Most materials converted from Biomedical Engineering topics in Dunn book to Biosystems Engineering topics and presented in Powerpoint slides and online lectures.
Other Supplemental materials:	Online lectures and power points
2015-2016 Catalog Description:	Application of systems analysis to biologically-related problems; computer modeling and use of simulations, optimization methods, decision support systems.
Prerequisites:	Adv. Stdg: Engineering
Co-requisites:	
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	Upon completing the course, students should be able to: 1. Use VBA, Excel, or Matlab (also Simulink) to carry out Euler Method and Runge-Kutta integration of ordinary biological differential equations with one or more species over time. 2. Understand difference between iterative matrix solvers (Jacobi and Gauss-Jordan) and direct matrix solvers (Gauss) and the classes of matrices that are possible to solve in iterative matrix solvers. 3. Understand and simulate epidemiology models such as SIS and SIR in Excel, VBA, Matlab, and Simulink. 4. Understand the basis for the derivation of finite difference equations for different orders of Taylor series for first and second order differential equations Calculate errors in Euler method solutions based on the first term left off in the Taylor series compared to the theoretical error.

5. Understand derivation of finite difference solutions of partial differential equations.
6. Simulation of the economics of a small urban farm for sales to a farmers market.
7. Simulate nutrients, fish growth, lettuce growth, economics, and scheduling of an aquaponics system.
8. Develop programs in **VBA** modules.
9. Use Simulink to solve a wide range of differential equations.

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

Outcome (a) an ability to apply knowledge of mathematics, science, and engineering: **1, 2, 3, 4, 7, 17, 20, 22**

Outcome (b) an ability to design and conduct experiments as well as to analyze and interpret data: **1, 2, 3, 6, 7, 10, 5, 13, 18, 19, 20, 21, 22**

Outcome (k) an ability to use techniques, skills, and modern engineering tools necessary for engineering practice: **2, 3, 4**

Topics covered:

Topics covered:

Error analysis: *calculate errors with Taylor series analysis, sources of error in simulations, reformulation of equations to eliminate error.* **First order growth equation and logistic model:** *derive exact and Euler method solutions, compare exact to Euler method solutions and compare with Taylor series estimate of error, derive logistic model with examples.* **Epidemiology models:** *derive SIS and SIR models; derive predator-prey models; simulate models in Excel/VBA and Matlab.* **Linear programming:** *derive matrix solution methods and show how to use Jacobi, Gauss-Jordan, and Gauss matrix solvers in Matlab;.* **Higher order solution methods for ordinary differential equations.** *Basis of Runge-Kutta methods; implementation of Runge Kutta methods in spreadsheet and VBA; implementation of Runge Kutta method in ode45; solutions for multiple equations in Excel, VBA, and Matlab ode45.* **Partial differential equations:** *derive finite difference solutions of partial differential equations for heat transfer, chemical advection and diffusion, and membrane deformation.* **Simulink:** *show how to set up Simulink models of sets of ordinary differential equations for biological systems; students simulate many examples from the first parts of the course.* **Analyze farm production systems:** *this is still under development. This year we gave them a program that enables them to analyze all parts of a farm operation. We are adding aquaponics analysis with an emphasis on growth rates, scheduling and nutrient balance.* **Projects.** *Group projects of analysis of biological systems, coding, report writing, and presentation (major emphasis in class).*

ABE 447, Sensors and Controls

Credits and Contact Hours:	W 11:00-1:30 (section 3); W 3:00-5:30 (section 4) Lab reports with homework questions (every week)
Instructor's or course coordinator's name:	Jeong Yeol-Yoon
Textbook, title, author and year:	Introduction to Biosensors: From Electric Circuits to Immunosensors By Jeong-Yeol Yoon (Springer). ISBN 978-1-4419-6021-4 ISBN 78-1-4419-6022-1 (eBook)
Other Supplemental materials:	
2015-2016 Catalog Description:	Principles of electric circuits. Selection, interfacing and calibration of digital and analog sensors to measure physical variables. Optical electrochemical and piezoelectric biosensors. Basic bioprocess control.
Prerequisites:	CHEM 151/152 (or equivalent).
Co-requisites:	
Required, Elective, or Selected Elective:	Required
Instruction Outcomes:	A typical sensor generates an electrical signal in response to a variable. Because of this, one needs to have some fundamental knowledge on electronics and circuitry in developing successful sensors. Modern sensors are now implementing DNA probes or antibodies to recognize other DNAs or antigens, which forms an exciting new area of biosensors. Topics related to advanced biological sciences also include optical fibers, fluorescence, pulse oximeter, immunosensors, lateral flow assays, glucose sensors, lab on a chip, and nano biosensors.
Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:	Outcome (b) an ability to design and conduct experiments as well as to analyze and interpret data Outcome (k) an ability to use techniques, skills, and modern engineering tools necessary for engineering practice

Topics covered:

Breadboard use, Resistor, Thevenin's theorem, Diode/transistor, Temperature sensor, Wheatstone bridge, Op-amp, Photodiode, Light sensor, Spectrometry, Fluorescence, pH/ion electrode, Electrochem. Sensor, Glucose sensor, Immunosensor, ELISA kit, Paper microfluidics, Arduino, Nano biosensors

ABE 496A, Seminar in Engineering Careers and Professionalism

Credits and Contact Hours:	1 credit, 1 hour per week
Instructor's or course coordinator's name:	Kitt Farrell-Poe
Textbook, title, author and year:	No text required for this class.
Other supplemental materials:	<ol style="list-style-type: none">1. Resource: Engineering and Technology for a Sustainable World. Magazine of the American Society of Agricultural Engineers.2. Development and Cooperation, German International Development & Cooperation Agency Invention and Technology.
2015-2016 Catalog Description:	<p>The seminar will focus on employment in agricultural and biosystems engineering and engineering professionalism. Topics will include how to find a job (finding opportunities, writing resumes, interviewing), continuing education (professional societies, schools, self-learning) and engineering ethics. Presentations and discussion will provide communication opportunities. Students will be required to registrar for the Fundamentals of Engineering Exam (FE).</p>
Prerequisites:	None.
Co-requisites:	None.
Required, Elective, or Selected Elective:	Required.
Instruction Outcomes:	<p>Upon completion of this class, students will be able to:</p> <ul style="list-style-type: none">• Compare and contrast the ethical consequences of engineering decisions and design options,• Explain the role of internships in engineering education,• Articulate the multifaceted aspects of current global trends which will influence the problems engineers will face in the near future, and• Demonstrate effective communication skills, both written and oral.

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

Outcome (f) has an understanding of professional and ethical responsibility: **1**

Outcome (g) can communicate effectively: **1, 2, 3, 4**

Outcome (h) as the broad education necessary to understand the impact of engineering solutions in global, economic, environmental, and societal context: **2, 3**

Outcome (j) has knowledge of relevant contemporary issues: **2, 3**

Topics covered:

- 1.** Introduction, Plagiarism, Grammar
- 2.** Interviewing Skills
- 3.** Building Your Resume
- 4.** Engineering Ethics, Engineering Code of Ethics
- 5.** Engineering Ethical Team Topic
- 6.** Internship Poster Presentations
- 7.** Company/Agency Presentations
- 8.** Why Take the FE Exam?

ABE 498a, Capstone Design

Credits and Contact Hours:	3 Units, 3 hours per week
Instructor's or course coordinator's name:	Peter Livingston, PhD, PE
Textbook, title, author and year:	N/A
Other Supplemental materials:	N/A
2015-2016 Catalog Description:	A culminating experience for majors involving a substantive project that demonstrates a synthesis of learning accumulated in the major, including broadly comprehensive knowledge of the discipline and its methodologies.
Prerequisites:	Advance Standing in College of Engineering
Co-requisites:	N/A
Required, Elective, or Selected Elective:	Required course
Instruction Outcomes:	Upon completion of this class, students are expected to: <ol style="list-style-type: none">1) Have a real world design experience;2) Formulate project;3) Learn to work with industry representative;4) Complete preliminary and draft design on chosen alternative of project;5) Complete an alternatives analysis and6) Have experience in giving formal and informal presentations. Students will gain experience in oral and written communications through leadership of group discussions and presentations of their designs to ABE faculty.
Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:	(c)An ability to apply knowledge of mathematics, science, and engineering. (1, 2, 4, 5) (d) An ability to design and conduct experiments (2, 4) (d) An ability to function on multidisciplinary teams (1, 3) (f) An understanding of professional and ethical responsibility (1, 3, 5) (g) An ability to communicate effectively (2, 6)

(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice(1, 2, 4, 5)

Topics covered:

- Engineering design process
- Technical report preparation
- Road to becoming a licensed professional
- LEED
- Engineering economics

ABE 498b, Capstone Design and Construction

Credits and Contact Hours:	3 Units, 3 hours per week
Instructor's or course coordinator's name:	Peter Livingston, PhD, PE
Textbook, title, author and year:	N/A
Other Supplemental materials:	N/A
2015-2016 Catalog Description:	A culminating experience for majors involving a substantive project that demonstrates a synthesis of learning accumulated in the major, including broadly comprehensive knowledge of the discipline and its methodologies.
Prerequisites:	Advance Standing in College of Engineering
Co-requisites:	N/A
Required, Elective, or Selected Elective:	Required course
Instruction Outcomes:	Upon completion of this class, students are expected to: 1) Have a real world design experience; 2) Build prototype project; 3) Learn to work with industry representative; 4) Complete final design on chosen alternative of project; 5) Complete a life cycle economic analysis of project; and 6) Have experience in giving formal and informal presentations. Students will gain experience in oral and written communications through leadership of group discussions and presentations of their designs to ABE faculty and during the College of Engineering Design Day competition, where over 20 judges will review their projects and 150 middle school students will query the students.
Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:	(e) An ability to apply knowledge of mathematics, science, and engineering. (1, 2, 4, 5) (f) An ability to design and conduct experiments (2, 4) (d) An ability to function on multidisciplinary teams (1, 3) (f) An understanding of professional and ethical responsibility

(1, 3, 5)

(g) An ability to communicate effectively (2, 6)

(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.(1, 2, 4, 5)

Topics covered:

- Engineering design process
- Fabrication process
- Technical report preparation
- Microsoft Project
- Engineering economics

ABE 426, Watershed Engineering

Credits and Contact Hours:	3 credits, 3 hours per week
Instructor's or course coordinator's name:	Donald C. Slack
Textbook, title, author and year:	Design Hydrology and Sedimentology for Small Catchments. C.T. Haan, B.J. Barfield and J.C. Hayes. Academic Press. 1994. 588p.
Other Supplemental materials:	<ol style="list-style-type: none">1. Soil and Water Conservation Engineering Fangmeier et. al. – Thomson Delmar Learning, 5th Edition2. RUSLE Users Manual and Software -- USDA3. Engineering Field Manual USDA-SCS (Selected sections will be made available as handouts)4. Design of Small Dams U.S. Bureau of Reclamation, 2nd Edition 1977.5. Technical Papers and Reports
2015-2016 Catalog Description:	Design of waterways, erosion control structures and small dams. Methods for frequency analysis and synthetic time distribution of rainfall. Methods for estimating infiltration and runoff from small watersheds, flow routing and storm water management. Estimating erosion using the Revised Universal Soil Loss Equation.
Prerequisites:	CE 218 or AME 331
Co-requisites:	None
Required, Elective, or Selected Elective:	ABE Design Elective or Technical Elective
Instruction Outcomes:	<ol style="list-style-type: none">1. Understanding of watershed hydrology focusing on design application.2. Understanding of the elements of probability and statistics relevant to watershed engineering to perform return period and flow frequency analysis.3. Ability to quantify runoff amounts and rates from ungaged watersheds4. Working knowledge of basic hydrologic data analysis.5. Ability to use spreadsheet software to perform hydrologic and hydraulic engineering calculations such as flow routing.6. Understanding of the derivation of basic hydrologic and hydraulic equations with focus in design applications.

7. Ability to solve watershed engineering problems utilizing multiple unknowns.
8. Ability to design hydraulic structures for water- control (flood control) systems.
9. Ability to design hydraulic structures for water- use (ponds, reservoirs, and small dams) systems.
10. Ability to design hydraulic structures for environmental restoration (erosion control) systems.
11. Understanding of upland erosion models and their application to conservation planning

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

Learning outcome (a) an ability to apply knowledge of mathematics, science, and engineering: **1,2,6,7**

Learning outcome (b) an ability to design and conduct experiments, as well as to analyze and interpret data: **3,4,5,**

Learning outcome (c) Can design a system, component or process to meet desired needs within realistic constraints: **8,9,10,11**

Learning outcome (e) an ability to identify, formulate, and solve engineering problems: **3,5,6,7**

Learning outcome (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice: **5,6, and 7**

Topics covered:

This course provides upper-division students in ABE/other engineering disciplines the ability to analyze hydrologic data mainly precipitation and runoff from gaged and ungaged watersheds and use the result for design of water-control, water-use, and environmental restoration systems. Specific topics include (1) **Hydrology:** Precipitation, characteristics, measurements, frequency, synthetic time distribution, (SCS method), infiltration, evaporation, evapotranspiration, estimating rainfall “excess” (SCS Curve Number Method), runoff; runoff volumes and yield, hydrographs (Unit Hydrographs), dimensionless hydrographs, development of runoff hydrographs from unit hydrographs, peak runoff rates. (2) **Hydraulic Design:** Open channels, basic energy relationships, earthen channel design, vegetated waterways, waterway design (riprap linings), hydraulics of structures & channel structures, erosion control structure designs, drop spillways, gabions & rockfill structures, culverts & pipe spillways, channel routing, flood routing (reservoir), storm detention ponds. (3) **Erosion Control:** Storm water management, estimating rainfall erosion; Revised Universal Soil Loss Equation, software, applications; erosion control practices. (4) **Design of Small Dams:** Earth embankments, small dams.

ABE 452, Globalization, Sustainability and Innovation

Credits and Contact Hours:	3 credits, 75min/lecture, 2 lectures/week, open door policy for student office visits with appointments
Instructor's or course coordinator's name:	Joel L. Cuello
Textbook, title, author and year:	No required textbook. References provided.
Other Supplemental materials:	<ul style="list-style-type: none">• Eriksen, T.H. 2014. Globalization: The Key Concepts. 2nd ed. London: Bloomsbury Academics.• Friedman, T.L. 2006. The World is Flat. 1st updated and expanded ed. New York : Farrar, Straus and Giroux.• Palmisano, J.P. 2006. The Globally Integrated Enterprise. Foreign Affairs. May/June 2006.• Collier, P. 2007. The Bottom Billion: Why the Poorest Countries are Failing and What Can Be Done About It. Oxford University Press.
2015-2016 Catalog Description:	Globalization, sustainability and innovation constitute the three principal forces that drive the world of the 21st century -- economically, politically, socially and culturally. Aimed at engineering and science students, the objective of the course is to foster among them global intelligence (or global smarts), defined as an inclusive and cross-disciplinary working knowledge of how the globe operates today - including (1) how global infrastructures in communication, transportation and information technology have transformed how nations and corporations conduct business, (2) how nurturing sustainability ensures competitive advantage while ignoring it imperils nations as well as the planet, and (3) how technological innovation is critical both in maintaining competitive advantage and in providing the essential sustainable solutions to many of our current global challenges. In a flat world, fostering global intelligence has become a vital component of a well-rounded engineering and science education.
Prerequisites:	Adv. Standing; Engineering major
Co-requisites:	
Required, Elective, or Selected Elective:	Elective
Instruction Outcomes:	Upon completing the course students should be able to acquire global intelligence (or global smarts), defined as an inclusive and cross-disciplinary working knowledge of how the globe operates today, including:

- (1) How global infrastructures in communication, transportation and information technology have transformed how nations and corporations conduct business,
- (2) How nurturing sustainability ensures competitive advantage, while ignoring it imperils nations as well as the planet; and,
- (3) How technological innovation is critical both in maintaining competitive advantage and in providing the essential sustainable solutions to many of our current global challenges.

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

- Outcome (d)** ability to function on multidisciplinary teams **(1-3)**
- Outcome (f)** understanding of professional and ethical responsibility **(1-3)**
- Outcome (g)** ability to communicate effectively **(1-3)**
- Outcome (h)** broad education necessary to understand the impact of engineering solutions in global, economic, environmental and societal context **(1-3)**
- Outcome (i)** Recognize the need for and the ability to engage in lifelong learning **(1-3)**
- Outcome (j)** knowledge of relevant contemporary issues **(1-3)**

Topics covered:

A. Making Sense of Globalization: 1) Global Snap Shots: population; income; living on up to \$10, \$20, \$50, \$100, \$200, \$200 a day; 2) The Globally Integrated Enterprise: China as factory of the world; India as service center of the world; the U.S. as innovation center of the world, 3) Media Consolidation and Web 2.0; 4) The Major Actors in Globalization: Government, Corporations, and Civil Society; 5) Is Globalization equal to Integration or Segmentation? The End of History, The Clash of Civilizations, and The Long Tail; Offshoring: pros and cons for the U.S.; engineers' ethics and rights; 6) Going Global; 7) Globalization Lessons. **B. Creating a Start Button for Sustainability:** 8) Ancient Environmental Collapse; Norse Greenland; 9) Water: Global Shortage and Pollution; 10) Soil: Desertification; 11) Air: Global Pollution; 12) The Amazon Rainforest: Deforestation; 13) Global Warming: Kyoto Protocol & Carbon Trading; 14) Global Oil Reserves & Biofuels; 15) Global Food Production & Fair Trade; 16) Current innovative solutions; 17) Solving Global Poverty: The End of Poverty & The Bottom Billion; 18) Sustainability Lessons. **C. Putting Innovation to Work:** 19) Disruptive Innovation vs. Sustaining Innovation; 20) Measuring Innovation; 21) Linking Competitive Advantage to Corporate Social Responsibility; 22) Disruptive Innovation for Social Change; 23) Innovation Ecosystem.

ABE 455, Soil and Water Resources Engineering

Credits and Contact Hours:	3 credits, 3 hours per week
Instructor's or course coordinator's name:	Donald C. Slack and Peter A. Livingston
Textbook, title, author and year:	No text required for this class. There will be class handouts for most of the topics as necessary to cover the topics as well as the supplemental references.
Other Supplemental materials:	<ol style="list-style-type: none">1. Jensen, M.E. (Ed). 1980. Design and Operation of Farm Irrigation Systems. ASAE Monograph #3. American Society of Agricultural Engineers. St. Joseph, MI. 829p2. FAO Irrigation and Drainage Paper No. 56. Crop Water Requirements. UN-FAO, Rome, Italy. 1995. http://www.fao.org/docrep/X0490E/X0490E00.htm3. FAO Irrigation and Drainage Paper No. 66. Crop Yield Response to Water. UN-FAO, Rome, Italy, 2012, http://www.fao.org/docrep/016/i2800e/i2800e.pdf4. Arizona Irrigation Scheduling System (AZSCHED). http://ag.arizona.edu/crop/irrigation/azsched/azsched.html5. CROPWAT 8.0 Software for Crop Water and Irrigation Requirements. UN-FAO, Rome, Italy, 2013. http://www.fao.org/nr/water/infores_databases_cropwat.html6. Technical Papers and Reports
2015-2016 Catalog Description:	Introduction to soil and water relationships, irrigation systems, irrigation water supply, irrigation management, and basic designs.
Prerequisites:	CE 218 or AME 331
Co-requisites:	None
Required, Elective, or Selected Elective:	ABE Design Elective or Technical Elective
Instruction Outcomes:	<ol style="list-style-type: none">1. Understanding the basic concepts of green plant anatomy and physiology and their relationship to plant water requirements and use.2. Understanding the flow of energy in the green plant environment and its relationship to plant water use.

3. Ability to quantify evapotranspiration for agricultural crops and determine plant water requirements.
4. Ability to use spreadsheet software to perform analysis of crop and irrigation systems such as crop ET and irrigation scheduling.
5. Understanding the derivation of basic equations governing water flow in the plant-atmosphere-continuum with focus in design applications.
6. Understanding the role of soil in plant and irrigation systems.
7. Understanding water supply and water policy in Arizona.
8. Understanding the different types of irrigation systems and the ability to do basic analysis and design of such systems.
9. Understanding the importance of water quality and salinity management and control for irrigation systems.

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

Outcome (a) an ability to apply knowledge of mathematics, science, and engineering: **1,2,3,4,5**

Outcome (e) an ability to identify, formulate, and solve engineering problems: **3,4,5,8,9**

Topics covered:

- (1) **Soil-Plant-Water Relations.**
- (2) **Elements of Green Plant Physiology.**
- (3) **Energy in the Green Plant Environment.**
- (4) **Water Supply.**
- (5) **Soil and Water Quality Considerations in Agriculture.**
- (6) **Irrigation with Reclaimed Wastewater.**
- (7) **Water Distribution.**
- (8) **Crop Water Requirements.**
- (9) **Overview of Irrigation Systems – Surface.**
- (10) **Overview of Irrigation Systems – Sprinkler.**
- (11) **Overview of Irrigation Systems – Drip.**
- (12) **Soil Environment of the Green Plant.**
- (13) **Irrigation Scheduling.**
- (14) **System Capacity Requirements.**

ABE 456, Irrigation System Design

Credits and Contact Hours:	3 Units, 3 hours per week
Instructor's or course coordinator's name:	Peter Livingston, PhD, PE
Textbook, title, author and year:	Irrigation and Drainage Engineering, Waller, Peter, and Yitayew, Muluneh, 2016
Other Supplemental materials:	
2015-2016 Catalog Description:	Design and operation of surface, sprinkler, and trickle irrigation systems based on economic and environmental criteria.
Prerequisites:	Math 124, CE 318
Co-requisites:	N/A
Required, Elective, or Selected Elective:	Design Elective or Technical Elective
Instruction Outcomes:	<p>This course is designed to give upper division students in ABE and other engineering disciplines the ability to analyze and design water and chemical application systems in agriculture and environmental systems. Students should develop the following specific capabilities in ABE/CE 556:</p> <ol style="list-style-type: none">1. Design irrigation systems based on economics and environmental protection.2. Understand fundamentals of surface, sprinkler, drip, and bubbler irrigation design.3. Understand fundamentals of chemical injection systems and water quality parameters.
Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:	<p>(g) An ability to apply knowledge of mathematics, science, and Engineering. (2 & 3)</p> <p>(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. (1, 2, 3)</p>
Topics covered:	<ul style="list-style-type: none">• Center Pivot irrigation system design• Turf irrigation design• Field drip irrigation system design• Chemigation• Surface Irrigation system design• Controlled environment irrigation system design

ABE 458, Wetlands, Permitting and Wastewater Treatment

Credits and Contact Hours:	3 Units, 3 hours per week
Instructor's or course coordinator's name:	Peter Livingston, PhD, PE
Textbook, title, author and year:	N/A
Other Supplemental materials:	Basic Environmental Technology, Water Supply, Waste Management, and Pollution Control, Nathanson, Jerry; and Schneider, Richard. 2015
2015-2016 Catalog Description:	Water quality and system design for agricultural drainage and waste-water systems.
Prerequisites:	Math 124, CE 318
Co-requisites:	N/A
Required, Elective, or Selected Elective:	Design Elective or Technical Elective
Instruction Outcomes:	<p>To provide students an ability to:</p> <ol style="list-style-type: none">1. Understand the role of the engineer with respect to the environment2. Know how to design a wetland to treat wastewater generated from facilities discharging 1,000 to 100,000 gpd3. Understand the permitting and design process for small wastewater treatment facilities and options for discharging the reclaimed water4. Students will gain experience in problem solving, design, and written communication.5. Apply EPANet to agricultural applications
Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:	(c) An ability to apply knowledge of mathematics, science, and engineering (2 & 3); Can design a system, component or process to meet desired needs within realistic constraints (1, 2 & 3); (e) Can identify, formulate and solve engineering problems (1, 2 & 3); (k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. (4)

Topics covered:

NEPA, ACOE 404 Permitting, Natural Wetlands, Constructed Wetlands for treatment, Small Wastewater System Design and Permitting, Groundwater Recharge, Bio solid Disposal, EPANet Water system model

ABE 459, Design of Onsite Wastewater Treatment and Dispersal Systems

Credits and Contact Hours:	3 credits, 3 hours per week (online)
Instructor's or course coordinator's name:	Kitt Farrell-Poe and Peter Livingston
Textbook, title, author and year:	<ol style="list-style-type: none">1. Arizona Administrative Code, Aquifer Protection Permits [Title 18. Environmental Quality, Chapter 9. Department of Environmental Quality Water Pollution Control, Article 3. Aquifer Protection Permits-General Permits].<ol style="list-style-type: none">a. The original code is available in the following formats:<ol style="list-style-type: none">i. http://apps.azsos.gov/public_services/Title_18/18-09.rtfii. http://apps.azsos.gov/public_services/Title_18/18-09.pdf2. NAWT Inspection Training Manuals [available through the instructor for \$17]
Other Supplemental materials:	<ol style="list-style-type: none">1. Burks, Bennette D. and Mary Margaret Minnis. 1994. <i>Onsite Wastewater Treatment Systems</i>. Hogarth House, Ltd, Madison, WI. [I have 4 available in my office for \$25 or you can obtain it directly from the author by sending her a check for \$23, with your mailing address and a lovely note to: M.M. Minnis, 15 Burchard Lane, Rowayton, CT 06853]2. Crites, Ron and George Tchobanoglous. 1998. <i>Small and Decentralized Wastewater Management Systems</i>. McGraw-Hill, Boston, MA.3. Additionally, there will be additional supplemental reading or websites listed at the end of many learning modules.
2015-2016 Catalog Description:	<p>The course will cover issues and concepts relating to the design of onsite wastewater treatment and recycling systems, including: Arizona regulations, site and soil evaluation, soil interactions with treated effluent, technology selection, design of simple and specialized treatment systems, operation and monitoring of simple and complex systems, inspection of systems for the Arizona Transfer of Ownership Program, biosolids and septage management, and water reuse.</p>
Prerequisites:	None.
Co-requisites:	None.
Required, Elective, or Selected Elective:	Elective.

Instruction Outcomes:

Upon completion of this class, students are expected to:

1. Demonstrate an awareness of the science and social disciplines that affect onsite wastewater treatment and the design of those systems.
2. Describe onsite wastewater treatment technologies and their design considerations.
3. Evaluate the choices of onsite wastewater technologies for clients' needs and desires, soil and site constraints, and regulatory environment.
4. Use creativity and innovation in designing wastewater collection and treatment systems for Arizona.

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

Outcome (a) can apply mathematics, science, and engineering principles to solve problems: **1**

Outcome (c) can design a system, component, or process to meet desired needs within realistic constraints: **2, 3, 4**

Outcome (e) can identify, formulate, and solve engineering problems: **2, 3, 4**

Topics covered:

Introduction & Review. History, terminology, glossary, Arizona regulations, wastewater treatment processes, fundamental microbiology, wastewater characteristics. **Site Investigation & Soil Evaluation.** Intro to soils, soil color, soil chemistry & morphology, soil & site investigations. **Review of Pretreatment Systems.** Intro to pretreatment, Holding tanks, Septic tanks, Aerobic treatment units, Media filters, Constructed wetlands: overview & design approaches, Disinfection, Nitrogen removal. **Review of Soil Treatment Systems.** Introduction & overview, System location & minimum vertical separation, Effluent distribution, In-ground systems (gravity distribution): Drainfields, Chambers, Gravelless pipe systems, ET systems. **Introduction to pressure distribution.** Mound systems, Low-pressure distribution systems, Drip dispersal systems. **Pumping systems.** Pumping systems, Hydraulic energy, Pumping systems, Selecting pumps. **Design.** System selection process, Design process. **Controls, Wiring, Operation & Maintenance, and Management.** Controls, Wiring, O&M, Management of Onsite Wastewater Systems. **Inspections.** Arizona Transfer of Ownership Inspection Program. **Septage, Biosolids, & Water Reuse.** Septage & biosolids management, Water reuse options.

ABE 479, Applied Instrumentation for Controlled Environment Agriculture

Credits and Contact Hours:	3 credits, 75min/week lecture, 75min/week lab, open door policy for student office visits with appointments
Instructor's or course coordinator's name:	Murat Kacira
Textbook, title, author and year:	No required textbook. See supl. materials.
Other Supplemental materials:	<ul style="list-style-type: none">• Langhans, R.W. and T.W. Tibbitts (Eds). 1997. Plant Growth Chamber Handbook. North Central Regional Publication No. 340.• Fraden J. 2004. Handbook of Modern Sensors; Physics, Design and Applications. Springer Science+Business Media , LLC, ISBN 978-0-387-00750-2• Dunn, W. C. 2006. Introduction to Instrumentation, Sensors, and Process Control. Arctech House, Inc. Norwood, MA 02062, ISBN: 1-58053-011-7
2015-2016 Catalog Description:	Principles, methods, and techniques related to the measurement and control of environmental factors affecting plant growth and plants' surrounding climate under controlled environments. Course covers application of sensors, instrumentation, and design of a simple system to measure and control environments for plant production systems.
Prerequisites:	MATH 110, MATH 113 and PHYS 102
Co-requisites:	
Required, Elective, or Selected Elective:	Elective
Instruction Outcomes:	Upon completing the course students should be able to: <ol style="list-style-type: none">1) Know how to measure, monitor, and control the various environmental variables affecting plant growth/development and interior climate in the controlled environment plant production system.2) Recognize the advantages, complexities, and problems associated with environmental control of plant growth and development.3) Know how to analyze and report the various environmental variables for a scientific journal for reproducibility.

- 4) Gain experience designing and developing a controlled environment system for plant growth and development.
- 5) Analyze and interpret the written description of the environment used in a scientific research report.
- 6) Understand the techniques and principles used for measurement of temperature, humidity, light intensity, light quality, air current, and CO₂ in CEA.
- 7) Understand and identify how to evaluate humidity in CEA.
- 8) Understand the techniques of controlling temperature, relative humidity, and CO₂ concentration.
- 9) Understand the principles of assessing CO₂ exchange rate of plants in a controlled environment.
- 10) Utilize information on the maintenance and calibration of sensors.
- 11) Utilize guideline for measuring and reporting the environment in which scientific research was conducted.
- 12) Become familiar with data loggers, data acquisition boards and greenhouse control systems.
- 13) Conduct student design experiments and report the design and experiment in technical presentation format.
- 14) Prepare and present a short seminar that reports the results of student group design experiments conducted in a controlled environment for plant growth and development.

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

Outcome (b) an ability to design and conduct experiments, as well as to analyze and interpret data **(1-9, 11-14)**

Outcome (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability **(13-14)**

Outcome (d) an ability to function on multidisciplinary teams **(13-14)**

Topics covered:

1. Introduction. 2. Environmental factors and plant growth. 3. Data acquisition: Sensor, signals & systems; sensor classification; units of measurements. **4. Data recording and monitoring:**. **5. Temperature:** Air temperature; plant leaf and canopy; temperature; growing media. **6. Light:** Light intensity & quality. **7. Humidity:** Relative & absolute humidity; vapor pressure deficit; psychrometrics. **8. Air velocity and boundary layer. 9. Carbon dioxide. 10. Transpiration. 11. Growing media moisture sensing. 12. Control Process:** ON/OFF control; feed-back and feed-forward control; PID control. **13. Environmental control technology in CEA. 14. Information and control technologies in CEA. 15. Greenhouse control systems.**

ABE 481A, Engineering of Biological Processes

Credits and Contact Hours	3 Units Lecture required 3 hours per week
Instructor's or course coordinator's name	Kimberly Ogden Professor of Chemical and Environmental Engineering
Textbook, title, author and year	Bioprocess Engineering, Shuler and Kargi, Prentice Hall 2002
Other supplemental materials	
Catalog Description	To learn to apply to the design of biological systems principles of engineering, science and mathematics, including, but not limited to statistics, kinetics, sensors and bioreactor design and scale up. To explore and be familiar with the principal areas of biological engineering such as food process engineering, tissue engineering, and other large-scale fermentation processes.
Prerequisites	Advanced Standing Engineering
Co-Requisites	none
Required, elective or selected elective	Can be a substitute for Required course ChEE 477, also can be an elective.
Instruction Outcomes	The purpose of this course is to introduce students to bioprocess engineering. The fundamentals of enzyme kinetics and bioreactor design are covered initially. Topics related to bioreactors and processes are also explored.
Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:	The course supports the student outcomes of an ability to apply knowledge of mathematics, science, and engineering; an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability; an understanding of professional and ethical responsibility;
Topics covered	<ul style="list-style-type: none">• Enzyme kinetics• Bioreactor design• Immobilized systems• Genetic engineering• Downstream separation overview• Special topics

ABE 481B, Cell and Tissue Engineering

Credits and Contact Hours:	Lecture (Social Sciences 206): WF 1:00-1:50 Lab (Marley 218): M 1-3:30 (section A) W 3-5:30 (section C)
Instructor's or course coordinator's name:	Jeong-Yeol Yoon
Textbook, title, author and year: Other Supplemental materials:	Tissue Engineering (recommended but not required) Palsson & Bhatia (Pearson Prentice Hall)
2015-2016 Catalog Description:	Development of biological engineering methods including applied genetics, metabolic regulation, and bioreactors employed in industrial processes for manufacture of pharmaceuticals and in the design of tissue engineered devices to replace normal physiological function.
Prerequisites: Co-requisites:	CHEM 151 and CHEM 152
Required, Elective, or Selected Elective:	ABE Design Elective
Instruction Outcomes:	<ol style="list-style-type: none">1. To explore and become familiar with cell and tissue engineering.2. To apply engineering and biological fundamentals to the design of pharmaceutical production system and tissue engineered devices, towards creating a profitable business model (for 481B) or a new research activity (for 581B).
Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:	(a) apply knowledge of math, science & engineering: moderate; (c) design a system, component, or process within realistic constraints: moderate; (d) multidisciplinary teams: moderate; (e) identify, formulate & solve engineering problems: moderate; (g) communicate effectively: moderate; (i) life-long learning: none; (j) contemporary issues: saturation; (k) techniques, skills & modern engineering tools: moderate

Topics covered:

Bacterial culture I, Cell culture, Bacterial culture II, Metabolism, Bacterial culture II, Mammalian culture I Bioreactors, Mammalian culture II, Tissue engineering, Cell imaging, Tissue dynamics, Cell imaging, Cytoskeleton imaging, Angiogenesis & stem cells, Contact guidance, Time constants, Focal adhesion, Biomaterials, Biomaterial surfaces, Sterilization, Cytotoxicity tests, Cell separation/isolation, Pharmaceutical products, Centrifugation, Organ-on-a-chip, Cellular mechanotransduction,

ABE 483, Controlled Environment Systems

Credits and Contact Hours:	3 credits, 3 hours per week
Instructor's or course coordinator's name:	Gene A. Giacomelli
Textbook, title, author and year:	Greenhouses: Advanced Technology for Protected Horticulture. J.J. Hanan 1997
Other Supplemental materials:	NRAES-33, Aldrich and Bartok, "Greenhouse Engineering" ACME, The Greenhouse Climate Control Book NRAES-3, Energy Conservation for Commercial Greenhouses E-130, Environmental Control of Greenhouses E-208, Soil Heating Systems for Greenhouse Crop Production Journal articles: HortTechnology; Transactions of the ASAE; Proceedings of National Agricultural Plastics; International Society on Soilless Culture; ACTA Horticulturae
2015-2016 Catalog Description:	An introduction to the technical aspects of greenhouse design, environmental control, hydroponic crop production, plant nutrient delivery systems, intensive field production systems, and post-harvest handling and storage of crops.
Prerequisites:	None
Co-requisites:	None
Required, Elective, or Selected Elective:	Elective or Technical Elective
Instruction Outcomes:	<ol style="list-style-type: none">1. Understanding of controlled environment plant production systems design focusing on design evaluation and application.2. Presenting procedures, techniques and available resources for the design, evaluation, operation and general understanding of CEPPS.3. Understanding the generalized processes and sub-systems of a CEPPS, including, crop production systems; nutrient delivery systems; microclimate heating, ventilation, cooling, humidifying, supplemental lighting and CO₂ enriching systems; monitoring and control systems; energy conservation and alternate energy systems; mechanization and labor management systems; glazing systems; and types of structures.

4. Ability to quantify heating, cooling, lighting systems operations.
5. Working knowledge of basic controlled environment systems data analysis.
6. Ability to use spreadsheet software to perform energy calculations for heating demands of a greenhouse.
7. Understanding of the derivation of basic greenhouse energy balance equations with focus in design applications.
8. Ability to solve controlled environment greenhouse engineering problems utilizing multiple unknowns.
9. Ability to design heating and cooling systems for controlled environment greenhouses.

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

Outcome (a) an ability to apply knowledge of mathematics, science, and engineering: **1,2,3,6,7**

Outcome (c) Can design a system, component or process to meet desired needs within realistic constraints: **6,8,9**

Outcome (e) an ability to identify, formulate, and solve engineering problems: **3,4,6,8,9**

Outcome (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice: **5,6, and 7**

Topics covered:

This course provides upper-division students in ABE and other engineering disciplines with the ability to analyze controlled environment systems and use the analyses for future design of controlled environment systems for crop production.

1. Greenhouse Structural Design, Glazings, Location, Orientation, Layout and Traffic Patterns
2. Environmental Control - Lighting, CO₂– Enrichment
3. Environmental Control – Psychrometrics
4. Environmental Control – Ventilation and Cooling
5. Environmental Control – Automated System
6. Greenhouse Crop Production Systems – irrigation and fertigation
7. Environmental Control – Air Heating Systems
8. Environmental Control -- Floor Heating
9. Energy Conservation Systems and Energy Sources for Greenhouses
10. Integrated Crop Production Systems - Plant Culture Techniques, Nutrient Delivery Systems Mechanization, Automation and Intelligent Mechanisms

ABE 486, Biomaterial-Tissue Interactions

Credits and Contact Hours:	Lecture: TR 11:00-12:15
Instructor's or course coordinator's name:	Jeong-Yeol Yoon
Textbook, title, author and year:	An Introduction to Tissue-Biomaterial Interactions Dee, Puleo & Bizios (Wiley-Liss)
Other Supplemental materials:	
2015-2016 Catalog Description:	Biomaterials and their applications; protein-surface and blood-biomaterial interactions, inflammation, wound healing, biocompatibility, implants, and tissue engineering.
Prerequisites:	CHEM 151 and 152.
Co-requisites:	
Required, Elective, or Selected Elective:	Elective
Instruction Outcomes:	<ol style="list-style-type: none">1. To explore and become familiar with biomaterials and their applications including protein-surface and blood-biomaterial interactions, inflammation, wound healing, biocompatibility, implants, and tissue engineering.2. To apply engineering and biological fundamentals to the design of industrial products towards creating a profitable business model (for 486) or a new research activity (for 586).
Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:	(a) apply knowledge of math, science & engineering: moderate; (c) design a system, component, or process within realistic constraints: moderate; (d) multidisciplinary teams: moderate; (e) identify, formulate & solve engineering problems: moderate; (f) professional & ethical responsibility: limited; (g) communicate effectively: moderate; (j) contemporary issues: saturation; (k) techniques, skills & modern engineering tools: moderate;(n) biological processes and systems: saturation.

Topics covered:

Introduction to biomaterials.
Proteins
Protein – surface interactions: fundamentals.
Protein – surface interactions: applications.
Blood. Blood coagulation cascade.
Inflammation.
Infection and immune system.
Wound healing
Surface characterization.
Surface modification.
3D printed biomaterials.
Electrospun nanofibers.
Lab-on-a-chip applications.
Drug/gene delivery applications.
Tissue engineering scaffolds.

ABE 487, Metagenomics: From Genes to EcoSystems

Credits and Contact Hours:	3 units
Instructor's or course coordinator's name:	Bonnie Hurwitz, PhD, Assistant Professor
Textbook, title, author and year	Izard, Jacques, and Maria Rivera, eds. <i>Metagenomics for Microbiology</i> . Academic Press, 2014.
Other Supplemental materials:	Peer-reviewed publications on metagenomics studies;
2015-2016 Catalog Description:	<p>Environmental genomics is revolutionizing our understanding of microbes from the environment to human health, towards a holistic view of ecosystems or "One-Health". At its core are new molecular methods called metagenomics to sequence DNA directly from an environmental sample, thus capturing the whole microbial community and bypassing culture. Modern (Next-Gen) sequencing technologies offer vast new datasets of short sequence reads representing these microbial communities, however many hurdles exist in interpreting data with high species complexity and given specialized software for microbial metagenomic analyses. This course focuses on the science of metagenomics towards understanding (1) questions that metagenomics can address, (2) possible approaches for metagenomic sequencing and analysis, and (3) how genes, pathways, and environmental context are translated into ecosystem-level knowledge. This course alternates between traditional lectures and hands-on experience with programming, bioinformatics tools, and metagenomic analysis. The course concludes with several weeks of seminar-format discussions on current research in metagenomic data analysis and a final project of your choice analyzing real-world experimental data.</p>
Prerequisites:	Bio 181
Co-requisites:	
Required, Elective, or Selected Elective:	Elective
Instruction Outcomes:	<ul style="list-style-type: none">• Weekly problem assignments through the first 2/3 of the course, focusing on performing specific manipulations in real sequence datasets.

- Paper presentations for the remaining 1/3 of the course demonstrating a grasp of the questions arising in current metagenomics publications.
- A final project of the student's choice, requiring substantial practical manipulation of one or more metagenomic datasets using a range of tools discussed in the course

Student Outcomes – Listed in Criterion 3 or any other outcomes are addressed by the course:

To develop the broad knowledge and skills needed to: (a) understand metagenomic experimental approaches; (b) describe methodologies for analyzing data from complex community samples, and (c) conduct and interpret results from project-based metagenomic analyses.

Topics covered:

Metagenomics experimental approaches; sequencing technologies; platforms and platform specific issues; methodologies; sample preparation; QC-reports & quality controls; mapping sequence reads; taxonomic annotation; functional annotation & determination; unknown gene prediction; comparative metagenomics; amplicon sequencing; shotgun metatranscriptomics; defining taxa; metagenome assembly; evaluation; visualization and reporting of results; tools & algorithms; 16S profiling; databases; mapability; k-mer profiling; cross assembly; bioinformatics tools

AME 489a, Fabrication Techniques for Micro- and Nanodevices

Credits and contact hours: 3 credits; 3 contact hours

Instructor/coordinator's name: Eniko Enikov

Textbook(s) and/or other supplemental materials: *Introduction of Microelectronic Fabrication*, Richard C. Jaeger, Prentice Hall, 2002,
Additional Suggested Texts: *The Science and Engineering of Microelectronic Fabrication* by Stephen A. Campbell. Gardner, J.W. 1994. *Microsensors, Principles and Applications*. John Willey & Sons

Class notes will be integral part of instruction. Material presented in class will supplement and will sometimes be different from the textbooks.

Catalog description: This course tackles the techniques for the design, fabrication, and testing of traditional microelectromechanical systems (MEMS) and nanodevices. Each student will be required to participate in weekly laboratory sessions, to keep a laboratory notebook, and to submit a project report (25% Honors final grade; 15% Undergraduate final grade) focusing on the design, fabrication, and testing of a MEMS device. Honors students receive additional homework assignments typically involving derivation or proof of a theory presented in class. Additionally, Honors students are asked to complete an independent MEMS/NEMS design, while undergraduates can use an existing device design. Grading differences are reflected in the syllabus.

Prerequisites/Co-Requisites: Adv Stdg: Engineering. ECE 207 or ABE 447

Required, Elective, Selected Elective: Elective

Specific outcomes of instruction:

- Design a process for fabricating basic semiconductor devices (resistors, diodes, transistors)
- Process for fabricating basic MEMS devices (pressure sensor, cantilever sensors, glucose sensors)

**Outcomes listed in
Criterion 3:**

- a. Apply mathematics, science and engineering principles
- c. Design a system, component or process to meet desired needs
- k. Use the techniques, skills and modern engineering tools necessary for engineering practice

Topics covered:

- Introduction to MEMs and NEMs: Substrates, Materials. Overview of the MEMS Fabrication cycle; Introduction of pressure/flow sensor/capacitive sensor project(s). Introduction to the lab and MATLAB for simulation and data acquisition; Design of pressure sensor structures: sensitivity, resolution, expected noise levels; Working Principles of MEMS; Pressure sensor readout: breadboard test circuit building: differential amplifiers, and low-pass filters; Theory of Micro-Cantilever Sensors, Capacitive Accelerometers, pressure sensor experiment - testing, calibration and analysis; Photolithography: photomask fabrication, exposure systems. Photoresists types, contrast, critical modulation transfer function. Lift-off process; Autocad Primer. Photomask Design with Autocad; Thermal Oxidation of Si. Oxide Thickness Characterization. Masking properties of the oxide; Doping profile measurement; Piezoresistivity; Photolithography experiment; Diffusion; Doping through diffusion; Junction Depth and Sheet Resistance; Matlab PDE Toolbox: Solving the diffusion equations; Ion Implantation Ion Implantation. Mathematical model of ion implantation; Channeling, lattice damage and annealing; Rapid Thermal Annealing; Doping profile measurement; Irvin's curves; Flow Sensor Mask Design; Etching concepts: isotropic vs. anisotropic; wet vs. dry; etch selectivity and masking; Wet etching of silicon oxide and Si. Anisotropic Etching of Si. Seidel's model of KOH etching; Thermal evaporation of Cr/Cu seed layer; Etching concepts: isotropic vs. anisotropic; wet vs. dry; etch selectivity and masking; Wet etching of silicon oxide and Si. Anisotropic Etching of Si. Seidel's model of KOH etching; Electrochemical etch stops; Photolithography in ECE clean room + lab tour; Vacuum Physics Vacuum Deposition: Review of kinetic gas theory; Evaporation rate; Cosine law of vacuum deposition; Electrodeposition; CVD Plasma processing: Chemical Vapor Deposition (CVD); CVD reactors and reactions; PECVD deposition of oxides and nitrides; Reactive Ion Etching; High density plasmas (ECR reactors); Cu/Cr wet etching; Release of Flow Sensor Flaps; Epitaxial Growth Packaging and yield. Eutectic die attachment. Formation of Ohmic contacts to Si.

CHEM 241a, Organic Chemistry

Credits and Contact Hours	3 units. Three 50 minute classes per week.
Instructor's or course coordinator's name	Professor Jon T. Njardarson
Textbook, title, author and year a. Other supplemental materials	<i>Organic Chemistry</i> 4rd Edition by Janice Smith, 2014 <i>Student Study Guide/Solutions Manual to Accompany Organic Chemistry</i> , 4 th edition by Janice Smith and Erin Berk, 2014 <i>Connect-LearnSmart Homework Program</i> <i>D2L Lecture Course Site & Organic Café Course Site</i> <i>Molecular Model Set</i>
Catalog Description	General principles of organic chemistry.
Prerequisites Co-Requisites	CHEM 152 or CHEM 105B and CHEM 106B. None
Required, elective or selected elective	Required
Instruction Outcomes	The course objective is to teach students the language of organic chemistry. Students will become proficient in using the graphical language to draw and analyze molecules, and apply it to explain and design reaction sequences.
Student Outcomes	This course supports one of the learning outcomes targeted by the department: can apply knowledge of mathematics, science and engineering to solve problems.
Brief list of topics covered	<ul style="list-style-type: none">• Structure and bonding, polar bonds, alkanes and cycloalkanes• Overview of chemical reactions, alkenes, alkynes, alkyl halides• structure determination, mass spectrometry, IR spectroscopy, NMR spectroscopy• Conjugated dienes and UV spectroscopy

CHEM 241b, Organic Chemistry

Credits and Contact Hours	3 units. Three 50 minute classes per week.
Instructor's or course coordinator's name	Dr. Lisa Dollinger
Textbook, title, author and year	<i>Organic Chemistry</i> 4rd Edition by Janice Smith, 2014 <i>Student Study Guide/Solutions Manual to Accompany Organic Chemistry</i> , 4 th edition by Janice Smith and Erin Berk, 2014
Other supplemental materials	<i>Connect-LearnSmart Homework Program</i> <i>D2L Lecture Course Site & Organic Café Course Site</i> <i>Molecular Model Set</i>
Catalog Description	General principles of organic chemistry.
Prerequisites and/or co-requisites	CHEM 241A or CHEM 242A or CHEM 246A
Co-Requisites	None
Required, elective or selected elective	Required
Instruction Outcomes	The main objective of this course is to teach you how to think about molecules and their reactivities. The structure-reactivity relationship is very important and can be applied to other molecular systems. This knowledge will then be applied to simple biological molecules and systems, such as carbohydrates, peptides, lipids, etc.
Student Outcomes	This course supports one of the learning outcomes targeted by the department: can apply knowledge of mathematics, science and engineering to solve problems.
Brief list of topics covered	<ul style="list-style-type: none">• Benzene and aromaticity, alcohols and phenols• Ethers and epoxides, thiols, and sulfides• Aldehydes and ketones, nucleophilic addition reactions• Carboxylic acids, carbonyl alpha-substitution reactions• Carbonyl condensation reactions, carbohydrates, amino acids, peptides, and proteins• Lipids• Synthetic polymers

CHEM 243a, Organic Chemistry Laboratory I

Credits and Contact Hours	1 credit
Instructor	Dr. Hamish Christie
Textbook, title, author and year	<i>Organic Chemistry Laboratory Manual</i> by Ann Padias, 6 th edition, 2016
Other supplemental materials	<i>Making the Connections</i> ³ ; <i>A How-To Guide for Organic Chemistry Lab Techniques</i> by Ann Padias, 3 rd edition, 2015 <i>D2L Laboratory Course Site</i>
Catalog Description	An introduction to the organic chemistry laboratory with an emphasis on development of laboratory skills and techniques, observation of chemical phenomena, data collection, and the interpretation and reporting of results in formal laboratory reports. Heavy emphasis on microscale techniques, laboratory safety and waste disposal. The experiments are designed to complement the principles concurrently presented in the corresponding lecture class and require knowledge of the lecture material.
Prerequisites or Concurrent	CHEM 241A or CHEM 242A or CHEM 246A.
Co-Requisites	None
Required, elective or selected elective	Required
Instruction Outcomes	The main objective of this course is to teach students the hands-on skills necessary to complement the organic chemistry lecture materials.
Student Outcomes	This course supports two of the learning outcomes targeted by the department: can apply knowledge of mathematics, science and engineering to solve problems; and, can design experiments and analyze results.
Brief list of topics covered	<ul style="list-style-type: none">• TLC, IR spectroscopy, extraction of spinach• Recrystallization, isolation of caffeine from tea• Hydrogenation, Fischer esterification• NMR Spectroscopy, menthone, limonene• Alkenes by elimination, S_N1 and S_N2 reactions.

Chemistry 243b, Organic Chemistry Laboratory II

Credits and Contact Hours	1 credit
Instructor's or course coordinator's name	Dr. Hamish Christie
Textbook, title, author and year	<i>Organic Chemistry Laboratory Manual</i> by Anne Padias, 6 th edition, 2016
Other supplemental materials	<i>Making the Connections</i> ³ ; <i>A How-To Guide for Organic Chemistry Lab Techniques</i> by Anne Padias, 3 rd edition, 2015 D2L Laboratory Course Site
Catalog Description	An introduction to the organic chemistry laboratory with an emphasis on development of laboratory skills and techniques, observation of chemical phenomena, data collection, and the interpretation and reporting of results in formal laboratory reports. Heavy emphasis on microscale techniques, laboratory safety and waste disposal. The experiments are designed to complement the principles concurrently presented in the corresponding lecture class and require knowledge of the lecture material.
Prerequisites or Concurrent Co-Requisites	CHEM 241B or CHEM 242B or CHEM 246B.
Required, elective or selected elective	None
Instruction Outcomes	Required
Student Outcomes	The main objective of this course is to teach students the hands-on skills necessary to complement the organic chemistry lecture materials. This course supports two of the learning outcomes targeted by the department: can apply knowledge of mathematics, science and engineering to solve problems; and, can design experiments and analyze results.
Brief list of topics covered	<ul style="list-style-type: none">• NMR• Diels-Alder Reaction• Nitration of Methyl Benzoate• Oxidation of Borneol to Camphor• Grignard Reaction• Qualitative of Analysis of Aldehydes and Ketones• Aldol Condensation• FAME• Multistep Synthesis of Tetraphenylcyclopentadienone• Polymers

Appendix B – Faculty Vitae

Faculty Vitae Agricultural and Biosystems Engineering

1. **Name and Academic Rank**

Lingling An, Associate Professor

2. **Education** (degree, discipline, institution, year)

Ph.D.	Statistics	Purdue University	2008
M.S.	Mathematical Statistics	Purdue University	2002
M.S.	Applied Mathematics	Shandong University	1996
B.S.	Applied Mathematics	Shandong University	1993

3. **Academic experience** (institution, rank, title, dates)

July 2015-present	Assoc. Prof.	University of Arizona	Agric. and Biosystems Engr.
2008-2015	Assist. Prof.	University of Arizona	Agric. and Biosystems Engr.

4. **Not academic experiences, consulting/industry, patents**

5. **Certifications or professional registrations**

6. **Current membership in professional organizations**

2004- present	American Statistical Association (ASA)
2005- present	Institute of Mathematical Statistics (IMS)
2008- present	International Biometric Society, Western North American Region (WNAR)
2009 - present	International Chinese Statistical Association (ICSA)
2011 - present	Alpha Epsilon, Agricultural Engineering Honor Society

7. **Honors and awards**

2014	ASABE Superior Paper Award, ASABE, Montreal, Canada
2009	I.W. Burr Award, Purdue University, Department of Statistics for excellence in dissertation research, teaching, and consulting as a graduate student at Purdue

8. **Service activities** (within and outside of the institution)

University: Executive Committee Member, Graduate Interdisciplinary Program (GIDP) in Statistics (2012-2015); Chair, Examination Committee, Statistics GIDP (2012-2015); Faculty advisor for the UA chapter of STATCOM (Statistics in the Community) organization. (2009-present)

International: Editorial Board Member, PLoS ONE (2016-present)

Peer Reviewer for Scientific Journals:

- Bioinformatics, BMC Bioinformatics, BMC Plant Biology, Cancer Informatics, Journal of Applied Biostatistics, Journal of the American Statistical Association, Journal of Natural Resources and Life Sciences Education, Molecular Biology and Evolution, Risk Analysis, PLoS ONE, Statistics in Medicine, Theoretical and Applied Genetics.

9. **Principal/Selected publications and presentations** (from the last five years)

Zhang, Y., M. Kacira, L. An. 2016. A CFD study on improving air flow uniformity in indoor plant factory system. Biosystems Engineering, 147: 193-205.

Ban Y, An L, Jiang H. (2015) Investigating microbial co-occurrence patterns based on metagenomic compositional data. Bioinformatics. doi: 10.1093/bioinformatics/btv364

Sohn M, Du R, An L*. (2015) A robust approach for identifying differentially abundant features in metagenomic samples. Bioinformatics 31: 2269-75 (*: corresponding author)

Drewry J, Choi C, An L, Gharagozloo P. (2015) A computational fluid dynamics model of algal growth: development and validation. Transactions of the American Society of Agricultural and Biological Engineers. 58:2, 203-213

- Yigiter A, Chen J, **An L**, Danacioglu N. (2015) An on-line CNV detection method for short sequencing reads. *Journal of Applied Statistics*. 42:7, 1556–1571
- Du R, Mercante D, **An L***, Fang Z*. (2014) A statistical approach to correcting cross-annotations in a metagenomic functional profile. *Journal of Biometrics & Biostatistics*. 5:208 (*: co-corresponding author)
- Pookhao N, Sohn M, Li Q, Jenkins I, Du R, Jiang H, **An L***. (2014) A two-stage statistical procedure for feature selection and comparison in functional analysis of metagenomes. *Bioinformatics* 31:158-165 (*: corresponding author)
- Sohn M, **An L***, Pookhao N, Li Q (2014) Accurate Estimation of Genome Relative Abundance for Closely Related Species in a Metagenomic Sample. *BMC Bioinformatics* 15:242 (*: corresponding author)
- An L***, Pookhao N, Jiang H, Xu J. (2014) Statistical approach of functional profiling for a microbial community. *PLoS ONE* 9(9): e106588 (*: corresponding author)
- Piegorsch W*, **An L***, Wickens A, West W, Peña E, Wu W. (2013) Information-theoretic model-averaged benchmark dose analysis in environmental risk assessment. *Environmetrics* 24:143-157 (*: co-first authors)
- Kadiyala V, Patrick N, Mathieu W, Jaime-Frias R, Pookhao N., **An L**, Smith C. (2013) Class I Lysine Deacetylases Facilitate Glucocorticoid-Induced Transcription. *Journal of Biological Chemistry* 288: 28900-12
- Tamimi E, Murat K, Choi C, **An L**. (2013) Analysis of Microclimate Uniformity in a Naturally Vented Greenhouse with High Pressure Fogging System. *Transactions of the American Society of Agricultural and Biological Engineers*. 56(3): 1241-1254
- An L** and Doerge RW. Dynamic Clustering of Gene Expression. *ISRN Bioinformatics*. Vol. 2012, Article ID 537217. Doi:10.5402/2012/537217
- West W, Piegorsch W, Peña E, **An L**, Wu W, Wickens A, Xiong H, and Chen W. (2012) The Impact of Model Uncertainty on Benchmark Dose Estimation. *Environmetrics*. 23(8): 706–716
- McDowell E, Kapteyn J, Schmidt A, Li C, Kang J, Descour A, Shi F, Larson M, Schillmiller A, **An L**, Howe G, Jones A, Pichersky E, Soderlund C, Gang D. (2011) Comparative analysis of Solanum glandular trichome types. *Plant Physiology*, 155: 524-539
- Story D, Kacira M, Kubota C, Akoglu A, **An L**. (2010) Plant Nutrient Deficiency Detection using Automated Morphology Based Sensing in Controlled Environments. *Computers and Electronics in Agriculture*, 74: 238-243

10. Professional development activities (Most recent)

Attended American Statistical Association Annual Meetings (2010 -2016); Attended Annual Conference of Institute Biological Engineering (2012); Attended the annual meeting of The Western North American Region of The International Biometric Society (2010, 2013, 2016)

1. Name and Academic Rank

Joel L. Cuello, Professor

2. Education (degree, discipline, institution, year)

Postdoc	Bioregenerative Space Life Support	NASA Kennedy Space Center	1994
Ph.D.	Agric. and Biological Engineering	Penn State University	1994
M.S.	Agric. Engineering	Penn State University	1990
M.S.	Plant Physiology	Penn State University	1999
B.S.	Agricultural Engineering	University of the Philippines	1984

3. Academic experience (institution, rank, title, dates)

2008-present	Professor	The University of Arizona	Agric. and Biosystems Engr.
2001-2008	Assoc. Prof.	The University of Arizona	Agric. and Biosystems Engr.
1995-2001	Asst. Prof.	The University of Arizona	Agric. and Biosystems Engr.
2009-present	Visiting Prof.	Zhejiang University, China	Biosys. Engr. & Food Sci.
2009-present	Faculty Fellow	Ateneo de Manila Univeristy	Ateneo Innovation Center
2015-present	Visiting Prof.	De La Salle University	Mechanical Engineering

4. Not academic experiences, consulting/industry, patents

Member, Scientific Advisory Board, Biopharmia, LLC, Oslo, Norway, 2009-present; Member, Scientific Advisory Board, C-Trade, Tucson, Arizona, U.S.A., 2011-present
Cuello, J.L., T. Hoshino, S. Kuwahara and C. Brown. 2009. ACCORDION Photobioreactor for Algae Production. Licensed exclusively by The University of Arizona to Biopharmia AS.
United States Patent No. 20110287541; China Patent No. 201080061791.9; European Union (EPO) Patent No. 10832185.2; Australia Patent (pending), 2010321943; Brazil BR Patent (pending), 112012012004-2; Canada Patent (pending), 2,781,115; India Patent (pending), 4555/DELNP/2012; Philippines (pending), 1-2012-500986; South Africa (pending), 2012/03954
Cuello, J.L., T. Hoshino, S. Kuwahara and C. Brown. 2015. AIR ACCORDION Photobioreactor for Algae Production. 2015. UA Ref. No. 14-089. PCT/US2015/013836. 01/30/2015.
Cuello, J.L. and C. Brown. 2015. ACCORDION AIR LOOP BIOREACTOR for Photoautotrophic, Mixotrophic and Heterotrophic Algae Prod. UA Ref. No. 15-106. PCT/US2015/062738. 11/25/2015.

5. Certifications or professional registrations

6. Current membership in professional organizations

1990-present	American Society of Agricultural and Biological Engineers (ASABE)
2012-present	Asia Pacific Society for Applied Phycology (APSAP)
2012-present	Philippine American Academy of Science and Engineering (PAASE)
2015-present	Association for Vertical Farming (AVF)

7. Honors and awards (from 2010)

2016	Elected Member (Corresponding), National Academy of Science and Technology – Philippines
2015	Visiting Professor Award, U.S. Agency for International Development (USAID) Science, Technology, Research and Innovation for Developemnt (STRIDE), De La Salle University, Philippines, 09/18-27/15
2015	Recipient, Tech Launch Arizona I-Squared (Innovation and Impact) Award
2013	Recipient, Outstanding Alumnus Award in Biosystems Engineering Global Education and Research, University of the Philippines at Los Banos, Philippines
2012	Elected Member, Philippine-American Academy of Science and Engineering (PAASE)

- 2010 Fulbright Senior Specialist, Center for Antarctic Programs, Universidad de Magallanes, Chile
- 2010 Visiting Professor Award, Philippine Department of Science and Technology (DOST) Engineering Research and Development for Technology (ERDT) Program, Ateneo de Manila University, Philippines

8. Service activities (within and outside of the institution)

University: UA Faculty Senator (2005-present); CALS Faculty Council, Chair (2015-present), Co-Chair (2009-2015); CALS Faculty P&T Committee, Chair (2014-present), Vice Chair (2014-2015); ABE Graduate Committee, Member; ABE Undergraduate Committee, Member.

National: President, Arizona Section ASABE (2012-2013); Elected Member, PAASE Board of Directors (2015-2017); Member, U.S. National Academies Committee for the Sustainable Development of Algal Biofuels (2011-2012); Member, External Advisory Committee, Arkansas EPSCoR Plant-Powered Production (P3) Center, Arkansas State University (2008-2013).

International: Knowledge Partner UA Liason, Global Forum for Innov. in Agric. (GFIA), United Arab Emirates (2014-present); Member, Working Group on Improving Sci., U.S.-Philippines Sci. and Tech. Agreement (2014-present); Tech. Adviser, Ministry of Water and Envr., Agric. Division, United Arab Emirates (2014-present); Tech. Adviser, King Abdulaziz City for Sci. and Tech., Saudi Arabia, (2011-present); External Advisor, Philippine Congressional Comm. on Sci., Technology and Engineering (COMSTE) Philippines (2011-2013).

Peer Review of Proposals: NSF INFEWS (2016); USDA NIFA (2013); NSF Environmental Sustainability (2012)

9. Principal/Selected publications and presentations (from 2011)

Ubando, A.T., **Cuello, J.L.**, El-Halwagi, M.M., Culaba, A.B., Promentilla, M.A.B., Tan, R.R.. 2015. Application of Stochastic Analytic Hierarchy Process for Evaluating Algal Cultivation Systems for Sustainable Biofuel Production. *Clean Technologies and Environmental Policy*. doi: 10.1007/s10098-015-1073-z. ISSN: 1618-9558. Refereed.

Ubando, A.T., Culaba, A.B., Aviso, K.B., Tan, R.R., **Cuello, J.L.**, Ng, D.K.S., El-Halwagi, M.M. 2015. Fuzzy Mathematical Programming Approach in the Optimal Design of an Algal Bioenergy Park. *Chemical Engineering Transactions*. Vol. 45. ISBN 978-8895608, ISSN 2283-9216. Refereed.

Ubando, A.T., **J.L. Cuello**, A.B. Culaba, M.M. El-Halwagi and R.R. Tan. 2014. Multi-regional multi-objective optimization of an algal biofuel polygeneration supply chain with fuzzy mathematical programming. *Proceedings of the American Society of Mechanical Engineers (ASME) 2014 8th International Conference on Energy Sustainability*. Refereed.

Ubando, A.T., **J.L. Cuello**, A.B. Culaba, M.A.B. Promentilla and R.R. Tan. 2014. Multi-criterion evaluation of cultivation systems for sustainable algal biofuel production using analytic hierarchy process and Monte Carlo simulation. *Energy Procedia*. Refereed.

Borines, M.G., R.L de Leon and **J.L. Cuello**. 2013. Biotehanol production from the macroalgae *Sargassum* spp. *Bioresource Technology*. 138:22-29.

Hoshino, T., D. Johnson and **J.L. Cuello**. 2012. Design of new strategy for algal photo-hydrogen production: Spectral selective photosystem I activation and photosystem II deactivation. *Bioresource Technology*. 120: 233-240.

Seo, I.H., I.B. Lee, H.S. Hwang, S.W. Hong, J.P. Bitog, K.S. Kwon, C.G. Lee, Z.H. Kim and **J.L. Cuello**. 2012. Numerical method of a bubble-column photobioreactor design for microalgae cultivation. *Biosystems Engineering*. 113: 229-241.

Wu, D., P. Nie, **J.L. Cuello**, Y. He, Z. Wang and H. Wu. 2011. Application of visible and near infrared spectroscopy for rapid and non-invasive quantification of common adulterants in *Spirulina* powder. *Journal of Food Engineering* 102: 278–286.

1. Name and Academic Rank

Kamel Didan, Research Associate Professor

2. Education (degree, discipline, institution, year)

Ph.D.	Agric. and Biosystems Engr.	University of Arizona	1999
M.S.	Agric. and Biosystems Engr.	University of Arizona	1991
B.S.	Hydrology & Rural Engineering	INAT, Tunisia	1988

3. Academic experience (institution, rank, title, dates)

2008-present	Res. Assoc. Prof.	University of Arizona	Electrical & comp Engr.
2005-2008	Res. Assoc.	University of Arizona	Soil Water & Env. Sciences
2000-2005	Res. Assist.	Univ. of Arizona	Soil Water & Env. Sciences

4. Not academic experiences, consulting/industry, patents

5. Current membership in professional organizations

1997-present	American Geophysical Union (AGU)
2004-present	Institute of Electrical and Electronics Engineering (IEEE)
2015 - present	IEEE Geosciences and Remote Sensing Society

6. Honors and awards

2009 CALS Appointed Personnel of the year Award, The Univ. of Arizona
2003 Twice NASA Certificate of Recognition for Services and Contribution to the EOS program
2001 NASA New Technology Software Award
1995 CALS Meritorious Teaching Award, the University of Arizona

7. Service activities (within and outside of the institution)

Science Community: Organizer and Chair of the AGU Fall meeting Session (2013, 2014)

"Multisensor Long-Term Land Surface Data Records"

Organizer and Chair of the "VIP Multisensor Workshop", Tucson, AZ, Jan. 2013

(http://vip.arizona.edu/vip_workshop.php)

Chair of the Long Term Data Record session, NASA Carbon Cycle and Ecosystem Workshop (April-May 2008)

National: Member of the Land Processes-DAAC User Working Group (2007)

Member of the Oak Ridge National Laboratory DAAC User Working Group (2010-2015)

Member of NASA Carbon Cycle and Terrestrial Ecology Working Group on Long Term Data (2010-present)

NASA-EOS MODIS Science Team Member (2001-present), NASA S-NPP VIIRS Science Team Member (2011-present)

President, ASAE student chapter, The University of Arizona (1992-1993)

International Scientific Committee member. The International Conference on Integrated Land and Water Resources Management in the Dry Areas under CC. Djerba, Tunisia, May 11-14th, 2015. Advisor to the Tunisian steering committee on Space programs (2016).

Peer Reviewer for Scientific Journals:

Remote Sensing (online), GRL, IEEE Transactions Geoscience and Remote Sensing, Remote Sensing of Environment, Canadian Journal of Remote Sensing, Journal of Climate Science, JGR Bioscience, Geophysical Research Letters, Springer Plus, International Journal of Remote Sensing, Sensors Journal, Remote Sensing Journal, Ecohydrology, IEEE International Geoscience & Remote Sensing Symposiums, AGU meetings, Jordanian Royal Scientific Society

8. Current funded research

2014-2017: Vegetation Indices from the Suomi-NPP VIIRS Sensor. NASA (\$870,298)
2014-2018: Maintaining the Terra and Aqua MODIS VI Product suite, NASA (\$542,700)

9. Principal/Selected publications and presentations (from the last five years)

- Nagler, P.L., Doody, T.M., Glenn, E.P., Jarchow, C.J., Barreto-Muñoz, A. and **Didan, K.** (2015). Wide-area estimates of evapotranspiration by red gum (*Eucalyptus camaldulensis*) and associated vegetation in the Murray–Darling River Basin, Australia. *Hydrological Processes*.
- Kim, Y., Kimball, J. S., **Didan, K.**, & Henebry, G. M. (2014). Response of vegetation growth and productivity to spring climate indicators in the conterminous United States derived from satellite remote sensing data fusion. *Agricultural and Forest Meteorology*, 194, 132-143.
- Kim, Y., Kimball, J. S., Zhang, **K.**, **Didan, K.**, Velicogna, I., & McDonald, K. C. (2014). Attribution of divergent northern vegetation growth responses to lengthening non-frozen seasons using satellite optical-NIR and microwave remote sensing. *International Journal of Remote Sensing*, 35(10), 3700-3721.
- Rahman A.F., Danilo D., **Kamel D.**, Armando B. M., Joseph A. H., (2013). Detecting large scale conversion of mangroves to aquaculture with change point and mixed-pixel analyses of high-fidelity MODIS data. *Remote Sensing of Environment*, 130(2013), pp 96-107.
- Whitsitt S., A M. Barreto, H. Maribel, H. Al-Helal, D. c. Chu, **K. Didan**, and J. Sprinkle. 2011, Constrained Data Acquisition for Mobile Citizen Science Applications. Proceedings of the Compilation of the co-located Workshops on DSM'11, TMC'11, AGERE!'11, AOOPEs'11, NEAT'11, & VMIL'11. pp 267-271.
- Didan K.**, Yitayew, M. (2010). Prototype Geographic Information System for Agricultural Water Quality Management. *ASCE Journal of Irrigation and Drainage Engineering*. Vol 135 No. 1, pp 58-67. DOI: 10.1061/_ASCE_0733-9437_2009_135:1(58)
- Michael A. White, Kirsten M. de Beurs, **Kamel Didan**, David W. Inouye, et. al, (2009), Intercomparison, interpretation, and assessment of spring phenology in North America estimated from remote sensing for 1982 to 2006. *Glob. Change Biol.* **15**-2335–59. DOI: 10.1111/j.1365-2486.2009.01910.x
- Glenn, Edward P., Kiyomi Morino, **Kamel Didan**, Fiona Jordan, Kenneth Carrol, Pamela L. Nagler, Kevin Hultine, Linda Sheader, and Jody Waugh. 2009. Vegetation Density and Evapotranspiration in a Heavily Grazed Phreatophytic Shrub Community in a Nitrate Contaminated Desert Watershed: Implications for the Local Water Balance. *Ecohydrology* (1):316-329.
- Huete, A., **Didan, K.** & Van Leeuwen, W. 2011, 'MODIS vegetation indices' in Ramachandran, B., Justice, C.O., and Abrams, M. (eds), *Land Remote Sensing and Global Environmental Change: NASA's Earth Observing System and the Science of ASTER and MODIS*, Springer-Verlag, New York, pp. 579-602.

10. Professional development activities (Most recent)

Attended the Annual NASA MODIS and VIIRS Science Team Meetings (2009-2016); Attended the American Geophysical Union Meetings (2009-2014); Attended the Annual ORNL-DAAC UWG Meetings (2010-2015); Chaired AGU Sessions on Multisensor Observations and Data records (2013-2014); Advisor to the Tunisian Space program, (2016).

1. Name and Academic Rank

Kathryn L. “Kitt” Farrell-Poe, Specialist & Professor

2. Education (degree, discipline, institution, year)

Ph.D.	Civil (Environmental) Engr.	Purdue University	1990
M.S.	Agricultural Engineering	Purdue University	1984
B.S.	Agricultural Engineering	University of Nebraska-Lincoln	1979

3. Academic experience (institution, rank, title, dates)

February 2014-present	Head	University of Arizona	Agric. and Biosystems Engr.
2005-2014	Specialist	University of Arizona	Agric. and Biosystems Engr.
1998-2005	Assoc. Prof.	University of Arizona	Agric. and Biosystems Engr.
1997-1998	Assoc. Prof.	Utah State University	Ag. Systems Technology & Ed.
1991-1997	Assist. Prof.	Utah State University	Ag. Systems Technology & Ed.
1989-1991	Envr. Engr. Specialist	Utah State University	Civil & Environmental Engr.
1980-1982	Engr. Special.	Univ. of Nebraska-Lincoln	Agricultural Engineering

4. Not academic experiences, consulting/industry, patents

1985-1986	Lab Tech.	The Farm Clinic	West Lafayette, IN
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5. Certifications or professional registrations

NAWT Certified Inspector, maintained since 2001
Engineer-in-Training, Spring 1980

6. Current membership in professional organizations

1989-present	American Society of Agricultural and Biological Engineers (ASABE)
2002-present	Consortium of Institutes for Decentralized Wastewater Treatment (CIDWT)

7. Honors and awards

2013 *Teaching Excellence* by Scottie Dayton in *Onsite Installer* magazine, July issue, pp. 12-16.
2011 Extension Faculty of the Year, UA-CALS-Cooperative Extension
2009 Universal Who's Who Among Business and Professional Achievers

8. Service activities (within and outside of the institution)

University: UA Continuing Status & Promotion Committee (2014-present, Chair 2015-present); UA Engineers Without Borders Faculty Advisor (Fall 2013-present); UA Society of Women Engineers Faculty Advisor (Fall 2013-present); UA-CALS Faculty Guidance Committee member (2010-2012); ABE Academic Programs Asses. Comm. Member (2009-present)

State: AZ Depts of Environmental Health Services Assn-Onsite Technical Advisory Group member (2009-present); AZ Dept of Environmental Quality-Onsite Wastewater Advisory Committee member (2012-present)

National: American Society of Ag & Biological Engineers member (1980-present); Consortium of Institutes for Decentralized Wastewater Treatment (member, 2002-present; president, 2005-2007)

9. Principal/Selected publications and presentations (from the last five years)

- Gold A.J., D. Parker, R.M. Waskom, J. Dobrowolski, M. O'Neil, P.M. Groffman, K. Addy, M. Barber, S. Batie, B. Benham, M. Biachi, T. Blewett, C. Evenson, C. Gardner, **K.L. Farrell-Poe**, C.M. Rock, W. Gratham, J. Harrison, T. Harter, J. Kushner, R. Lowrance, J. Lund, M.P. McClaran, R. Mahler, M. McFarland, D. Osmond, J. Pritchett, L. Propkopy, A. Shober, M. Silitonga, D. Swackhammer, J. Thurston, D. Today, R. Turco, G. Vellidis, and L. Wright-Morton. 2013. Advancing water resource management in agricultural, rural, and urbanizing watersheds: why land-grant universities matter. *J. of Soil & Water Conservation*. 68(4):337-348.
- Artiola, J., G. Hix, C. Gerba, and **K. Farrell-Poe**. 2013. What well owners should know about shock chlorination. UA Extension publication, AZ1605. Tucson, AZ: UA.
- Artiola, J.F., **K.L. Farrell-Poe**, and J.C. Moxely. 2012 (originally published 2004; revised 2006). Arizona: Know Your Water. UA CALS booklet. University of Arizona: Tucson, AZ. (106 pages).
- Farrell-Poe, K.**, J. Garrett, and D. Long. 2012. What you should know when you're having your septic system inspected for the Transfer of Ownership Program. UA Extension publication, AZ1554. Tucson, AZ: UA.
- Farrell-Poe, K.**, L. Jones-McLean, and S. McLean. 2011. Do deeper wells mean better water? UA Extension publication, AZ1486c. Tucson, AZ: UA.
- Farrell-Poe, K.**, L. Jones-McLean, and S. McLean. 2011. Maintaining private water well systems. UA Extension publication, AZ1486d. Tucson, AZ: UA.
- Farrell-Poe, K.**, L. Jones-McLean, and S. McLean. 2011. Private water well components. UA Extension publication, AZ1486b. Tucson, AZ: UA.
- Farrell-Poe, K.**, L. Jones-McLean, and S. McLean. 2011. Private well protection. UA Extension publication, AZ1486e. Tucson, AZ: UA.
- Farrell-Poe, K.**, L. Jones-McLean, and S. McLean. 2011. Well water testing and understanding the results. UA Extension publication, AZ1486f. Tucson, AZ: UA.
- Waters, S., **K. Farrell-Poe**, and K. Wagner. 2011. When it rains it runs off: Runoff and urbanized areas in Arizona. UA Extension publication, AZ1542. Tucson, AZ: UA.
- Farrell-Poe, K.** 2010. Arsenic in private water wells. UA Extension publication, AZ1486h. Tucson, AZ: UA.
- Farrell-Poe, K.**, L. Jones-McLean, and S. McLean. 2010. Lead in private water wells. UA Extension publication, AZ1486j. Tucson, AZ: UA.
- Farrell-Poe, K.**, L. Jones-McLean, and S. McLean. 2010. Nitrate in private water wells. UA Extension publication, AZ1486i. Tucson, AZ: UA.
- Farrell-Poe, K.**, L. Jones-McLean, and S. McLean. 2010. Microorganisms in private water wells. UA Extension publication, AZ1486h. Tucson, AZ: UA.
- Farrell-Poe, K.** 2010. Obtaining a water sample for bacterial analysis. UA Extension publication, AZ1486g. Tucson, AZ: UA.
- Artiola, J.F., **K.L. Farrell-Poe**, and K. Uhlman. 2009. Water facts: Home water treatment options. UA Extension publication, AZ1498. Tucson, AZ: UA.
- Berens, R.U., S.E. Poe, E.A. Franklin, and **K.L. Farrell-Poe**. 2009. The effect of education on perception and acceptance of genetically engineered foods on community college students. *Proc. of the 28th Annual National Ag. Mechanics Prof. Devel. Seminar*, vol. XXVIII, pp 1-10.

10. Professional development activities (Most recent)

Attended ASABE Annual Meetings (2009, 2010, 2012, 2013, 2014); Program Assessment and Outcomes Workshop, UA Office of Instruction and Assessment (2015); Attended UA Teaching Academies (2009, 2010, 2011, 2012, 2013); UA College of Agriculture & Life Sciences Leadership Development, Spring 2012; Western Regional Teaching Symposium, September 10-11, 2010, Corvallis, Oregon

1. Name and Academic Rank

Gene A. Giacomelli, Professor

2. Education (degree, discipline, institution, year)

Ph.D.	Plant Science / Biol.&Agric.Eng'r.	Rutgers University	1983
M.S.	Agricultural Engineering.	University of California at Davis	1980
B.S.	Biological & Agricultural Engineering	Rutgers University	1977
B.S.	Agricultural Science	Rutgers University	1977

3. Academic experience (institution, rank, title, dates)

2000-present	Prof.	University of Arizona	Agric. and Biosystems Engr
2000-present	Director	University of Arizona	Controlled Env Ag Center
2001-present	Prof.	University of Arizona	School Plant Sciences
2004-present	Member	University of Arizona	Bio-5 Institute
1999-2000	Director	Rutgers University	Center for Controlled Env Ag
1996-2000	Professor	Rutgers University	Bioresource Engineering Dept
1989-1996	Associate Prof.	Rutgers University	Bioresource Engineering Dept
1983-1989	Assistant Prof.	Rutgers University	Biol. & Ag. Engineering Dept.
1980-1983	Res. Assoc.	Rutgers University	Biol. & Ag. Engineering Dept.

4. Non-academic experiences, consulting/industry, patents

2009 - 2010 Resident CEA Advisor to aerospace company, Aero-Sekur, SpA, Aprilia, Italy.

G.A. Giacomelli, H. Studer, R.C. Cavaletto 1984. Method and Apparatus for Stemming Tomatoes.
US Patent No. 4,472,444.

K.C. Ting, G.A. Giacomelli, W. Kabala, S. Williamson 1991. Piercing Element Gripping Apparatus.
US Patent No. 5,054,831

5. Certifications or professional registrations – none

6. Current membership in professional organizations

1980-present American Society of Agricultural and Biological Engineers (ASABE)

1982-present International Society for Horticultural Science (ISHS)

7. Honors and awards

2015 Emmy, Western Region Emmy Awards for *Earthlight* Documentary <http://cals.arizona.edu/earthlight/>

2012 – 2014 The Lunar Greenhouse Outreach & Teaching Module (LGH-OTM) developed from Arizona-NASA Ralph Steckler Space Colonization grant program with CEAC, Hungry Planets Systems and Services, and Sadler Machine Company. LGH-OTM received awards for educational and training opportunities at San Diego County Fair; Chicago Museum of Science & Industry; and, at Arizona Pavilion at the Biotechnology Industries Organization 2014 Expo.

2013 Finalist, Annual Innovator of the Year – Academia for LGH-OTM Arizona Governor's Celebration of Innovation, Phoenix, AZ

2012 Recipient of "Future Leaders" Award for LGH-OTM. Arizona Governor's Celebration of Innovation, Phoenix, AZ

2007 Moon Society Award for South Pole Food Growth Chamber (with Phil Sadler, SMC)

2005 Outstanding Team Award for CEAC, College of Agriculture and Life Sciences (CALS)

8. Service activities (within and outside of the institution)

Local/Community: Member and Lecturer (2008-present), Organizing Committee, UA-CEAC Annual Greenhouse Crop Production & Engineering Design Short Course.

University: Director CEAC; Chair, ABE PT & CS Comm. (2012-present)

National: Organized NGMA Annual Meeting at CEAC (2013 & 2016); Organized Annual CEAC Greenhouse Crop Production & Engineering Design Short Course (2002 – present); Member, Coalition for Sustainable Organics, inaugural meeting, Phoenix, AZ 2016; Member, SE-303 Environment of Plant Structures Committee, ASABE; Member, USDA Multistate Project Committee NE1035; Member, USDA Regional Committee NCERA-101.

International: Organized AgroSpace Workshop, Sperlonga, Italy (2010, 2012, 2014, 2016), with Aero Sekur (Italy) and DLR (Germany); Member, Comm. Hort. Engineering, ISHS; Member, International Society for Horticultural Science (ISHS)

9. Principal/Selected publications and presentations (from the last five years)

- Giacomelli, G., R. Costantino, and R. Brand, 2016. Role of CEA and Hydroponic Crop Production in the Food, Energy, Water Nexus, 16th National Confence and Global Forum on Science, Policy and the Environment, NSF, Washington, D.C. (invited speaker)
- G. Giacomelli, 2015. Urban Agriculture using Natural Light in Roof-top Greenhouses. Symposium “Plant Factory 2015: Role of Plant Factory and its Contribution to Urban Agriculture and Future Life” Nov. 26-27, 2015, Seoul National University, Seoul, Korea (invited speaker).
- G. Giacomelli, 2015. AgroSpace Studies Benefit Space Agriculture and Earth Applications in Food Production, Seminare nel Futuro Raccogliere nel Presente, Convegno organizzato dalla regione Lazio e Aero-Sekur, Milan Expo 2015, Milan, Italy (keynote speaker).
- G. Giacomelli, 2015. AgTech Investors Conference, Wooster, OH. AGrown, LLC (invited speaker).
- G. Giacomelli, 2015. GreenSYS 2015, Evora, Portugal. ISHS Acta Horticulturae. (keynote speaker).
- G. Giacomelli, 2015. Feeding the World with CEA -- Technology Today and for the Future, ASABE-NABEC’15, Newark, DE, July 12 – 14 (keynote speaker).
- G. Giacomelli, 2015. Technology Challenges for Water Use and more in Controlled Environment Agriculture, High-level International Forum on Protected Horticulture (HIFPH 2015), Shouguang, China. (keynote speaker).
- Tollefson, S., G. Curlango-Rivera, D.A. Huskey, T. Pew, G. Giacomelli and M. C. Hawes. 2014 Altered carbon delivery from roots: rapid, sustained inhibition of border cell dispersal in response to compost water extracts. Plant and Soil, doi: 10.1007/s11104-014-2350-z, Springer International Publishing.
- Villarreal-Guerrero, F., M. Kacira, E. Fitz-Rodríguez, R. Linker, **G. A. Giacomelli**, A. Arbel, C. Kubota. 2013. Implementation of a greenhouse cooling strategy with natural ventilation and variable fogging rates. Transactions of ASABE. Vol. 56(1): 295-304.
- Boscheri, G., M. Kacira, L. Patterson, **G. Giacomelli**, P. Sadler, R. Furfaro, C. Lobascio, M. Lamantea, L. Grizzaffi. 2012. Modified energy cascade model adapted for a multicrop lunar greenhouse Prototype. Advances in Space Research, 50: 941-951
- Villarreal-Guerrero, F., M. Kacira, E. Fitz-Rodríguez, C. Kubota, **G.A. Giacomelli**, R. Linker, A. Arbel. 2012a. Comparison of three evapotranspiration models for greenhouse cooling strategy with natural ventilation and variable high pressure fogging. Scientia Horticulturae, 134: 210-221.
- S. Proietti, S. Moscatello, **G. Giacomelli** and A. Battistelli, 2013. Influence of the interaction between light intensity and CO₂ concentration on productivity and quality of spinach (*Spinacia oleracea* L.) grown in fully controlled environment. Advances in Space Research 52 (2013) 1193–1200.
- Sabeh, N.C., **G. Giacomelli**, C. Kubota. 2011. Water use in a greenhouse in a semi-arid climate, Trans. ASABE. 54(3)

10. Professional development activities (Most recent)

Helped create documentary of Lunar Greenhouse NASA project, 2014; Global Food & Nutrition XPRIZE Expert Visioneering event, Las Vegas, NV, 2016; University & Industry Consortium Conference (UIC), Yuma, AZ, invited presentation for food industry focus on CEA in the Food, Energy, Water Nexus for future of production ag.

1. **Name and Academic Rank**

Bonnie Hurwitz, Assistant Professor

2. **Education** (degree, discipline, institution, year)

Ph.D.	Ecology and Evolutionary Biology	University of Arizona	2012
B.S.	Biochemistry and Molecular Biology	Univ of California-Santa Cruz	1996

3. **Academic experience** (institution, rank, title, dates)

Aug 2014-present	Assist. Prof.	University of Arizona	Agric. and Biosystems Engr.
2012-2014	Prgm Director	University of Arizona	Health Informatics, VP Health Sciences

4. **Not academic experiences, consulting/industry, patents**

2004-2008	Bioinformatics Consultant	Cold Spring Harbor Lab	Ware and Stein Lab
2002-2004	Bioinformatics Scientist	Third Wave Technologies	Dept of Bioinformatics
2001-2002	Project Leader	Accelrys	Bioinformatics Data Serv
1997-2001	Assoc. Bioinformatics Scientist	Incyte Genomics	Bioinformatics Services

Hurwitz, B. and Watts, W. (2014) Bacterial identification in clinical infections, Arizona Board of Regents, Tucson, AZ

Hurwitz, B. et al. (2014) Assays for the direct measurement of gene dosage, Third Wave Technologies, Madison, WI

Hurwitz, B. et al. (2004) Molecules for diagnostics and therapeutics, Incyte Genomics, Palo Alto CA

5. **Certifications or professional registrations**

6. **Current membership in professional organizations**

2015-present	Institute of Biological Engineering
2015-present	American Medical Informatics Association
2014-present	American Society for Oceanography and Limnology
2013-present	American Society for Microbiology
2001-present	International Society for Computational Biology

7. **Honors and awards**

2010	Graduate Research Fellowship, National Science Foundation
2008	Integrative and Graduate Education Research Traineeship, National Science Foundation

8. **Service activities** (within and outside of the institution)

Grant panelist, National Science Foundation: annually, 2015-present, molecular and cellular biology; **NSF invited external reviewer,** >2 proposals in 2 NSF programs/directorates; reviewer; **Manuscript reviewer,** > 20 manuscripts for > 6 journals; **Symposium organizer,** two symposia at UA since 2014. **Chair,** UA Research Computing Governance Committee 2014-present; **Member,** Cluster Hire Search Committee, Ecosystem Genomics (five positions) 2014-present; **Technical Steering Committee Member,** EarthCube ECOGEO RCN 2014-present; **Member,** Search Committee, Engineering Faculty, ABE 2014-present; **Member,** Search committee, Molecular Plant Breeding and Genetics, Plant Sciences 2015-2016; **Member,** Graduate Committee, ABE; **Member,** Provost's committee, big data (four positions) 2015-2016; **Member,** Search Committee, Management Information Systems 2015-2016; **Member,** Search committee, Intestinal Microbiology Faculty, ACBS 2015-2016; **Member,** Search Committee, Pharmacogenomics, College of Pharmacy 2014-2015; **Member,** Search Committee, Director, ACBS 2014-2015. I have coordinated a **two-day computational workshop for under-represented students** from Tucson high schools (20+ students, in 2014); I have served as a **judge at the UA**

STEAMWORKS in 2016. I was a **Workshop Convener**, American Society for Oceanography and Limnology in 2015.

9. Principal/Selected publications and presentations (from the last five years)

- Bouldoc, B., Youens-Clark, K., Roux, S., Hurwitz, B.L., Sullivan, M.B. 2016. iVirus: facilitating new insights in viral ecology with software and community datasets imbedded in a cyberinfrastructure. *ISME*, in press.
- Hurwitz, B.L., U'Ren, J.M. and Youens-Clark, K., 2016. Computational prospecting the great viral unknown. *FEMS Microbiology Letters*, 363(10), p.fnw077.
- Hurwitz, B.L. and U'Ren, J.M., 2016. Viral metabolic reprogramming in marine ecosystems. *Current Opinion in Microbiology*, 31, pp.161-168.
- Armstrong, D.G., Hurwitz, B.L. and Lipsky, B.A., 2015. Set Phages to Stun: Reducing the Virulence of *Staphylococcus aureus* in Diabetic Foot Ulcers. *Diabetes*, 64(8), pp.2701-2703.
- Armstrong, D.G., Lew, E.J., Hurwitz, B. and Wild, T., 2015. The quest for tissue repair's holy grail: The promise of wound diagnostics or just another fishing expedition?. *Wound Medicine*, 8, pp.1-5.
- Brum, J.R., Hurwitz, B.L., Schofield, O., Ducklow, H.W. and Sullivan, M.B., 2015. Seasonal time bombs: dominant temperate viruses affect Southern Ocean microbial dynamics. *The ISME journal*.
- Roux, S., Enault, F., Hurwitz, B.L. and Sullivan, M.B., 2015. VirSorter: mining viral signal from microbial genomic data. *PeerJ*, 3, p.e985.
- Spichler, A., Hurwitz, B.L., Armstrong, D.G. and Lipsky, B.A., 2015. Microbiology of diabetic foot infections: from Louis Pasteur to 'crime scene investigation'. *BMC medicine*, 13(1), p.1.
- Hurwitz, B.L., Brum, J.R. and Sullivan, M.B., 2015. Depth-stratified functional and taxonomic niche specialization in the 'core' and 'flexible' Pacific Ocean Virome. *The ISME journal*, 9(2), pp.472-484.
- Hurwitz, B.L., Westveld, A.H., Brum, J.R. and Sullivan, M.B., 2014. Modeling ecological drivers in marine viral communities using comparative metagenomics and network analyses. *Proceedings of the National Academy of Sciences*, 111(29), pp.10714-10719.
- Rankin, T.M., Giovinco, N.A., Cucher, D.J., Watts, G., Hurwitz, B. and Armstrong, D.G., 2014. Three-dimensional printing surgical instruments: are we there yet?. *Journal of Surgical Research*, 189(2), pp.193-197.
- Hurwitz, B.L., Hallam, S.J. and Sullivan, M.B., 2013. Metabolic reprogramming by viruses in the sunlit and dark ocean. *Genome Biol*, 14(11), p.R123.
- Hurwitz, B.L. and Sullivan, M.B., 2013. The Pacific Ocean Virome (POV): a marine viral metagenomic dataset and associated protein clusters for quantitative viral ecology. *PLoS One*, 8(2), p.e57355.
- Hurwitz, B.L., Deng, L., Poulos, B.T. and Sullivan, M.B., 2013. Evaluation of methods to concentrate and purify ocean virus communities through comparative, replicated metagenomics. *Environmental microbiology*, 15(5), pp.1428-1440.

10. Professional development activities (Most recent)

Attended two NSF CAREER award lecture series (at UA in 2015 and at NSF Headquarters 2016); Attended grant writing Workshop by the UA Office of Research; Attended instruction workshops by the UA Office of Instruction and Assessment (2015); Attended and gave invited talks: Diabetic Limb Salvage Conference, Washington, D.C. (2016); University of Michigan Institute for Data Science Distinguished Lecture Series (2016); Ocean Sciences Meeting, Town hall, New Orleans, LA. (2016); Plant Animal Genome Conference, San Diego, CA. (2016); University of Hawaii, Dept. of Oceanography, Honolulu Hawaii (2015); ASM ICAAC, San Diego, CA. (2015); Woods Hole Oceanographic Institute, Woods Hole, MA. (2015); 7th International Symposium on the Diabetic Foot, The Hague, Netherlands (2015); Diabetic Limb Salvage Conference, Washington, D.C. (2014); DFCon, Los Angeles, CA (2014); Plant Animal Genome Conference, San Diego, CA (2014); American Society for Microbiology, Viromics Workshop (2014).

1. Name and Academic Rank

Murat Kacira, Professor

2. Education (degree, discipline, institution, year)

Ph.D.	Food, Agric. and Biological Engr.	Ohio State University	2000
M.S.	Food, Agric. and Biological Engr.	Ohio State University	1996
B.S.	Agricultural Engineering	Cukurova University	1991

3. Academic experience (institution, rank, title, dates)

July 2015-present	Professor	University of Arizona	Agric. and Biosystems Engr.
2007-2015	Assoc. Prof.	University of Arizona	Agric. and Biosystems Engr.
2005-2007	Assoc. Prof.	Haran University, Turkey	Agricultural Machinery
2000-2005	Assist. Prof	Harran University, Turkey	Agricultural Machinery
2003-2004	Vist. Scholar	Lab. Cont. Envr. Agric., Japan	National Inst. Rural Engr.

4. Not academic experiences, consulting/industry, patents

Jia, F., M. Kacira, K. Ogden, G. Ogden. 2015. Optical Device for inline and realtime monitoring of microalgae. US Provisional Patent Application. UA Ref. No: UA15-095.

Ryan, R., P. Waller, M. Kacira, P. Li. 2012. Aquaculture raceway integrated design. US Patent No: US 8245440 B2.

5. Certifications or professional registrations

6. Current membership in professional organizations

1999-present	American Society of Agricultural and Biological Engineers (ASABE)
2008-present	International Society for Horticultural Science (ISHS)

7. Honors and awards

2014	ASABE Superior Paper Award, ASABE, Montreal, Canada
2014	EurAgEng Outstanding Paper Award Nomination, Biosystems Engineering Journal, Switzerland
2011	Early Career Faculty Teaching Award Nomination, UA-CALS
2010	Leading Edge Research Award, University of Arizona, as a UA-CEAC Team Member.
2008	Grand challenge award, Bio Energy Awareness Days, USDA

8. Service activities (within and outside of the institution)

Local/Community: Member and Lecturer (2008-present), Organizing Committee, UA-CEAC Annual Greenhouse Crop Production & Engineering Design Short Course.

University: Director of Grad. Studies, Prof. Sci. Master's Program, CEA Track, App. Biosci. GIDP (2011-present); Executive Comm. Member, Applied Biosciences GIDP (2011-present); Chair, ABE Academic Programs Asses. Comm. (2012-present); Member, ABE Biosystems Engr. Undergrad. Curriculum Comm. (2008-present); Member, UA-CALS Vision 2021 Comm. (2012)

National: Secretary (2010), Vice-Chair (2011), Chair (2012), SE-303 Environment of Plant Structures Committee, ASABE; Member (2008- 2013), Secretary (2010, 2013), Chair (2011), USDA Multistate Project Committee NE1035; Member (2008-present), USDA Regional Committee NCERA-101.

International: Elected Chair (August 2014-present), Vice-Chair (2010-2014), Comm. Hort. Engineering, ISHS; Member (August 2014-present), Executive Committee, Int. Society for Hort. Science (ISHS); Chair (2013-2015), Vice-Chair (2008-2013), ISHS CFD Working Group; Member (2010-2015), Int. Comm. for Contr. Envir. Guidelines on Monitoring & Reporting Envr.

Parameters for Experiments in Greenhouses: Member of Sci. Comm. for Int. Sym. and Congress, Meetings, 9 total since 2009: Editorial Board Member, Euro. Journal of Hort. Sci. (2015-present)
Peer Reviewer for Scientific Journals: Trans. of ASABE, Biosystems Engr., Applied Engr. in Agric., Computers and Electronics in Agric., ActaHorticulturae, Agric. and Forest Meteorology, HortTechnology, ScientiaHorticulturae, Environment, Systems and Decisions, Computers in Biology and Medicine, European J. of Hort. Sci.
Peer Review of Proposals: Natural Sci. & Engr. Res. Council, Canada, USDA NIFA, USDA SBIR, USDA SBIR, USDA Hatch, Binational Agric. & Res. Devp. Fund (BARD), The Sci. & Tech. Res. Council, Turkey.

9. **Principal/Selected publications and presentations** (from the last five years)

- Zhang, Y., **M. Kacira**, L. An. 2016. A CFD study on improving air flow uniformity in indoor plant factory system. Biosystems Engineering, 147: 193-205.
- Jia, F., **M. Kacira**, K. Ogden. 2015. Multi-Wavelength Based Optical Density Sensor for Autonomous Monitoring of Microalgae. Sensors, 15(9): 22234-22248.
- Story, and **M. Kacira**. 2015. Design and implementation of a computer vision-guided greenhouse crop diagnostics system. J. of Machine Vision Applications, March 2015, 1432-1769.
- Tamimi, E., **M. Kacira**, C. Choi, L. An. 2013. Analysis of climate uniformity in a naturally ventilated greenhouse equipped with high pressure fogging system. Trans. of ASABE, 56(3): 1241-1254.
- Villarreal-Guerrero, F., **M. Kacira**, E. Fitz-Rodríguez, R. Linker, G. A. Giacomelli, A. Arbel, C. Kubota. 2013. Implementation of a greenhouse cooling strategy with natural ventilation and variable fogging rates. Trans. of ASABE, 56(1): 295-304.
- Bartzanas, T., **M. Kacira**, H. Zhu, S. Karmakar, E. Tamimi, N. Katsoulas, I. Lee, C. Kittas. 2013. Computational fluid dynamics applications to improve crop production systems. Computers and Electronics in Agriculture, 93: 151-167
- Sase, S., **M. Kacira**, T. Boulard, L. Okushima. 2012. Determination of porosity parameters for tomato canopy: An experimental study in a wind tunnel. Trans. of the ASABE, 55(5): 1921-1927
- Waller, P., R. Ryan, **M. Kacira**, P. Li. 2012. The algae raceway integrated design for optimal temperature management. Biomass and Bioenergy, 46: 702-709
- Boscheri, G., **M. Kacira**, L. Patterson, G. Giacomelli, P. Sadler, R. Furfaro, C. Lobascio, M. Lamantea, L. Grizzaffi. 2012. Modified energy cascade model adapted for a multicrop lunar greenhouse prototype. Advances in Space Research, 50: 941-951
- Villarreal-Guerrero, F., **M. Kacira**, E. Fitz-Rodríguez, R. Linker, C. Kubota, G.A. Giacomelli, A. Arbel. 2012. Simulated performance of a greenhouse cooling control strategy with natural ventilation and fog cooling. Biosystems Engineering, 111: 217-228.
- Linker, R., **M. Kacira**, A. Arbel. 2011. Robust climate control of a greenhouse equipped with variable-speed fans and a variable-pressure fogging system. Biosystems Engr. 110(2): 153-167.
- Striemer, G.M., D. L. Story, A. Akoglu and **M. Kacira**. 2011. A node and network level self-recovering distributed wireless sensor architecture for real-time crop monitoring in greenhouses. Transactions of ASABE, 54(4): 1521-1527.
- Story, D., **M. Kacira**, C. Kubota, A. Akoglu, L. An. 2010. Lettuce calcium deficiency detection with machine vision computed plant features in controlled environments. Computers and Electronics in Agriculture, 74: 238-243.

10. **Professional development activities** (Most recent)

Attended ASABE Annual Meetings (2009, 2010, 2012, 2013, 2014); Attended ISHS GreenSys Int. Symposiums (2009, 2011, 2013, 2015); International Organic Greenhouse Hort. Symposium (2016), Program Assessment and Outcomes Workshop, UA Office of Instruction and Assessment (2015); Executive Comm. Meeting of Int. Soc. of Hort. Sci. (ISHS) (Turkey, 2015); Online Course Development, UA CALS Summer Institute (2015); High-level International Forum on Protected Horticulture, China (2015).

1. Name and Academic Rank

Peter Livingston, Associate Professor of Practice

2. Education (degree, discipline, institution, year)

Ph.D.	Biosystems Engr.	University of Arizona	2013
M.S.	Food, Agric. and Biological Engr.	Colorado State University	1982
B.S.	Agricultural Engineering	University of Arizona	1991

3. Academic experience (institution, rank, title, dates)

July 2013-present	Assoc. Prof.	University of Arizona	Agric. and Biosystems Engr.
2005-2013	Mentor	University of Arizona	Agric. and Biosystems Engr.

4. Not academic experiences, consulting/industry, patents

2004 – Present: Bosque Engineering, LLC
1997 – 2004: Westland Resources
2000-2004: SWCA Environmental Consultants
1992- 2000: CH2M Hill
1992 – 1995: Tohono O’Odham Natio
1992: Franzoy Corey Engineering.

5. Certifications or professional registrations

Professional Engineer, Agricultural Engineering, 1987

6. Current membership in professional organizations

1980-present	American Society of Agricultural and Biological Engineers (ASABE)
2000-present	Arizona Hydrological Society

7. Honors and awards

2016 Honorary member, FFA

8. Service activities (within and outside of the institution)

Local/Community: 2004 – Present: Tanque Verde Unified School District Governing Board.
Pima County Department of Environmental Quality Advisory Committee.
University: 2013 to Present: Chair of Undergraduate Curriculum Committee, Chair of Marketing and Branding Committee, Chair of Centennial Committee. Member of COE Dean’s Undergraduate Curriculum Committee. National: ABET PEV and ABET Commissioner. ASABE member of Irrigation and Accreditation Committees

9. Principal/Selected publications and presentations (from the last five years)

Teegerstrom, Trent, Livingston, Peter, and Slack, Donald. 2015. Sweet Sorghum to Ethanol A Guidance Manual for the Grower. Proceedings of Thai Society of Agricultural Engineering International Symposium, April 2015.

Livingston, Peter, Gene Giacomelli, and Slack, Donald. 2014 Management of the Schmutzdecke Layer in a Slow Sand Filter to Reuse Drainage Water from a Greenhouse. Proceedings of 2014 KAU International Engineering Conference, March 2014.

Livingston, Peter, and Slack, Donald. Pilot-Scale Continuous Conveyor Diffusion Extraction System for Sweet Sorghum. Proceedings of 2014 KCU International Engineering Conference, March 2014.

Livingston, Peter and Slack, Donald. 2013 Management of the Schmutzdecke Layer in a Slow Sand Filter. Proceedings of 2013 Thai Society of Agricultural Engineering International Symposium, April 2013.

Currier, Kristen; Lau, Theresa; Yanes, Merianna; Livingston, Peter; and Slack, Donald. 2013. Sweet Sorghum Diffusion Extraction System. Proceedings of 2013 Thai Society of Agricultural Engineering International Symposium, April 2013.

McCracken, Katie; Espinoza, Paola; York, Greg; and Livingston, Peter. 2013. Hydroponic Barley Fodder System. Proceedings of 2013 Thai Society of Agricultural Engineering International Symposium, April 2013.

Livingston, Peter. 2013. Biofuels in Arizona, Presented at 2013 Southwest Indian Agriculture Association

10. Professional development activities, (Most recent)

Attended Thai Society of Agricultural Engineering Annual Meeting (2013), Kaun Keen University International Engineering Conference (2014); Attended Cornell Aquaculture Short Course, 2013; Attended Southwest Indian Agriculture Association Meeting (2013).

1. Name and Academic Rank

Stephen E. Poe, Specialist & Professor

2. Education (degree, discipline, institution, year)

Ph.D.	Agricultural Engineering	Purdue University	1987
M.S.	Agricultural Education	Purdue University	1981

3. Academic experience (institution, rank, title, dates)

1998-present	Professor	University of Arizona	Agric. and Biosystems Engr.
1988-1998	Assist./Assoc. Professor	Utah State University	Ag. Systems Technology & Ed.

4. Not academic experiences, consulting/industry, patents

2005	Circle Four Farms	Waste Management	Milford, UT
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5. Certifications or professional registrations

NAWT Certified Inspector, maintained since 2001

6. Current membership in professional organizations

1989-present American Society of Agricultural and Biological Engineers (ASABE)

7. Honors and awards

8. Service activities (within and outside of the institution)

University: UA Committee on Academic Freedom and Tenure, CALS Post Tenure Review

National: American Society of Ag & Biological Engineers member (1980-present); National FFA Superintendent/Associate Ag Mechanics.(1980-present)

9. Principal/Selected publications and presentations (from the last five years)

Poe, S.E., K. Farrell-Poe, C. Daily. 2014. Irrigation. Arizona Master Gardener Manual. Irrigation, chapter 18.

Berens, R.U., S.E. Poe, E.A. Franklin, and **K.L. Farrell-Poe**. 2009. The effect of education on perception and acceptance of genetically engineered foods on community college students. Proc. of the 28th Annual National Ag. Mechanics Prof. Devel. Seminar, vol. XXVIII, pp 1-10.

10. Professional development activities (Most recent)

Attended ASABE Annual Meetings (2009, 2010, 2012, 2013, 2014); Program Assessment and Outcomes Workshop, UA Office of Instruction and Assessment (2015); Attended UA Teaching Academies (2009, 2010, 2011, 2012, 2013); UA College of Agriculture & Life Sciences Leadership Development, Spring 2012; Western Regional Teaching Symposium, September 10-11, 2010, Corvallis, Oregon

1. Name and Academic Rank

Pedro Andrade-Sanchez, Associate Professor

2. Education (degree, discipline, institution, year)

Ph.D.	Agric. and Biological Engr.	University of California Davis	2004
M.S.	International Ag. Development	University of California Davis	1997
B.S.	Soil Science	University of Chihuahua	1987

3. Academic experience (institution, rank, title, dates)

June 2014-present	Assoc. Prof.	University of Arizona	Agric. and Biosystems Engr.
2007-2014	Assist. Prof.	University of Arizona	Agric. and Biosystems Engr.
2006-2007	Post-doc	Washington State University	Center for Prec. Ag. Systems
2004-2006	Researcher	National Ag. Res. System	Tillage Research

4. Not academic experiences, consulting/industry, patents

Soil profile force measurement using an instrumented tine. United States Patent No. US 6,834,550 B2. December 2004.

Plant height measurement system for mobile platforms. Provisional Patent Application No. UA11-135. August 2011.

5. Certifications or professional registrations

6. Current membership in professional organizations

1999-present	American Society of Agricultural and Biological Engineers (ASABE)
2008-present	NCERA-180 North Central Extension and Research Activity - Site-Specific Crop Management Project

7. Honors and awards

2009 Superior Paper Award. American Society of Agricultural and Biological Engineers (ASABE).

2005 Graduate Student Research Award, 3rd place in Ph.D. category. American Society of Agricultural and Biological Engineers (ASABE).

1996/2005 Jastro Shields Research Award. University of California Davis (1996 and 2000).

8. Service activities (within and outside of the institution)

Local/Community: Central Arizona College-Engineering Technology Division Advisory Committee, (2010-present).

University: Cooperative Extension Integrated Crop Management Working Group (2007-present); Member, ABE Marketing and Branding Committee; Member

National: PM-54 Precision Agriculture Committee, ASABE; Member (2009-date), PM-45 Soil Dynamics Research Committee, ASABE; Member (1999-date).

Peer Reviewer for Scientific Journals: Trans. of ASABE, Biosystems Engr., Applied Engr. in Agric., Computers and Electronics in Agric.

9. Principal/Selected publications and presentations (from the last five years)

Thorp K.R., M.A. Gore, **P. Andrade-Sanchez**, A.E. Carmo-Silva, S.M. Welch, J.W. White, A.N. French. 2015. Proximal hyperspectral sensing and data analysis approaches for field-based plant phenomics. Computers and Electronics in Agriculture 118(12) 225-236. DOI: 10.1016/j.compag.2015.09.005

- Hunsaker D.J., A.N. French, P.M. Waller, E. Bautista, K.R. Thorp, K.F. Bronson, **P. Andrade-Sanchez**. 2015. Comparison of traditional and ET-based irrigation scheduling of surface-irrigated cotton in the arid southwestern USA. *Agricultural Water Management*. 159 209-224. DOI: 10.1016/j.agwat.2015.06.016
- Yang S., R. J. Kaggwa, **P. Andrade-Sanchez**, M. Zarnstorff, G. Wang. 2015. Lint yield compensatory response to main stem node removal in upland cotton (*Gossypium hirsutum*). *Journal of Agronomy and Crop Science*. DOI: 10.1111/jac.12142.
- Andrade-Sanchez P.**, M.A. Gore, J.T. Heun, K.R. Thorp, A.E. Carmo-Silva, A.N. French, M.E. Salvucci, and J.W. White. 2014. Development and evaluation of a field-based high-throughput phenotyping platform. *Functional Plant Biology* 41(1) 68-79.
- Kaggwa-Asiimwe R., **P. Andrade-Sanchez**, G. Wang. 2013. Plant architecture influences growth and yield response of upland cotton to population density. *Field Crops Research* 145: 52-59.
- Carmo-Silva E.A., M.A. Gore, **P. Andrade-Sanchez**, A.N. French, D.J. Hunsaker, M.E. Salvucci. 2012. Decreased CO₂ availability and inactivation of Rubisco limit photosynthesis in cotton plants under heat and drought stress in the field. *Envir. and Experimental Botany*.83: 1-11.
- Bagiotto-Rosato O., **P. Andrade-Sanchez**, S.P. Sebastiao-Guerra, and C.A. Costa-Cruscio. 2012. Use of reflectance and fluorescence sensors to test the effect of Nitrogen fertilizer rates on biomass production and productivity of cotton. *Brasilian Agric. Research*. 47 (8): 1133-1141
- White J.W., **P. Andrade-Sanchez**, M.A Gore, K.F Bronson, T.A. Coffelt, M.M. Conley, K.A. Feldmann, A.N. French, J.T. Heun, D.J. Hunsaker, M.A. Jenks, B.A. Kimball, R.L. Roth, R.J. Strand, K.R. Thorp, G.W. Wall, G. Wang. 2012. Field-based phenomics for plant genetics research. *Field Crops Research* 133: 101-112.

Peer-reviewed Extension Bulletins:

- Andrade-Sanchez P.** and Heun J.T. 2013. Operation of yield monitors in Central Arizona: Grains and cotton. Bulletin AZ1598. The University of Arizona - Cooperative Extension. Tucson, Arizona 85721
- Andrade-Sanchez P.** and Heun J.T. 2013. Yield monitoring technology for irrigated cotton and grains in Arizona: Hardware and software selection. Bulletin AZ1596. The University of Arizona - Cooperative Extension. Tucson, Arizona 85721
- Andrade-Sanchez P.** and Heun J.T. 2012. From GPS to GNSS: Enhanced functionality of GPS-integrated systems in agricultural machines. Bulletin AZ1558. The University of Arizona - Cooperative Extension. Tucson, Arizona 85721
- Wang G., R. K. Asiimwe, and **Pedro Andrade**. 2011. Growth and yield response to plant population of two cotton varieties with different growth habits. *Cotton Research & Outreach* 2010-2011 Bulletin AZ1548. The University of Arizona - Cooperative Extension. Tucson, Arizona 85721
- Andrade-Sanchez P.** and Heun J.T. 2011. A general guide to Global Positioning Systems (GPS) – Understanding operational factors for agricultural applications in Arizona. Bulletin AZ1553. The University of Arizona - Cooperative Extension. Tucson, Arizona 85721

Book Chapters:

- Andrade-Sanchez P.** and Upadhyaya S. 2007. Book Chapter: Using GIS and on-the-go soil strength sensing technology for variable-depth tillage assessment. *GIS Applications for Agriculture*, Volume I, by Francis J. Pierce. CRC Press-Taylor and Francis Group, Boca Raton, Florida.
- Andrade-Sanchez P.** and Chancellor W.J. 2007. Chapter 3, Part IV: Empirical Determination of Draft, Energy and Soil Condition in Tillage Studies. *Advances in Soil Dynamics Volume III*. Shrinivasa K. Upadhyaya Editor. American Society of Agricultural and Biological Engineers. St. Joseph, Michigan.

10. Professional development activities (Most recent)

Attended ASABE Annual Meetings (2009, 2010, 2012, 2013)

1. Name and Academic Rank

Mark C. Siemens, Associate Specialist and Professor

2. Education (degree, discipline, institution, year)

Ph.D.	Agricultural & Biosystems Engineering	University of Arizona	1996
M.S.	Mechanical and Industrial Engineering	University of Illinois	1990
B.S.	Mechanical and Industrial Engineering	University of Illinois	1988

3. Academic experience (institution, rank, title, dates)

2008-present	Assoc. Specialist/Prof.	University of Arizona	Agric. & Biosystems Engr.
1999-2008	Agricultural Engineer	USDA-ARS	CPCRS, Pendleton, OR
1997-1998	Asst. Prof./Ext. Engineer	University of Georgia	Biological & Agric. Engr.

4. Not academic experiences, consulting/industry, patents

Siemens, M.C. & Gayler, R.R. 2014. Seed metering system and apparatus for precision metering of seed. Invention Disclosure. University of Arizona Tech Launch Arizona. Docket Number UA 15-098. 7 pp.

Siemens, M.C. & Gayler, R.R. 2012. A solenoid valve and nozzle configuration for precision thinning, weeding and spot spraying. U.S. Provisional Patent Application. 25 Jan. 2012. 31 pp

Siemens, M.C., Herbon, R., Gayler, R.R. & Nolte, K.D. 2011. Automated machine for selective *in-situ* manipulation of plants. International Patent Application No. PCT/US2011/064957. 14 December 2011. 74 pp.

Siemens, M.C., Herbon, R., Gayler, R.R. & Nolte, K.D. 2011. Automated machine for selective *in-situ* manipulation of plants. U.S. Provisional Application No. 61/552,728. 28 Oct. 2011. 77 pp.

Siemens, M.C., Correa, R.F. & Wilkins, D.E. 2002. Flexible ground-driven residue management wheel. United States Patent No. US 6,345,671 B1.

5. Certifications or professional registrations

Illinois EIT

6. Current membership in professional organizations

1991-present American Society of Agricultural and Biological Engineers (ASABE)

7. Honors and awards

2015 Elsevier Outstanding Reviewer – Computers and Electronics in Agriculture

2014 ASABE Certificate of Appreciation for Support and Contributions in Revision of ASAE Standard S477.1, “Terminology for Soil-Engaging Components for Conservation-Tillage Planters, Drills and Seeders”.

8. Service activities (within and outside of the institution)

Local/Community: Member (2008-Present), Technical Session Organizer and Session Moderator (2008-Present), Southwest Ag Summit Planning Committee, Yuma Fresh Vegetable Association (YFVA); Chair (2008-2011), Field Demonstration Planning Committee, Southwest Ag Summit Planning Committee, YFVA.

University: Member (2014-present) Marketing and Branding Committee, Dept. of Agricultural and Biosystems Engineering (ABE); Member (2010-present) Forward Planning Committee, ABE; Member (2009-present) Promotions and Tenure Committee, ABE; Member (2008-2009) Ag Systems Management Program Committee, ABE.

National: Member (2008-Present), Vice-Chair (2012), Chair (2013-2014), Past-Chair (2015-2016), MS 48 Specialty Crop Production Engineering Committee, ASABE; Member (2014-Present), MS-58

Agricultural Equipment Automation Committee, ASABE; Member (2013-Present), Organizer (2016) USDA Multistate Project Committee W2009; PM-48 Representative (2012-2014), PM 02/03 Steering/Standards Committees, ASABE; FPE-712 Representative (2012-2014), FPE 01/02/03 Executive and Steering, Standards Committee; Member (1996-Present), Sub-Committee Chair (2010-2013), PM 42 Cultural Practices Equipment Committee, ASABE.

International: Member (2013-2014), Intl. Horticulture Congress Scientific Committee (ISHS).

Peer Reviewer for Scientific Journals: Trans. ASABE, Biosyst. Eng., Applied Eng. in Agric., Comput. and Electron. in Agric., Agric. Engr. Intl.: CIGR J., Proc. 29th Intl. Hort. Conf., Spanish J. Agric. Res., 120th ASAE Conf. and Expo., Univ. of Arizona Coop. Ext. Publ., Virginia Tech Ext. Publ.

9. **Principal/Selected publications and presentations** (from the last five years)

Fennimore, S.A., Slaughter, D.C., **Siemens, M.C.**, Leon, R.G. & Saber, M.N. 2016. Technology to automate weed control for specialty crops. *Weed Tech.* (submitted).

Siemens, M.C. & Gayler, R.R. 2016. Improving seed spacing uniformity of precision vegetable planters. *Applied Eng. in Agric.* (accepted).

Lati, R.N., **Siemens, M.C.**, Rauchy, J.S. & Fennimore, S.A. 2016. Intra-Row weed removal in broccoli and transplanted lettuce with an intelligent cultivator. *Weed Tech.* (in-press).

Siemens, M.C. & Kirchhoff, C. 2016. Robovator – Robotic Intra-Row Weeding, Automated Technologies Field Day, Yuma, Ariz., January 15. 30 minutes. Attendance - 55.

Siemens, M.C. & Soni, A. 2015. Web-Based Tool for Analyzing Planter and Automated Lettuce Thinning Machine Performance V.1. Tucson, Ariz.: University of Arizona. Available at <http://seedandplantspacinganalyzer.webhost.uits.arizona.edu/sps-analyzer>.

Siemens, M.C., Nolte, K.D., Gayler, R.R. Gayler & Wang, S. 2015. Innovative Cultural Practices for Improving Nutrient Use Efficiency. 2015 Southwest Ag Summit, Yuma, Ariz., 25 February. Attendance 300.

Siemens, M.C. Robotic weed control. 2014. In Proc. 66th Annual California Weed Science Society 66: 76-80. Salinas, Calif.: California Weed Science Society.

Fennimore, S.A., Hanson, B. D., Sosnoskie, L. M., Samtani, J. B., Datta, A., Knezevic, S. Z. & **Siemens, M. C.** 2013. Chapter 9: Field Applications of Automated Weed Control: Western Hemisphere. In Automation: The Future of Weed Control in Cropping Systems, 151-169. S.L. Young and F.J. Pierce, eds. Dordrecht: Springer Science+Business Media.

Siemens, M.C., Herbon, R., Gayler, R.R., Nolte, K.D. & Brooks, D. 2012. Automated machine for thinning lettuce - Evaluation and development. ASABE paper No. 12-1338169, pp. 14. St. Joseph, Mich: ASABE.

Siemens, M.C., Herbon, R. & Gayler, R.R. 2011. Development and Demonstration of an Automated Machine for Thinning Lettuce. University of California Cooperative Extension Field Day, Salinas, Calif., May 26. 2 hours. Attendance - 65.

Nolte, K.D., **Siemens, M.C.** & Andrade-Sanchez, P. 2011. Integrating variable rate technologies for soil-applied herbicides in Arizona vegetable production. Arizona Cooperative Extension Publication AZ1538. Tucson, Ariz.: University of Arizona College of Agriculture and Life Sciences.

Siemens, M.C., Nolte, K.D. & Gayler, R.R. 2011. Improving lettuce production through utilization of spike wheel liquid injection systems. ASABE paper No. 1111245, pp. 11. St. Joseph, Mich.: ASABE.

10. **Professional development activities** (Most recent)

ASABE Annual Meetings (2009-2015); ASABE CPD Developing Native Apps for Android Devices (20015); CALS Effective Workplace Communication (2012); UNM-MTEC Solid Modeling Design Short course (2012); ASABE CPD Hydraulic System Design (2010); CALS Drupal Training (2009); ASABE CPD Hyperspectral and Multispectral Imaging (2008).

1. Name and Academic Rank

Donald C. Slack, Professor

2. Education (degree, discipline, institution, year)

Ph.D.	Agricultural Engineering	University of Kentucky	1975
M.S.	Agricultural Engineering	University of Kentucky	1968
B.S.	Agricultural Engineering	University of Wyoming	1965

3. Academic experience (institution, rank, title, dates)

1984- Present	Professor	University of Arizona	Agric. and Biosystems Engr.
1991-2009	Dept. Head	University of Arizona	Agric. and Biosystems Engr
Oct. 2012-Feb. 2014	Interim Head	University of Arizona	Agric. and Biosystems Engr
2009- June-Nov.	Visiting Prof.	Khon Kaen University, Thailand	Agricultural Engineering
2000 – Jul-Dec	Visiting Prof.	Chapingo Autonomous University	Texcoco, Mexico
1975-1984	Assoc. Prof.	University of Minnesota	Agricultural Engineering
1973-1975	Research Asst.	University of Kentucky	Agricultural Engineering
1970-1973	Adjunct Lect.	Khon Kaen University, Thailand	Agricultural Engineering

4. Non academic experiences, consulting/industry, patents

January 2010-October 2012: Consultant to Gila Valley and Duncan Irrigation Districts in SE Arizona on ET and water use of crops grown in the districts.

May 2012 – May 2014: Consultant to Desert Whale Jojoba Company, Tucson, AZ on drip irrigation, water allocation and watershed management/hydrology

5. Certifications or professional registrations

Registered Professional Engineer – Arizona and Kentucky

6. Current membership in professional organizations

1965-present	American Society of Agricultural and Biological Engineers (ASABE) - Fellow
1965-present	American Society of Civil Engineers (ASCE) – Fellow and Life Member
1990- present	U.S. Committee on Irrigation and Drainage (USCID) – Life Member
1994 - present	Thai Society of Agricultural Engineers (TSAE) – Life Member

7. Honors and awards

2014	Excellence in Global Education Award. UA, Office of Global Initiatives
2013	Administrator of the Year, UA College of Ag. and Life Sciences
2006	Cecil H. Miller, Jr. and Cecil H. Miller, Sr. Families, Dean's Chair for Excellence in
Present	Agriculture and Life Sciences, UA, CALS
2011	Kishida International Award, ASABE
2010	Honorary Doctorate in Agricultural Engineering, Khon Kaen University, Thailand

8. Service activities (within and outside of the institution)

Local/Community: Technical Advisory Committee, Altar Valley Conservation Alliance (2014-present)
University: ABE Academic Programs Asses. Comm. (2010-present); Member, ABE Biosystems Engr. Grad. Comm. (2010-present); Member, University of Arizona, International Travel Safety Oversight Committee, Subject Matter Expert (2015- present). Member, University of Arizona, Arid Lands Steering Committee,(2014-present). Faculty Advisor – Alpha Epsilon, Arizona Eta Beta Chapter (2009-present).

National: ABET Engineering Accreditation Commission – Executive Committee, 2015-Present; ABET Engineering Accreditation Commission – Commissioner 2010-2015; ABET Program Evaluator for Agricultural and Biological and Civil Engineering Programs, 2001-present; ABET Board of Delegates, 2015-present.; ASABE Committee for Establishment of a New International Service Award, Chair; ASABE Kishida International Award Committee, 2012-2015, Member; USDA Multistate Project Committee W3128; Member (2013-present).

International: Member, Editorial Advisory Board, “Journal for Scientific Research – Agricultural Sciences”, Sultan Qaboos University. Muscat, Oman., 1999-present; Member, Scientific Editorial Council, “Revista Ciência Agronômica” Journal of Agronomic Science). Brazil. 2005 – Present; Member, Editorial Board. “KKU Engineering Journal”, Khon Kaen University, Faculty of Engineering, Khon Kaen, Thailand. 2013-present.

Peer Reviewer for Scientific Journals: Irrigation and Drainage (ICID); Advances in Water Resources.

Peer Review of Proposals: Binational Agric. & Res. Devp. Fund (BARD)

9. Principal/Selected publications and presentations (from the last five years)

Martínez-Cruz T. E., Slack D. C., Ogden K. L., and Ottman M. (2014) THE WATER USE OF SWEET SORGHUM AND DEVELOPMENT OF CROP COEFFICIENTS, Irrig. and Drain., doi:10.1002/ird.1882.

Sanchez Cohen, I., G.D. Padilla, M.V. Valle, D. Slack, P. Heilman and A.P. Sandoval. 2014. A Decision Support System for Rainfed Agricultural Areas of Mexico. Computers and Electronics in Agriculture. 04/2015; 114. DOI:10.1016/j.compag.2015.03.009.

Villarreal, L, P. Waller and D.C. Slack. 2010. Water Conservation in Biofuels Development: Greenhouse and Field Crop Production with Biochar. Lambert Academic Publishing. 256p.

Slack, D.C. and M.J. Liga. 2010. A Modeling Approach to Determination of Appropriate Depth and Spacing of Subsurface Drip Irrigation Tubing. Proceedings of the International Conference on Technology and Innovation for Sustainable Development. Nongkhai, Thailand. March 4-6, 2010. pp.

Martínez, T.E., D.C. Slack, K.L. Ogden and M. Ottman. 2012. The Effect of Water Stress on Sweet Sorghum (*Sorghum bicolor* (L.) Moench) and the Development of Crop Coefficients. Proceedings of the 4th KKU International Conference 2012 (KKU-IENC 2012). Khon Kaen Thailand. May 10-12, 2012.

Rojas, I., D.C. Slack, M. Riley and M. Orbach. 2012. Bioconversion of Lignocellulosic Components of Sweet Sorghum Stalks to Ethanol Utilizing Fungi and Yeast. Proceedings of the 4th KKU International Conference 2012 (KKU-IENC 2012). Khon Kaen Thailand. May 10-12, 2012

Yanes, M., K. Currier, T. Lau, D. Slack and P. Livingston. 2013. Pilot Scale Continuous Conveyor Diffusion Extraction System for Sweet Sorghum. Proceedings of the 6th International Conference of TSAE. Thai Society of Agricultural Engineers. April 1-4, Hua Hin, Thailand.

Terrazas-Onofre, L., D. Slack, D. Lopez and C. Gerba. 2015. Solar Disinfection of Grey Water. Proceedings of the 8th International Conference of TSAE. Thai Society of Agricultural Engineers. March 17-19, Bangkok, Thailand

Teegerstrom, T., P. Livingston and D. Slack. 2015. Sweet Sorghum to Ethanol: A Guidance Manual for the Grower. Proceedings of the 8th International Conference of TSAE. Thai Society of Agricultural Engineers. March 17-19, Bangkok, Thailand

10. Professional development activities (Most recent)

Attended ASABE Annual International Meetings (2011-2015); Attended International Engineering Conference – KKUIENC in Khon Kaen, Thailand, (2010, 2012, 2014); Attended International Meeting of the Thai Society of Agricultural Engineers (2013, 2015). Attended ABET Symposium, 2016.

1. **Name and Academic Rank**

Peter Waller, Associate Professor

2. **Education** (degree, discipline, institution, year)

Ph.D.	Agricultural Engineering	University of California, Davis	1992
M.S.	Agricultural Engineering	University of California, Davis	1989
B.S.	Agricultural Engineering	University of California, Davis	1981

3. **Academic experience** (institution, rank, title, dates)

1999-present	Assoc. Prof.	University of Arizona	Agric. and Biosystems Engr.
1994-1999	Assist. Prof	University of Arizona	Agric. and Biosystems Engr.
1992-1993	Post-doc	National Soil Tilt Lab.	Agricultural Engineering

4. **Not academic experiences, consulting/industry, patents**

Ryan, R., P. Waller, M. Kacira, P. Li. 2012. Aquaculture raceway integrated design. US Patent No: US 8245440 B2.

WINDS model simulation of cassava fields in Costa Rica, Oct. 2014

Summer salary for algae modeling, DOE, 2 weeks: 2014, 2015

5. **Certifications or professional registrations**

6. **Current membership in professional organizations**

1999-present American Society of Agricultural and Biological Engineers (ASABE)

7. **Honors and awards**

8. **Service activities** (within and outside of the institution)

University: Chair CALS CyberIntelligence Committee (2014-2015); Member, CALS Undergrad Curriculum Committee. (2009-present); Member, ABE Biosystems Engr. Undergrad. Curriculum Comm. (2010-present); Chair, ABE Awards Committee. (2009-2014); Member ABE Forward Planning Committee (2014-present); Member ABE Branding and Marketing Committee (2014-2015).

Peer Reviewer for Scientific Journals: Assoc. Editor, Irrigation Science (2009-2014).

Peer Review of Proposals:

9. **Principal/Selected publications and presentations** (from the last five years)

B Xu; Peiwen Li; **P Waller**; M Huesemann. Evaluation of flow mixing in an ARID-HV algal raceway using statistics of temporal and spatial distribution of fluid particles. Algal Research. 2015;9:27-39.

D.J. Hunsaker; A.N. French; **P.M. Waller**; E. Bautista; K.R. Thorp; K.F. Bronson; P. Andrade-Sanchez. Comparison of traditional and ET-based irrigation scheduling of surface-irrigated cotton in the arid southwestern USA. Agricultural Water Management. 2015;159:209-224.

Waller, P. and M. Yitayew. Irrigation and Drainage Engineering. 2015. Springer. 31 chapters. In press. The book includes many VBA/Excel models that enable the user to carry out relatively complex design and analysis.

Huesemann, M.H., M. Wigmosta, B. Crowe, **P. Waller**, A. Chavis, S. Hobbs, B. Chubukov, V.J. Tocco, and A. Coleman. 2015 "Estimating the maximum achievable productivity in outdoor ponds: Microalgae biomass growth modeling and climate-simulated culturing", In: Micro-Algal

- Production for Biomass and High-Value Products, Dr. Stephen P. Slocombe and Dr. John R. Benemann (Eds.), CRC Press, Taylor and Francis, LLC, in press.
- Attalah, S., **P. Waller**, G. Khawam, R. Ryan. 2015. Energy productivity of High Velocity Algae Raceway Integrated Design (ARID-HV). Transactions of the ASABE. 31(3):365-375
- Khawam, G., **P. Waller**, S. Attallah, R. Ryan. 2014. ARID raceway temperature model evaluation. Transactions of the ASABE. 57(1): 333-340 DOI 10.13031/trans.57.10198
- Xu, B., P. Li, and **P. Waller**. 2014. Study of the flow mixing in a novel open-channel raceway for algae production. Renewable Energy. 62:249-57. doi:10.1016/j.renene.2013.06.049
- Waller, P.**, R. Ryan, M. Kacira, and P. Li. 2012. The Algae Raceway Integrated Design for optimal temperature management. Biomass and Bioenergy. 46:702-709.
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- Haberland, J., P. Colaizzi, M. Kostrzewski, **P. Waller**, C. Choi, E. Eaton, E. Barnes, and T. Clarke. 2010. Agricultural Irrigation Imaging System. App. Engineering in Agriculture. 26(2): 247-253
- Waller, P. M.**, P. Li, and B. Xu. (2012, November). Computational Fluid Dynamics Modeling of ARID Raceway. NAABB conference. Phoenix, AZ.
- Waller, P. M.**, Murat, K., Ryan, R., Choi, C., Li, P., Ogden, K., & Kyndt, J. (2012, November). New High Velocity ARID (HV-ARID) Raceway. NAABB conference. Phoenix, AZ.
- Waller, P. M.**, Murat, K., Ryan, R., Choi, C., Li, P., Ogden, K., & Kyndt, J. (2011, November). Computational Fluid Dynamics Modeling of ARID Raceway. NAABB conference. Phoenix, AZ.
- Hunsaker, D., A. French, **P. Waller**, J. Heun, and P. Andrade-Sanchez. 2012. Irrigation scheduling decision support for field scale surface irrigation using remote sensing and ground based data, IAHS-AISH Publication; 352: 414-418.
- Xu, B., P. Li, and **P. Waller**, Optimization of the flow field of a novel ARID raceway (ARID-HV) for algal production, Proceedings of the ASME 2013 7th International Conference on Energy Sustainability, ES-FuelCell2013-18003, July 14-19, 2013, Minneapolis, MN, USA.

10. Professional development activities

1. Name and Academic Rank

Muluneh Yitayew, Professor

2. Education (degree, discipline, institution, year)

Ph.D.	Civil Engineering	University of Arizona	1982
M.S.	Agricultural Engineering	University of Arizona	1977
B.S.	Agricultural Engineering	Haile Sellasie I University	1973

3. Academic Experience (institution, rank, title, date)

1999-Present	Professor	University of Arizona	Agric. and Biosystems Engr.
1992-1997	Assoc. Prof.	University of Arizona	Agric. and Biosystems Engr.
1984-1991	Asst. Prof.	University of Arizona	Agric. and Biosystems Engr.
1982-1983	Research Assoc.	Univ. of Cal. Riverside	Earth Sciences Dept.
2001-2003	Visiting Prof.	Addis Ababa University, Eth.	Civil Engineering Dept.
2002-2003	Visiting	Prof. Arbaminch Univ., Ethiopia	Civil Engr. Dept.
1977-1982	Research Asst.	University of Arizona	Soils, Water, Engr. Dept.

4. Non academic experiences

5. Certification or professional registration: FE

6. Current Membership in professional registration

1984-Present	American Society of Agricultural and Biological Engineers (ASABE)
1984-Present	American Society of Civil Engineers (ASCE)

7. Honors and Awards

2014 Excellence in Research on Sustainable water use - Western Agricultural Experiment Directors

8. Service activities

2015-present	Member College of Agriculture Faculty Council
2009-present	Chair of the Graduate Comm. and Director of Grad. Studies, ABE Dept., UA
2006-2012	Chair, ABE Academic Programs Assessment Committee
20010-2012	Member of the Promotion and Tenure Committee, ABE Dept.
2009- Present	Member, Undergraduate Curriculum Committee
2006-present	Member, ABE Acad. Prog. Assessment Committee. Was chair 2006 to 2012
2014-present	Member of the Organizing Comm., Ethiopian Diaspora for STEM Ethiopia at the request of Ethiopia's Prime Minister
2014-present	Advisor, Addis Ababa Science and Techn. University, Addis Ababa, Ethiopia
2006- Present	Program Evaluator for ABET, Inc.
1985-present	Member, Western Regional Research Committee on Microirrigation

9. Principal /selected publications and presentations

Textbook: Waller, P. and **M. Yitayew**. 2016. Irrigation and Drainage Engineering. Springer International Publishing, Switzerland

Nouiri, I. , **M. Yitayew**, J. Maßmann, J. Tarhouni. 2015. Multi-objective Optimization Tool for Integrated Groundwater Management. Journal of Water Resources Mangement, Volume 29, Issue 14, pp5353-5375

- Yitayew, M.-., & Kitaw, M.** 2014. Water Governance in the Nile Basin for Hydropower Development. In *Nile River Basin Ecohydrological Challenges, Climate Change and Hydropolitics*. Melesse et al. Editors (p. 17). Springer International Publishing Switzerland
- Yitayew, M.** 2012. Discussion “Simplified method for sizing laterals with two or more diameters”. *Journal of Irrigation and Drainage Engineering*, 138(7), 697–702
- Yitayew, M., & Melesse, A.** 2011. Critical Water Resources Issues in the Nile River Basin. *Nile River Basin Hydrology, Climate and Water Use*. Springer
- Stewart, D., Canfield, E., **Yitayew, M.,** & Nichols, M. (2010). Estimating an impedance-to-flow parameter for flood peak prediction in semiarid watersheds. *Journal of Hydrologic Engineering*, 15(3), 182–190.
- Melesse, A. M., Loukas, A. G., Senay, G., & **M. Yitayew**. 2009. Climate change, land-cover dynamics and ecohydrology of the Nile River Basin. *Hydrological Processes*, 23(26), 3651–3652
- Didan, K., & **M. Yitayew**, 2009. Prototype geographic information system for agricultural water quality management using cropsyst. *Journal of Irrigation and Drainage Engineering*, 135(1), 58–67.
- Yitayew, M.** 2009. Simplified method for sizing laterals with two or more diameters. *Journal of Irrigation and Drainage Engineering*, 135(1), 111–114.
- Yitayew, M.-.** 2013. *Prototype Climate Data Services in Support of Climate Change Studies*. Climate Change and Development in Africa UN-ECA. UN-ECA, Addis Ababa, Ethiopia.
- Yitayew, M.-.** (2012, Spring). *Enhancing Energy Access and Security in the Nile River Basin*. *Enhancing Energy Access and Security in the Eastern Africa Sub-Region, Seventeenth Meeting of the Intergovernmental Committee of Experts (ICE)*. Kampala, Uganda: United Nations Economic Commission for Africa.
- Yitayew, M.** (2012, October). *Water-agriculture-energy nexus under climate change. The second Climate Change and Development in Africa (CCDA-II) conference of the Climate for Development in Africa*. Addis Ababa: ClimDev-Africa
- Barreto, A.-., & Didan, K., and **M. Yitayew**. 2013. *Nile Basin Vegetation Response and Vulnerability to Climate Change*. American Geophysical Union Annual Meeting. San Francisco, California

10. Professional development

- Attend the annual African Climate Change and Development Conferences Since 2011.
- Attend Brown Bag Seminars Water Resources Research Center UA

1. Name and Academic Rank

Jeong-Yeol Yoon, Professor

2. Education (degree, discipline, institution, year)

Ph.D.	Biomedical Engr.	UCLA	2004
Ph.D.	Chemical Engr.	Yonsei University	1999
M.S.	Chemical Engr.	Yonsei University	1994
B.S.	Chemical Engr.	Yonsei University	1992

3. Academic experience (institution, rank, title, dates)

2015-present	Prof.	University of Arizona	Agric. & Biosystems Engr. / Biomed. Engr.
2010-2015	Assoc. Prof.	University of Arizona	Agric. & Biosystems Engr. / Biomed. Engr.
2004-2010	Assist. Prof.	University of Arizona	Agric. & Biosystems Engr.

4. Not academic experiences, consulting/industry, patents

US Provisional Patent Application 62/320093 (2016); US Patent Applications 2015/057081, 2013/0149710, 2010/0136521, 2010/0136610;
US Patent 8,889,424 B2 (2014)
Consultant, Seoul VioSys (2014)

5. Certifications or professional registrations

6. Current membership in professional organizations

2005-present	Institute of Biological Engineering (IBE)
2005-present	American Society of Agricultural and Biological Engineers (ASABE)
2005-present	SPIE – The International Society for Optics and Photonics

7. Honors and awards

2014	ASABE Superior Paper Award
2012, 2010, 2009	Presidential Citations, IBE

8. Service activities (within and outside of the institution)

University: Member of multiple departmental, college, and university-wide committees; Chair (2009-2014), Biosystems Engineering Undergraduate Curriculum Committee; Chair (2008-2012), Agricultural and Biosystems Engineering Forward Planning Committee.

National: Councilor-at-Large (2010-2011), President-Elect (2014), President (2015), Immediate Past President (2016), IBE; Program Co-Chair (2009), Progr Chair (2010), Progr Committee Mem (2011), Annual Conf of IBE; DS202 Progr Com Mem (2009), SPIE Defense, Security + Sensing; BE-01 and BE-02 Biological Engineering Executive and Steering Committee Member (2009-2012), ASABE Annual International Meeting; BE-23 Program Committee Member (2007-2012); Member (2005-2011, 2015-present), Secretary (2012), Vice Chair (2013), Chair (2014), NCDC-201/NC-1031/NC-1194 Nanotechnology and Biosensors Multistate Research Committee, USDA.

International: Editorial Board Member (2015-present), Scientific Reports, Nature Publishing Group; Editorial Board Member (2007-2013), Editor-in-Chief (2014-present), Journal of Biological Engineering, IBE and BioMed Central; Editorial Board Member (2008-2012), Resource, ASABE.

Peer Reviewer for Scientific Journals: Reviewer for >40 academic journals.

Peer Review of Proposals: Reviewer for >10 funding agencies.

9. Principal/Selected publications and presentations (from the last three years)

* = corresponding author.

- Dustin K. Harshman, Brianna M. Rao, Jean E. McClain, George S. Watts and Jeong-Yeol Yoon*, "Innovative qPCR Using Interfacial Effects to Enable Low Threshold Cycle Detection and Inhibition Relief," *Science Advances*, **2015**, 1(8): e1400061. *Highlighted in 3D Perspectives, KUAZ/KUAT (PBS/NPR) Radio, Genomeweb, BioCentury, UANews, and more.*
- Soohee Cho, Tu San Park, Tigran G. Nahapetian and Jeong-Yeol Yoon*, "Smartphone-Based, Sensitive μ PAD Detection of Urinary Tract Infection and Gonorrhea," *Biosensors and Bioelectronics*, **2015**, 74: 601-611.
- Scott V. Angus, Soohee Cho, Dustin K. Harshman, Jae-Young Song and Jeong-Yeol Yoon*, "A Portable, Shock-Proof, Surface-Heated Droplet PCR System for *Escherichia coli* Detection," *Biosensors and Bioelectronics*, **2015**, 74: 360-368.
- Pei-Shih Liang, Ariana M. Nicolini, Kimberly L. Ogden and Jeong-Yeol Yoon*, "Use of Biosensors in Secondary Education Classrooms," *Transactions of the ASABE*, **2015**, 58(2): 181-190.
- Ariana M. Nicolini, Christopher F. Fronczek and Jeong-Yeol Yoon*, "Droplet-Based Immunoassay on a 'Sticky' Nanofibrous Surface for Multiplexed and Double Detection of Bacteria Using Smartphones," *Biosensors and Bioelectronics*, **2015**, 67: 560-569. *Highlighted in Genetic Engineering & Biotechnology News.*
- Tu San Park and Jeong-Yeol Yoon*, "Smartphone Detection of *Escherichia coli* from Field Water Samples on Paper Microfluidics," *IEEE Sensors Journal*, **2015**, 15(3): 1902-1907.
- Pei-Shih Liang, Tu San Park and Jeong-Yeol Yoon*, "Rapid and Reagentless Detection of Microbial Contamination within Meat Utilizing a Smartphone-Based Biosensor," *Scientific Reports*, **2014**, 4: 5953.
- Tu San Park, Cayla Baynes, Seong-In Cho and Jeong-Yeol Yoon*, "Paper Microfluidics for Red Wine Tasting," *RSC Advances*, **2014**, 4(46): 24356-24362. *Highlighted in RSC Advances Blog.*
- Dustin K. Harshman, Roberto Reyes, Tu San Park, David J. You, Jae-Young Song and Jeong-Yeol Yoon*, "Enhanced Nucleic Acid Amplification with Blood in Situ by Wire-Guided Droplet Manipulation (WDM)," *Biosensors and Bioelectronics*, **2014**, 53: 167-174.
- Tu San Park, Wenyue Li, Katherine E. McCracken and Jeong-Yeol Yoon*, "Smartphone Quantifies Salmonella from Paper Microfluidics," *Lab on a Chip*, **2013**, 13(24): 4832-4840.
- Phat L. Tran, Jessica R. Gamboa, Katherine E. McCracken, Mark R. Riley, Marvin J. Slepian* and Jeong-Yeol Yoon*, "Nanowell-Trapped Charged Ligand-Bearing Nanoparticle Surfaces - A Novel Method of Enhancing Flow-Resistant Cell Adhesion," *Advanced Healthcare Materials*, **2013**, 2(7): 1019-1027. *Back cover. Highlighted in UANews.*
- Pei-Shih Liang and Jeong-Yeol Yoon*, "Optofluidic Lab-on-a-chip Monitoring of Subsurface Bacterial Transport," *Biological Engineering Transactions*, **2013**, 6(1): 17-28. *Featured in ASABE Publications and Arizona Engineer. Received 2014 ASABE Superior Paper Award.*
- Jessica R. Gamboa, Samir Mohandes, Phat L. Tran, Marvin J. Slepian* and Jeong-Yeol Yoon*, "Linear Fibroblast Alignment on Sinusoidal Wave Micropatterns," *Colloids and Surfaces B: Biointerfaces*, **2013**, 104: 318-325.
- Christopher F. Fronczek, David J. You and Jeong-Yeol Yoon*, "Single-Pipetting Microfluidic Assay Device for Rapid Detection of Salmonella from Poultry Package," *Biosensors and Bioelectronics*, **2013**, 40(1): 342-349.
- David J. You, Tu San Park and Jeong-Yeol Yoon*, "Cell-Phone-Based Measurement of TSH Using Mie Scatter Optimized Lateral Flow Assays," *Biosensors and Bioelectronics*, **2013**, 40(1): 180-185.

10. Professional development activities (Most recent)

Attended numerous conferences, including IBE Annual Conference, ASABE Annual International Meeting, Biosensors World Congress, MicroTAS, KSBB International Meeting, In Vitro Biology Meeting, etc. Made numerous seminar presentations throughout US and worldwide.

APPENDIX C – Equipment

Laboratory facilities in ABE include some dedicated space used entirely for teaching activities and some space used both for research and for small demonstrations and laboratory exercises associated with classes.

Biological Big Data Laboratory: Dr. Hurwitz directs the biological big data laboratory (BBD) to develop algorithms and computational systems for analyzing large-scale-omics datasets. Offices are located on the 4th floor of the Bio5 Keating Building (4- cubicles, 1 office) and 6th floor of the Shantz building (3-120 sq. ft. offices). Offices are comprehensively equipped with personal computers, scanners, software, and various color and black-and-white printers. Currently, offices house two graduate students, one postdoc, two software developers, one community outreach coordinator, and four undergraduates. The BBD partners with high-performance computing centers both locally and nationally to develop next-generation data analysis platforms for integrating and analyzing biological big data.

Bioprocess Engineering Laboratory: Bench-top bioreactors, cell culture incubators (CO₂ controlled and flow), controlled environment growth chamber, fluorescence microscope, uv-vis 96-well plate reader, Nicolet Magna 560 Fourier Transform Infrared (FTIR) spectrometer with InSb and MCT infrared detectors, portable Enwave Raman spectrometer, a uv-vis spectrophotometer, high-pressure liquid chromatography (HPLC), gas chromatograph, chlorophyll fluorometer, microscopes (visible, inverted, fluorescence), plate reader, several desktop computers, laminar flow hoods, orbital shakers, microscopes, light meters, a temperature controlled high speed centrifuge, freezer, analytical balance, two controlled temperature water baths, a Silicon Graphics O2 workstation, two biological safety cabinets, microscope for cell enumeration, liquid nitrogen facilities for cell storage, two CO₂ incubators, one atmospheric incubator, several liquid and vapor pumps, MilliQ water purification, a pH meter, centrifuge, quantum sensors, an autoclave. Additional facilities include facility core centers for electron microscopy, mass spectrometry, magnetic resonance imaging, Affymetrix gene chip readers, and macromolecular structure evaluation.

Biosensors Laboratory: Equipment includes ball-bearing linear and rotational positioning stages, inverted fluorescent microscope with digital image/movie capturing, dynamic contact angle/surface tension analyzer, flow-cell quartz crystal microbalance, PCR thermocycler, gel electrophoresis system, gel documentation system, electrochemical DNA sensor, 18 megaohm - cm water purification systems, two miniature UV/visible spectrometers, optical fiber spectrometer, electronic balance, digital multimeters, centrifuge, vortex mixer, heating block, deep freezer, autoclave, two incubators, two refrigerators, oven, and hood. PCR thermocycler, gel electrophoresis system, gel documentation system.

Chemical and Water Analysis Laboratory: Equipment includes two fume hoods, HPLC (high pressure liquid chromatograph), gas chromatography (GC), chemical hood, microbial hood, bacterial detection equipment, refrigerator, an instrumented fermenter (with gas and pH control), and microwave.

Controlled Environment Agriculture (CEA) Center Research Facilities: Two research/demonstration greenhouses (GH#2091A & C) (2700 sq. ft. each), computer environmental controllers, drip irrigation and fertigation systems, and general greenhouse actuators for environmental control by heating, fan or natural ventilation, pad or fog evaporative cooling, shading, and carbon dioxide enrichment. Other greenhouses available for rent from the Campus Agricultural Center have been renovated for specialty or specific project purposes and include: (1) a 1875-sq. ft., single-bay aquaponics research facility (GH#3018), with multiple, computer-controlled environmental zones for fish culture and for hydroponic plant culture (Dr. Giacomelli); (2) two 1500-sq. ft., single-bay greenhouses with automated climate monitoring, is used for alternative energy integrated greenhouse systems research and education (Dr. Kacira); (3) a 1000-sq ft, single-bay greenhouse (GH#2078-1) with an ebb & flood table system for production of lettuce and other small green crops (Dr. Kubota, School of Plant Sciences with joint appointment with ABE); (4) a 1000-sq ft, single-bay greenhouse (GH#2078-3) for testing and demonstrating crop production in hydroponic systems (Dr. Giacomelli); and (5) a 1000-sq ft, single-bay greenhouse (GH#2077-4) for testing and demonstrating novel hydroponic plant nutrient delivery system designs (Dr. Rorabaugh, School of Plant Sciences). The controlled environment chamber facilities include a 900-sq. ft. metal building which houses three 9-sq ft, reach-in growth chambers; a 150-sq ft, walk-in growth chamber; and a 150-sq ft, walk-in cooler. There are also two 150-sq ft, walk-in low temperature storage rooms adjacent to building #2075. A new (750 sq. ft. foot print) indoor vertical farm based urban agriculture research, teaching and outreach facility equipped with state of the art environmental monitoring and control systems is underway at Controlled Environment Agriculture Center (CEAC).

CEA Extreme Climate Laboratory: The Mars/Moon Inflatable Greenhouse, which is a lightweight, 18 foot long by 7 foot diameter climate controlled flexible film, collapsible structure, light by high intensity discharge lamps, air temperature and relative humidity, and root zone nutrition, and specifically to monitor carbon, hydrogen and oxygen as biomass, water and carbon dioxide, respectively, within a semi-closed bioregenerative life support system prototype. A web connection for remote monitoring and control of web cameras and data monitoring is operable.

CEA Laboratory: Located at CEAC, greenhouses, growth chambers, temperature control rooms, and various faculty laboratories. The CEA building: capability for plant photosynthesis and transpiration measurement, nutrient and plant constituent analysis, and general laboratory functions; automated monitoring and control of plant health and growth with machine vision. The CEA building annex is a wet lab with exhaust fume hood, an instrumentation preparation room. The greenhouse teaching facilities include a 5200-sq ft, multi-bay, educational laboratory

Geographic Information Systems Laboratory: Two SUN System microcomputers which implement an ARC INFO GIS program.

Sensing/Control Lab for Controlled Environment Plant Production: Sensors and sensing system capabilities for measurements of growing media-plant-surrounding climate related parameters including soil moisture probes, hand-held and inline EC/pH sensor, dissolved oxygen sensors, porometer, chlorophyll content sensor, infrared thermocouple, sap flow meters, load cell, quantum sensors, pyranometers, spectroradiometer, hot wire anemometer, cup anemometer,

infrared CO₂ analyzer, thermisters, relative humidity sensors, solid state relays, data loggers, and data acquisition boards, optical density sensors, computer vision system. These sensors and instrumentation are used as part of teaching in Applied Instrumentation in Controlled Environment Agriculture course taught by Dr. Kacira. The equipment is also used by students in the department for internships, student design and research projects.

Soil and Water Resources Engineering Laboratory: Soil measurement capabilities include pressure plate measurement of water characteristic curves for soils and other porous media, oven drying of soils and plants, measurement of water distribution in porous media, soil sieves, weighing scales, and hydrometer method for soil particle size distribution. Remote sensing equipment includes unmanned aerial vehicles with an autonomous guidance system, cameras, GPS receivers, sensors for measurement of remote sensing indices from the plane, and temperature and humidity sensors. Field and greenhouse research associated with the laboratory includes biochar incorporation in soils, greenhouse growing media, and remote sensing of agricultural fields.

Water Distribution Network Laboratory: Continuous-monitoring sensors for water hydraulics and quality (e.g., flow meters, pressure gages, salinity, pH, temperature, dissolved solids, etc.); data loggers, a high-speed camera, and various sensors for real-time, remote (using RF and cell phone modem); two high-speed workstations are dedicated to running Fluent, MATLAB, and EPANET; four additional workstations and laptops for data acquisition and processing.

Statistical Bioinformatics Laboratory: This is a dry lab and directed by Dr. Lingling An and is used for conducting research studies on statistical and computational research in bioinformatics, genomics and metagenomics, and other related areas. It includes three desktop computers, three laptop computers, and three printers/copiers/scanners. It usually holds 5~6 students/postdocs working in this lab.

Water Sensing Laboratory: Variety of equipment for monitoring biological contaminants in water: a water purification system (deionized to reverse osmosis). On-line sensors include those for electrical conductivity, total organic carbon, ultraviolet light scattering, turbidity, and flow. Other sensors include a JMar Biosentry system to quantify bacteria, protozoa, and spores; a system for quantifying bacteria, TOC, DOC, and others; and a Hach event monitor system which includes individual sensors for pH, TOC, turbidity, free chlorine, and a pattern matching expert system to predict and classify water intrusion events.

Additional Facilities

In addition to the laboratories specifically under control by the ABE department are facilities in the College of Engineering and the College of Agriculture.

In Engineering, the AME S436 Unix computer laboratory equipped with 32 workstations and is used to teach ABE 221 (Computer aided Design). The Rapid Prototyping Laboratory, in Old Engineering 210, is equipped with two RP machines (Z310, Zcorp and inVision 3D systems).

In the College of Agriculture and Life Sciences:

Maricopa Agricultural Center (MAC): Pedro Andrade-Sanchez is an ABE extension/research faculty located at the Maricopa Agricultural Center. Dr. Andrade-Sanchez has an office and laboratory space available to his program the Cardon Building. His office is located in room 179 which is 126 sq. ft. in size. Instrumentation laboratory is located across the hallway (room 176) with 294 sq. ft. Dr. Andrade's laboratory is used for design, development, and testing of electronic instrumentation for precision agriculture research. Dr. Andrade also converted a storage room into a small shop (1000 sq. ft.) that he uses for fabrication of equipment and mounting of instrumentation for field deployment.

Yuma Agricultural Center (YAC):

The Ag Mechanization Shop at YAC, Yuma, AZ is directed by Dr. Mark Siemens. The 3,200 sq. ft. facility is equipped with CNC lathes, milling machines, welders and other general purpose machine shop tools necessary for the design and fabrication specialized. Electronic test equipment, sensors, data acquisition hardware and electronic equipment are housed in the building's clean room. Office space for technicians and students is also provided. The Ag Mechanization Shop is located adjacent to YAC's Glen G. Curtis Research Building. The 19,000 sq. ft. facility is equipped with state of the art laboratories and meeting and conference rooms. Dr. Mark Siemens has office space in this facility.

Appendix D – Institutional Summary

1. The Institution

- a. Name and address of the institution

The University of Arizona, Tucson, AZ 85721

- b. Name and title of the chief executive officer of the institution

Ann Weaver Hart, Ph.D.
President of The University of Arizona

- c. Name and title of the person submitting the Self-Study Report.

Kitt Farrell-Poe, Ph.D.
Department Head, Specialist, and Professor
Department of Agricultural and Biosystems Engineering Department

- d. Name the organizations by which the institution is now accredited, and the dates of the initial and most recent accreditation evaluations.

University-Wide:

Higher Learning Commission
North Central Association of Colleges and Schools
Date of initial accreditation: 01/01/1917
Date of most recent reaffirmation of accreditation: 05/16/2011
Next reaffirmation of accreditation: 2020-21

VP for Research:

Association for the Assessment and Accreditation of Laboratory Animal Care International

Agriculture and Life Sciences:

American Association of Veterinary Laboratory Diagnosticians
American Dietetics Association
Society for Range Management

Architecture, Planning and Landscape Architecture:

American Planning Association
American Society of Landscape Architects
National Architectural Accrediting Board
Planning Accreditation Board

Education:

Association for the Education and Rehabilitation of the Blind and Visually Impaired (on all three areas: Orientation & Mobility, Teaching Impaired Students, and Rehabilitation)
Commission on Rehabilitation Education
Council for Education of the Deaf
Council on Education in Journalism and Mass Communications
Council on Rehabilitation Education
International Association of Counseling Services

Engineering:

Accreditation Board for Engineering and Technology

Fine Arts:

National Association of Schools of Art & Design
National Association of Schools of Dance
National Association of Schools of Music
National Association of Schools of Theatre

Law, James E Rogers:

Association of American Law Schools and American Bar Association

Management, Eller College:

American Assembly of Collegiate Schools of Business
National Association of Schools of Public Affairs and Administration
International Association for Management Education

Medicine:

Accreditation Association for Ambulatory Health Care
Accreditation Council for Continuing Medical Education
Accreditation Council for Graduate Medical Education (for residency and fellowships)
Association for the Assessment and Accreditation of Laboratory Animal Care International
Liaison Committee on Medical Education
American Dietetic Association
National Accrediting Agency for Clinical Laboratory Sciences

Nursing:

Commission on Collegiate Nursing Education

Pharmacy:

American Association of Poison Control Centers
American Council on Pharmaceutical Education
American Society of Health-System Pharmacists for Residency Accreditation

Public Health:

Council on Education for Public Health

Science:

American Chemical Society
American Meteorological Society
American Speech-Language-Hearing Association
Council on Academic Accreditation in Audiology and Speech-Language Pathology
National Accrediting Agency for Clinical Laboratory Sciences
National Oceanic and Atmospheric Administration, National Weather Service

Social and Behavioral Sciences:

American Library Association
American Psychological Association (graduate programs in clinical psychology and school psychology)
Council on Education in Journalism and Mass Communications

Additional Accreditations:

Advisory Committee for International Scholars
Air Force Institute of Technology
American Association of Museums

2. Type of Control

The University of Arizona is a state land grant university under the control of the Arizona Board of Regents (ABOR).

3. Educational Unit

The organizational structure for the Biosystems Engineering degree reflects a partnership between the University of Arizona College of Engineering (CoE) and the College of Agriculture and Life Science (CALS). CoE takes the lead on all undergraduate academic issues including matriculation, curriculum, and accreditation. ABE faculty are financially supported and tenured by CALS. See organizational chart below.

The head of the educational unit in which the program is housed is Dr. Kitt Farrell-Poe. Professor Farrell-Poe reports to the Dean of the College of Engineering, Jeffrey B. Goldberg, Ph.D., for student matriculation, program accreditation, and differential tuition. Professor Farrell-Poe also reports to the Dean of College of Agriculture and Life Sciences, Shane Burgess, Ph.D, for faculty support and promotion and tenure processes.

Dean Goldberg reports to Andrew C. Comrie, Ph.D., Senior Vice President for Academic Affairs and Provost.

Dr. Comrie reports to Ann Weaver Hart, Ph.D., President of the University of Arizona.

An organizational chart for the College of Engineering is shown in Figure D.1 on the following page.

4. Academic Support Units

The names of the department heads for units that offer engineering course required by the program are shown in Figure D-1, the organization chart for the College of Engineering.

Other units that offer engineering courses, in partnership with the College of Engineering are:

College of Agriculture & Life Sciences

Department of Agricultural & Biosystems Engineering

Department Head
Kathryn L. Farrell-Poe, Ph.D.
Professor of Agricultural & Biosystems Engineering

College of Optical Sciences

Dean
Thomas L. Koch, Ph.D.
Professor of Optical Sciences and Electrical & Computer Engineering

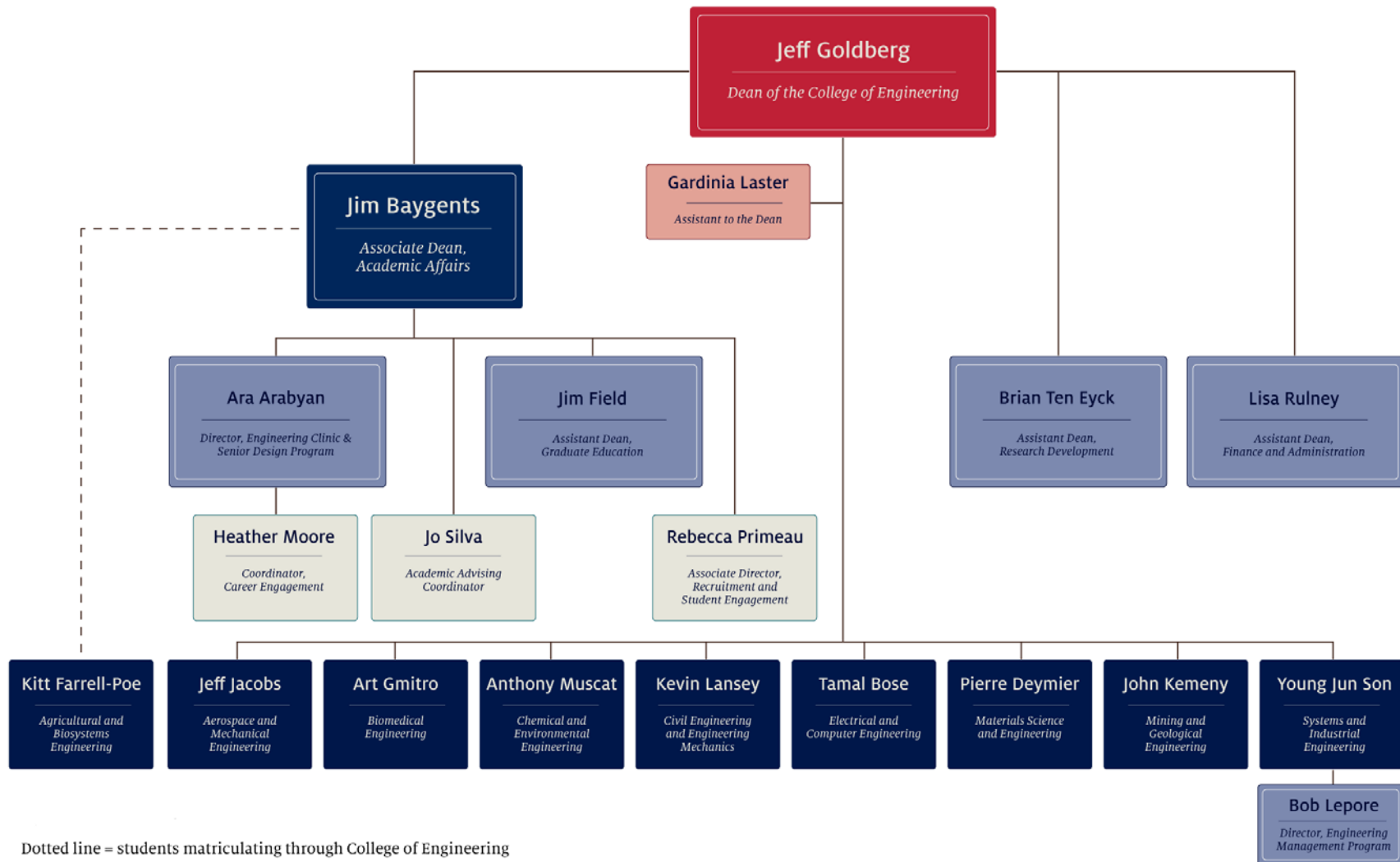


Figure D-1. Organizational chart: College of Engineering, University of Arizona, Tucson, AZ.

Below are the names and titles of the individuals responsible for each of the units that teach non-engineering courses required by the program.

Department of Mathematics

Department Head
Kenneth D. T. McLaughlin, Ph.D.
Professor of Mathematics and Applied Mathematics

Associate Head for Instruction
Robert Indik, Ph.D.
Associate Professor of Mathematics

Department of Physics

Department Head
Sumit Mazumdar, Ph.D.
Professor of Physics, Chemistry and Optical Sciences

Department of Chemistry and Biochemistry

Department Head
Roger L. Miesfeld, Ph.D.
Professor of Chemistry & Biochemistry and Molecular & Cellular Biology

Department of Ecology & Evolutionary Biology

Department Head
Michael Worobey, Ph.D.
Professor of Ecology and Evolutionary Biology

Department of Molecular and Cellular Biology

Department Head
Tricia Serio, Ph.D.
Professor of Molecular & Cellular Biology

Department of Physiology

Department Head
Nicholas A. Delamere, Ph.D.
Professor of Physiology and Ophthalmology

Department of Computer Science

Department Head
Todd A. Proebsting, Ph.D.
Professor of Computer Science

Department of English

Department Head
Lee Medovoi, Ph.D.
Professor of English

Director, Writing Program
Susan Miller-Cochran, Ph.D.
Professor of English

University of Arizona General Education Program

Chair, University-Wide General Education Committee

AY 2015-16

Jennifer Ricketts, Ph.D.

Lecturer, Nutritional Sciences

AY 2016-17

Thomas Fleming, Ph.D.

Senior Lecturer, Astronomy

The Honors College

Dean
Patricia J. MacCorquodale, Ph.D.

5. Non-academic Support Units

Below is an extensive list the names and titles of the individuals responsible for units that provide non-academic support to the program:

Library: Karen Williams, Dean, University of Arizona Libraries

University Information Technology Services (UITS): Karen A. Williams, Interim Vice President for Information Technology and Chief Information Officer

Bursar's Office: Mark J. Burton, Bursar and Director, Catcard Services

Office of the Registrar: Beth Acree, University Registrar and Assistant Vice President, Enrollment Management & Student Affairs Advancement

Office of the General Counsel: Laura Todd Johnson, Senior Vice President for Legal Affairs and General Counsel

Dean of Students Office: Kendal H. Washington White, Dean of Students and Assistant Vice President, Student Affairs

Office of Scholarships & Financial Aid: Beth Acree, University Registrar and Assistant Vice President, Enrollment Management & Student Affairs Advancement

Global Initiatives (Study Abroad and International Student Services): Mike Proctor, Vice President, Office of Global Initiatives

Room & Course Scheduling: Fernando Chavez, Assistant Registrar, Courses & Scheduling

Facilities Management: Christopher M. Kopach, Assistant Vice President, Facilities Management

Risk Management Services: Steve Holland, Assistant Vice President, Risk Management Services

University of Arizona Police Department: Brian Seastone, Chief of Police

Parking & Transportation Services: David Heineking, Director

Office of Instruction & Assessment: Debra Tomanek, Associate Vice Provost, Instruction and Assessment

University Analytics & Institutional Research: Hank Childers, Executive Director

Financial Services Office: Duc D. Ma, Interim Associate Vice President, Financial Services

Sponsored Projects Services: Sherry Esham, Director

University Relations: Melinda Burke, Interim Senior Vice President, University Relations

Office of Institutional Equity: Mary Beth Tucker, Assistant Vice President, Equity Compliance

Office of Diversity & Inclusion: Jesús Treviño, Vice Provost, Inclusive Excellence and Senior Diversity Officer

Student Affairs & Enrollment Management: Melissa Vito, Senior Vice President for Student Affairs & Enrollment Management and Senior Vice Provost for Academic Initiatives and Student Success

Undergraduate Admissions:

University: Kasandra K. Urquidez, Dean, Undergraduate Admissions and Vice President, Enrollment Management & Student Affairs Advancement

College of Engineering: Rebecca Myren Primeau, Associate Director, Recruitment & Student Engagement, College of Engineering

Academic Advising:

University: Roxie Catts, Director, Advising Resources Center

College of Engineering: Joanne Silva, Coordinator, Academic Advisors

English Placement: Susan Miller-Cochran, Director, Writing Program, Department of English

Mathematics Placement: Robert A. Indik, Associate Head for Instruction, Department of Mathematics

Career Services: Eileen M. McGarry, Executive Director

Center for English as a Second Language: Suzanne K. Panferov, Director

Arizona Student Unions: Jonathan T. Millay, Interim Director

Residence Life: Nicholas J. Sweeton, Interim Executive Director

Campus Recreation:

John Lloyd, Interim Director, Facilities & Operations

Michele Schwitzky, Interim Director, Programs & Outreach

Campus Health Services: Harry McDermott, M.D., M.P.H., Executive Director for Health & Wellness and Director of the Campus Health Service

The Think Tank (Tutoring and Academic Support): Dorothy Briggs, Director

SALT Center for Learning Disabilities: Rudy Modesto Molina, Director

Disability Resource Center: Sue A. Kroeger, Director

6. Credit Unit

According to Arizona Board of Regents Policy Number 2-224 (Academic Credit), a unit of credit is defined as follows:

An hour of work is the equivalent of 50 minutes of class time (often called a "contact hour") or 60 minutes of independent study work. *A minimum of 45 hours of work by each student is required for each unit of credit.* Ordinarily, a course must cover a 1-week period for every unit of credit given. During summer sessions, however, 6 units of credit may be given over a 5-week period.

- a. At least 15 contact hours of recitation, lecture, discussion, testing or evaluation, seminar, or colloquium, as well as a minimum of 30 hours of student homework is required for each unit of credit;
- b. Workshops must involve a minimum of 45 hours for each unit of credit, including a minimum of 15 contact hours, with the balance of the requirement in homework;
- c. Studios must involve at least 30 contact hours and at least 15 hours of homework for each unit of credit;

- d. Laboratory courses require a minimum of 45 contact hours per unit of credit;
- e. Field trips will be counted hour-for-hour as laboratory meetings;
- f. Each unit of internship or practicum must require a minimum of 45 clock hours of work; and
- g. Music instruction and specialized types of music performance offerings must conform to the requirement for accreditation of the National Association of Schools of Music.
- h. Off-campus courses, regardless of mode of delivery, may be assigned credit based on competencies or learning outcomes that are acquired through coursework and are equivalent to those of students in a traditional classroom setting. An equivalent of 45 hours of work by each student is required for each unit of credit.

In short, one semester credit represents one class hour or three laboratory hours per week. One academic year represents 30 weeks of classes, exclusive of final examinations.

7. Tables

The following are the tables summarizing information on Biosystems Engineering Program enrollment and degree data (Table D-1) and personnel (Table D-2), and College of Engineering student enrollment data (Table D-3).

Table D-1. Biosystems Engineering Program Enrollment and Degree Data

Below are Official fall term enrollment figures (head count) for the current and preceding four academic years and undergraduate and graduate degrees conferred during each of those years. The "current" year means the academic year preceding the on-site visit.

*Grand Total for Census data was gathered from UA Decision Support Data System located at <http://dsda.arizona.edu/node/543>

BS: Biosystems Engineering; MS & PhD: Agricultural & Biosystems Engineering

	Academic Year	Enrollment Year					Total Undergrad	Total Grad	Degrees Awarded			
		1st	2nd	3rd	4th	5th			Associates	Bachelors	Masters	Doctorates
Fall 10	FT	2	11	14	31		66	33		18	4	7
	PT											
Fall 11	FT	4	6	11	22		43	30		15	7	1
	PT											
Fall 12	FT	4	9	5	21		39	23		10	6	5
	PT											
Fall 13	FT		7	17	26		50	20		17	1	5
	PT											
Fall 14	FT		1	14	30		45	19		14	4	3
	PT											
Fall 15	FT		7	9	27		44	17		17	6	1
	PT											

FT--full time; PT--part time

Table D-2. Agricultural and Biosystems Engineering Department Personnel

Year: 2015

	HEAD COUNT		FTE
	FT	PT	
Administrative		1	0.4
Faculty (tenure-track)	10	1	10.8
Other Faculty (excluding student Assistants) ¹	3		2.6
Student Teaching Assistants			
Technicians/Specialists	2		2
Office/Clerical Employees	5	6	8
Others			

1-Extension Specialists with continuing status

Table D-3: College of Engineering Student Enrollment 2010-2015 (Fall Semester).

Degree Program	Fall '05	Fall '06	Fall '07	Fall '08	Fall '09	Fall '10	Fall '11	Fall '12	Fall '13	Fall '14	Fall '15
Aerospace Engineering	252	212	208	213	208	189	166	144	123	109	132
Agricultural & Biosystems Engineering	10	4	2		1	1	1	1			
Biomedical Engineering						65	126	156	193	185	175
Biosystems Engineering	49	70	80	73	95	66	42	38	50	45	50
Chemical Engineering	178	176	176	186	195	197	198	198	182	201	245
Civil Engineering	242	204	182	184	169	148	147	120	97	107	116
Computer Engineering	334	245	169	166	121	86	57	13	3		
Electrical & Computer Engineer					56	98	145	189	255	296	379
Electrical Engineering	364	315	306	264	178	136	91	38	11	3	1
Engineering	28	32	30	21	13	5	2	1			
Engineering Management	189	215	179	167	150	137	108	85	63	53	71
Engineering Mathematics	27	31	19	19	13	6					
Engineering Physics	53	37	45	36	17	4	2				
Environmental Engineering											1
Geological Engineering	18	15	16	9	3	2					

Industrial Engineering	50	37	40	31	31	37	45	48	53	56	61
Materials Science & Engr	58	64	53	44	48	45	58	72	85	84	78
Mechanical Engineering	512	444	421	383	372	341	277	270	270	303	387
Mining Engineering	40	53	51	62	63	64	65	70	81	90	87
No Major Selected Engineering	102	71	77	108	143	393	589	763	886	917	746
Nondegree Seeking, Engineering	16	21	18	40	9						
Optical Sciences & Engineering	185	146	144	137	153	130	121	129	108	85	91
Pre-Engineering		119	170	271	328	130	45	4			
Systems Engineering	65	42	29	33	45	53	69	64	63	85	101

Further Supporting Information

Appendix E1. Biosystems Engineering Curriculum (2015-2016)

B.S. in Biosystems Engineering

General four-year plan

Below is the advised sequence of courses for this degree program and prerequisites as of 12/15/15.
The official degree requirements and prerequisites can be found in the University General Catalog and the prerequisites are subject to change.

Course Number and Title	Units	Prerequisites
1ST SEMESTER		18/16
MATH 122A/MATH 122B or MATH 125 Calculus I	5/3	Appropriate Math Placement
CHEM 151 General Chemistry I	4	
ENGL 101 First-Year Composition	3	
ENGR 102 Introduction to Engineering or ENGR102A & ENGR102B	3	Concurrent enrollment or completion of MATH 122B or MATH 124 or MATH 125
Tier I General Education	3	
2ND SEMESTER		17
MATH 129 Calculus II	3	MATH 122A/MATH 122B or MATH 124 or MATH 125
CHEM 152 General Chemistry II	4	CHEM 151
PHYS 141 or PHYS 161H Introductory Mechanics	4	MATH 122A/MATH 122B or MATH 124 or MATH 125; Concurrent enrollment in MATH 129
ENGL 102 First-Year Composition	3	ENGL 101
Tier I General Education	3	
3RD SEMESTER		16
CE 214 Statics	3	PHYS 141 or PHYS 161H ; MATH 129 or MATH 250A
ABE 284 Biosystems Thermal Engineering	3	MATH 129; PHYS 141
ABE 201 Introduction to Biosystems Engineering	2	MATH 122A/MATH 122B or MATH 124 or MATH 125
MATH 223 Vector Calculus	4	MATH 129 or MATH 250A
MCB 181 R & L Introductory Biology I or PLS 240 Plant Bio	4	Appropriate Math Placement
4TH SEMESTER		17
ABE 205 Engineering Analytic Computer Skills	3	MATH 122A/MATH 122B or MATH 124 or MATH 125
MATH 254 Intro to Ordinary Differential Equations	3	MATH 129
PHYS 241 or PHYS 261H Introductory Electricity and Magnetism	4	PHYS 141
ECOL 182 R & L Introductory Biology II or MIC 205 A & L General Microbiology or PSIO 201 Human Anatomy and Physiology	4	

Advanced Standing is required for 300 and 400 level courses (See advisor for requirements)

Tier 1 General Education	3
7TH SEMESTER	15
CE 218 Mechanics of Fluids or AME 331 Introduction to Fluid Mechanics	3
SIE 265 Engineering Management I	3
ABE 221 Introduction to Computer Aided Design	3
ABE 447 Sensors and Controls	3
SIE 305 Engineering Probability and Statistics	3
6TH SEMESTER	15
ABE 423 Biosystems Analysis and Design	3
ABE Design Elective	3
ABE Technical Elective	3
AGTM 422 or ENGL 308 Technical Writing	3
Tier I General Education	3
7TH SEMESTER	17
ABE 496A Seminar in Engineering Careers and Professionalism	1
ABE 498A Senior Capstone: Biosystems Engineering Design I	3
ABE Technical Elective	3
ABE Design Elective	3
ABE 393 Internship	1
AME 324A Mechanical Behavior of Engineering Materials	3
Tier II General Education	3
8TH SEMESTER	15
ABE 498B Senior Capstone: Biosystems Engineering Design II	3
AME 431 Numerical Methods in Fluid Mechanics or AME 432 Heat Transfer, or an approved ABE 400 level course	3
ABE Technical Elective	3
ABE Design Elective	3
Tier II General Education	3

Total Units needed for Graduation 128: (Total Units with Math 125 option = 130 or Total Units with Math 122A/B option = 128)

- BE students should review their Student Academic Advisement Report (SAAR), with either the ABE Academic Program Coordinator or their assigned ABE Faculty Advisor at least once a semester.
- Students who do not take ENGR 102, will be required to take an approved 300 or 400 Engineering Elective 3 unit course.
- ABE Engineering Design Electives: Students need to complete 9 units of upper division courses, see SAAR for list of acceptable courses.
- Technical Electives: Students need to complete 9 units of upper division courses, see SAAR for a list of acceptable courses.

Appendix E2. Biosystems Engineering Curriculum, Pre-Health Track (2015-2016)

B.S. in Biosystems Engineering Pre Health Track four-year plan

Below is the advised sequence of courses for this degree program and prerequisites as of 12/15/15.
The official degree requirements and prerequisites can be found in the University General Catalog and the prerequisites are subject to change."

Course Number and Title	Units	Prerequisites
1ST SEMESTER	18/16	
MATH 122A/MATH 122B or MATH 124 or MATH 125 Calculus I	5/3	Appropriate Math Placement
CHEM 151 General Chemistry I	4	
ENGL 101 First-Year Composition	3	
ENGR 102 Introduction to Engineering or ENGR102A & ENGR102B	3	Concurrent enrollment or completion of MATH 122B or MATH 124 or MATH 125
Tier I General Education	3	
2ND SEMESTER	17	
MATH 129 Calculus II	3	MATH 122A/MATH 122B or MATH 124 or MATH 125
CHEM 152 General Chemistry II	4	CHEM 151
PHYS 141 or PHYS 161H Introductory Mechanics	4	MATH 122A/MATH 122B or MATH 124 or MATH 125; Concurrent enrollment in MATH 129
ENGL 102 First-Year Composition	3	ENGL 101
Tier I General Education	3	
3RD SEMESTER	16	
CE 214 Statics	3	PHYS 141 or PHYS 161H ; MATH 129 or MATH 250A
ABE 284 Biosystems Thermal Engineering	3	MATH 129; PHYS 141
ABE 201 Introduction to Biosystems Engineering	2	MATH 122A/MATH 122B or MATH 124 or MATH 125
MATH 223 Vector Calculus	4	MATH 129 or MATH 250A
MCB 181 R & L Introductory Biology I or PLS 240 Plant Bio	4	Appropriate Math Placement
4TH SEMESTER	17	
ABE 205 Engineering Analytic Computer Skills	3	MATH 122A/MATH 122B or MATH 124 or MATH 125
MATH 254 Intro to Ordinary Differential Equations	3	MATH 129
PHYS 241 or PHYS 261H Introductory Electricity and Magnetism	4	PHYS 141
ECOL 182 R & L Introductory Biology II or MIC 205 A & L General Microbiology or PSIO 201 Human Anatomy and Physiology	4	

Advanced Standing is required for 300 and 400 level courses (See advisor for requirements)

ECOL 182 R & L Introductory Biology II or MIC 205 A & L General Microbiology or PSIO 201 Human Anatomy and Physiology	4
Tier 1 General Education	3
5TH SEMESTER	16
CE 218 Mechanics of Fluids or AME 331 Introduction to Fluid Mechanics	3
SIE 265 Engineering Management I	3
ABE 221 Introduction to Computer Aided Design	3
CHEM 241 A & CHEM 243 A Organic Chemistry	4
SIE 305 Engineering Probability and Statistics	3
6TH SEMESTER	16
ABE 423 Biosystems Analysis and Design	3
ABE Design Elective	3
ABE Technical Elective	3
AGTM 422 or ENGL 308 Technical Writing	3
CHEM 241 B & CHEM 243 B Organic Chemistry	4
7TH SEMESTER	16
ABE 496A Seminar in Engineering Careers and Professionalism	1
ABE 498A Senior Capstone: Biosystems Engineering Design I	3
ABE 447 Sensors and Controls	3
ABE Design Elective	3
AME 324A Mechanical Behavior of Engineering Materials	3
Tier I General Education	3
8TH SEMESTER	16
ABE 498B Senior Capstone: Biosystems Engineering Design II	3
AME 431 Numerical Methods in Fluid Mechanics or AME 432 Heat Transfer or an approved ABE 400 level course	3
ABE 393 Internship	1
ABE Design Elective	3
Tier II General Education	3
Tier II General Education	3

Total Units needed for Graduation 128: (Total Units with Math 125 option = 130 or Total Units with Math 122A/B option = 128)

- BE students should review their Student Academic Advisement Report (SAAR), with either the ABE Academic Program Coordinator or their assigned ABE Faculty Advisor at least once a semester.
- Students who do not take ENGR 102, will be required to take an approved 300 or 400 Engineering Elective 3 unit course.
- ABE Engineering Design Electives: Students need to complete 9 units of upper division courses, see SAAR for list of acceptable courses.
- Technical Electives: Students need to complete 9 units of upper division courses, see SAAR for a list of acceptable courses.

Appendix E3. Academic Advisement Report

Academic Advisement Report
UGRD.UENGR.BEBSBE
Undergraduate Career
College of Engineering Program
Biosystems Engineering Major (BSBE) Requirement Term: Fall 2015

Undergraduate Graduation Requirements(RG511)

All course work and requirements for this degree must be completed prior to the date the degree is awarded. The University of Arizona requirements to follow in this audit are required for graduation and awarding of the degree.

Curriculum:

The University of Arizona and the Arizona Board of Regents have sole discretion over all curricula changes.

Courses, programs & requirements may be suspended, deleted, restricted, or changed in any manner, at any time.

Students must remain currently informed about all policies & other info that bears on completing a degree.

Required Units:

Additional units will be required to complete this degree if a student is admitted to the UA with deficiencies; changes his/her academic plan(s); fails to meet minimum course/plan requirements; ineffectively plans or fails to execute a course of study that leads directly to degree completion; or is completing more than one baccalaureate degree. Completing a second bachelor's degree at The University of Arizona requires no fewer than 30 units in addition to the units required for the first degree, and all requirements for the second degree must be met.

The following requirements must be met for graduation.

Units Required and Cumulative GPA(R2903/L30)

128 units are required at a 2.0 GPA. View the pdf report grid for units earned toward this degree and cumulative GPA.

Completing a second bachelor's degree at The University of Arizona requires no fewer than 30 units in addition to the units required for the first degree, and all requirements for the second degree must be met.

Upper Division Units(R538/L40)

Not Satisfied: A minimum of 42 units of upper-division credit are required for this degree.

Units: 42.00 required, 0.00 completed, 42.00 needed

Units in Residence(R538/L60)

Not Satisfied: A minimum of 30 units in residence at The University of Arizona (excluding

correspondence credit and credit by exam) is required.

Units: 30.00 required, 0.00 completed, 30.00 needed

Final Units in Residence(R538/L70)

A minimum of 18 of the final 30 units taken toward degree requirements must be in residence at The University of Arizona. Consult with your academic advisor if you plan to use transfer credits to fulfill your degree requirements.

Correspondence and/or Exam Credit Limit(R2075/L10)

Satisfied: A maximum of 60 units of Correspondence Credit and/or Exam Credit may apply toward graduation.

Units: 0.00 completed

Non Degree Seeking Limit(R838/L10)

A maximum of 15 units completed as a non-degree seeking student may be used for fulfilling undergraduate degree requirements.

Units exceeding this limit (shown below) must be subtracted from the units required towards the degree and graduation requirements.

Community College Limit(R1227/L30)

Not Satisfied: A maximum of 64 units of community college course work may apply toward graduation. A minimum of 64 units of course work must be completed at a 4-year institution, military institution, or as test credit.

Units: 64.00 required, 0.00 completed, 64.00 needed

Success Course Limit(R3297/L15)

Satisfied: No more than 3 units will apply toward a student's graduation requirements.

All Success courses taken can be seen below. Success Course units exceeding the 3 unit maximum must be subtracted from the total units, residency requirements and cumulative grade point average.

PE Activity Course Limit(R3297/L25)

Satisfied: No more than 3 units will apply toward a student's graduation requirements.

All PE activity courses taken can be seen below. PE Activity units exceeding the 3 unit maximum must be subtracted from the total units, residency requirements and cumulative grade point average.

Foundation Mathematics(RG1434)

Not Satisfied: Foundation Mathematics

GE Substantial Math Strand(R2439)

Not Satisfied: GE Substantial Math Strand

GE Substantial Math Strand(R2439/L10)

Not Satisfied: Complete 1 course.

Units: 2.67 required, 0.00 completed, 2.67 needed

Courses: 0.00 completed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

MATH 122B, MATH 124, MATH 125, MATH 125-CC

Undergraduate General Education and Foundation Requirements(RG507)

Overall Requirement Not Satisfied: Undergraduate General Education and Foundation Requirements

Foundation Composition(R532)

Not Satisfied: Select from 1 of the 3 following options:

First and Second Semester Composition OR

Honors Composition with grade of C or higher OR

Honors Composition with a grade of D and Second Semester Composition.

Please note: Students who earn a grade of D in Honors Composition may choose to repeat the course in order to earn a higher grade to satisfy the requirement. Please consult with your major advisor.

Mid-Career Writing Assessment - Complete 2nd semester English Composition with a B grade or higher. Students who do not earn a grade of B or better in 2nd semester English Composition must also satisfy a college or department writing requirement. Consult your major advisor if you do not earn a grade of B in 2nd semester English Composition.

Option 1: First Semester Composition(R532/L10)

Not Satisfied: Complete 1 course

Courses: 1.00 required, 0.00 completed, 1.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

ENGL 101, ENGL 101A, ENGL 103H, ENGL 107, ENGL 107A

AND Option 1: Second Semester Composition(R532/L20)

Not Satisfied: AND Complete 1 course

Courses: 1.00 required, 0.00 completed, 1.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

ENGL 102, ENGL 104H, ENGL 108

OR Option 2: Honors Composition(R532/L30)

Not Satisfied: OR Complete 1 course with a C or better.

Courses: 1.00 required, 0.00 completed, 1.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type
	ENGL	109H						

Courses Available

ENGL 109H

GE Foundation Second Language not required(R3219)

Satisfied: There is no second language required for your major.

General Education Tier I(R522)

Overall Requirement Not Satisfied: Complete 2 courses in each of the following areas.

Tier I Individuals & Societies(R522/L10)

Not Satisfied: Fulfillment of Individuals and Societies requires completion of two distinctly numbered courses (e.g., INDV 101 & 103 or PSY 150A1 & ANTH 150B1 or PSY 150A1 & INDV 103).

Only one course may be completed from the 150A options OR INDV 101. Only one course may be completed from the 150B options OR INDV 102. Only one course may be completed from the 150C options OR INDV 103.

INDV 101 = 150A# INDV 102 = 150B# INDV 103 = 150C#

Courses: 2.00 required, 0.00 completed, 2.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

(***) (###), ANTH 150B1, ANTH 150B1-SA, ART 150B1, ART 150B1-SA, ART 150B2, EDP 150B1, EDP 150B1-SA, ENGL 150B1, ENGL 150B1-SA, ESOC 150B1, FSHD 150B1, GEOG 150B1, GEOG 150B1-SA, GER 150B1, GER 150B1-SA, GWS 150B1, GWS 150B1-SA, GWS 150B2, GWS 150B2-SA, GWS 150B3, GWS 150B3-SA, GWS 150B4, GWS 150B4-SA, HNRS 150B1, HNRS 150B1-SA, HNRS 150B2, LAR 150B1, LAR 150B1-SA, LAS 150B1, LAS 150B1-SA, MAS 150B1, MAS 150B2, MIS 150B1, MIS 150B1-SA, PA 150B1, PA 150B1-SA, PHIL 150B1, PHIL 150B1-SA, POL 150B1, POL 150B1-SA, RCSC 150B1, RCSC 150B1-SA, RCSC 150B2, RCSC 150B2-SA, RSSS 150B1, RSSS 150B1-SA, SOC 150B1, SOC 150B1-SA, SOC 150B2, SOC 150B2-SA, TLS 150B1, TLS 150B1-SA, AED 150A1, AED 150A1-SA, ANTH 150A1, ANTH 150A1-SA, ART 150A1, ART 150A1-SA, HWRS 150A1, LING 150A1, LING 150A1-SA, MIS 150A1, MIS 150A1-SA, PHIL 150A1, PHIL 150A1-SA, POL 150A1, POL 150A1-SA, PSY 150A1, PSY 150A1-SA, AED150C1, AREC 150C1, AREC 150C1-SA, AREC 150C2, AREC 150C2-SA, ECON 150C1, ECON 150C1-SA, GEOG150C1, GEOG 150C1-SA, HIST 150C1, HIST 150C1-SA, HIST 150C2, HIST 150C2-SA, HIST 150C3, HIST 150C3-SA, HIST 150C4, HIST 150C4-CC, HIST 150C4-SA, HIST 150C5, HIST 150C5-CC, HIST 150C5-SA, HIST 150C6, HIST 150C6-SA, HNRS 150C1, JOUR 150C1, JOUR 150C1-SA, MAS 150C1, MAS 150C1-SA, MENA 150C1, MENA 150C1-SA, PHIL 150C1, PHIL 150C1-SA, PLP 150C1, PLP 150C1-SA, POL 150C1, POL 150C1-SA, POL 150C2, POL 150C2-SA, POL 150C3, RNR 150C1, SOC 150C1, SOC 150C1-SA, SOC 150C2, SOC 150C2-SA, TLS 150C1

Tier I Traditions & Cultures(R522/L30)

Not Satisfied: Fulfillment of Traditions and Cultures requires completion of two distinctly numbered courses (e.g., TRAD 102 & 104 or AFAS 160C2 & RSSS 160C1 or TRAD 101 & RSSS 160C1).

Only one course may be completed from the 160A options OR TRAD 101. Only one course may be completed from the 160B options OR TRAD 102. Only one course may be completed from the 160C options OR TRAD 103. Only one course may be completed from the 160D options OR TRAD 104.

TRAD 101 = 160A# TRAD 102 = 160B# TRAD 103 = 160C# TRAD 104 = 160D#

Courses: 2.00 required, 0.00 completed, 2.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

(***) (###), AFAS 160A1, AFAS 160A1-SA, AFAS 160A2, AFAS 160A2-SA, AIS 160A1, AIS 160A1-SA, ANTH 160A1, ANTH 160A1-SA, EAS 160A1, EAS 160A1-SA, EAS 160A2, EAS 160A2-SA, EAS 160A3, EAS 160A3-SA, EAS 160A4, EAS 160A4-SA, EAS 160A5, EAS 160A5-SA, ENGL 160A1, ENGL 160A1-SA, FREN 160A1, FREN 160A1-SA, HIST 160A1, HIST 160A1-CC, HIST 160A1-SA, HIST 160A2, MAS 160A1, MAS 160A1-SA, MENA 160A1, MENA 160A1-SA, MENA 160A2, MENA 160A2-SA, MENA 160A3, MENA 160A3-SA, POL 160A1, POL 160A1-SA, CLAS 160B1, CLAS 160B1-SA, DNC 160B1, DNC 160B1-SA, ENGL

160B1, ENGL 160B1-SA, HIST 160B1, HIST 160B1-SA, HIST 160B2, HIST 160B2-SA, ITAL 160B1, ITAL 160B1-SA, POL 160B1, POL 160B1-SA, ARC 160C1, ARC 160C1-SA, DNC 160C1, DNC 160C1-SA, ENGL 160C1, ENGL 160C1-SA, GER 160C1, GER 160C1-SA, GWS 160C1, GWS 160C1-SA, HIST 160C1, HIST 160C1-SA, POL 160C1, POL 160C1-SA, RSSS 160C1, RSSS 160C1-SA, SPAN 160C1, SPAN 160C1-SA, ACBS 160D1, ACBS 160D1-SA, AFAS 160D1, AFAS 160D1-SA, ANTH 160D1, ANTH 160D1-SA, ANTH 160D2, ANTH 160D2-SA, ANTH 160D3, ANTH 160D3-SA, ARC 160D1, ARC 160D1-SA, ART 160D1, ART 160D1-SA, ART 160D2, ART160D2-SA, ART 160D3, ART 160D3-SA, CLAS 160D1, CLAS 160D1-SA, CLAS 160D2, CLAS 160D2-SA, CLAS 160D3, CLAS 160D3-SA, ENGL 160D1, ENGL 160D1-SA, ENTO 160D1, ENTO 160D1-SA, GER 160D1, GER 160D1-SA, HNRS 160D1, HNRS 160D1-SA, HNRS 160D2, JUS 160D1, JUS 160D1-SA, MUS 160D1, PHIL 160D1, PHIL 160D1-SA, PHIL160D2, PHIL 160D2-SA, PHIL 160D3, PHIL 160D3-SA, POL 160D1, POL 160D1-SA, RELI 160D1, RELI 160D1-SA, RELI160D2, RELI 160D2-SA, RELI 160D3, RELI 160D3-SA, RNR 160D1, RNR 160D1-SA, RSSS 160D1, SPAN 160D1, SPAN 160D1-SA, TAR 160D1

General Education Tier II(R2778)

Overall Requirement Not Satisfied: Majors must complete Tier II Individual and Societies. Choose one additional Tier II courses from Tier II Arts or Tier II Humanities to complete the requirement.

Option 1: Tier II Arts(R2778/L10)

Not Satisfied: Complete 3 units

Units: 3.00 required, 0.00 completed, 3.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

AFAS 318, AFAS 318-SA, AFAS 371, ANTH 318, ARC 325, ARE 130, ARH 201, ARH 202, ARH 202-SA, ARH 203, ARH 312, ARH 314, ARH 314-SA, ARH 315, ARH 315-SA, ARH 316A, ARH 316A-SA, ARH 316B, ARH 319, ARH 320, ARH 321, ARH 322, ARH 324, ARH 325, ARH 329, ART 203, ART 242, ART 329, ART 358, ART 358-SA, CLAS 310, CLAS 329, DNC 100, DNC 101, DNC 112A, DNC 112B, DNC 112C, DNC 143, DNC 144A, DNC 144B, DNC 144C, DNC 152A, DNC 152B, DNC 152C, DNC 175, DNC 176A, DNC 176B, DNC 177C, DNC 177D, DNC 200, DNC 276A, ENGL201, ENGL 201-SA, ENGL 209, ENGL 210, ENGL 300, ENGL 300-SA, ENGV 300, FTV 252, FTV 375, HNRS 203H, HNRS 216, HNRS 218, HNRS 220, HNRS 222, ISTA 301, JPN 245, LAS 322, LAS 337, MAS 337, MUS 100, MUS 100-CC, MUS 101A, MUS 107, MUS 107-CC, MUS 108, MUS 108-CC, MUS 109, MUS 206, MUS 231, MUS 328, MUS 334, MUS 334-CC, MUS 337, MUS 344, MUS 360, RELI 227, RELI 345, TAR 100, TAR 103, (***) (###)

Option 2: Tier II HumanitiesR2778/L20)

Not Satisfied: Complete 1 course. Prerequisite course work in Tier 1 Traditions and Cultures (TRAD) must be completed prior to taking. If LAT 201 or 202 are used to fulfill Foundation Second Language Proficiency, they cannot be used to fulfill Tier II Humanities.

Courses: 1.00 required, 0.00 completed, 1.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

AFAS 200, AFAS 222, AFAS 224, AFAS 230, AFAS 245, AFAS 245-CC, AFAS 249, AFAS 255, AFAS 310, AFAS 314, AFAS 320, AFAS 342, AFAS 365, AFAS 373, AFAS 374, AFAS 375, AFAS 381, AIS 381, ANTH 222, ANTH 300, ARH300, ARH 329, ART 329, CHN 245, CLAS 220, CLAS 220-SA, CLAS 221, CLAS 221-SA, CLAS 260, CLAS 300, CLAS300-SA, CLAS 329, CLAS 335, CLAS 335-SA, CLAS 342, CLAS 346, ENGL 220A, ENGL 220B, ENGL 230, ENGL 231, ENGL 245, ENGL 245-CC, ENGL 248B, ENGL 260, ENGL 260-SA, ENGL 265, ENGL 265-CC, ENGL 267, ENGL 267- SA, ENGL 280, ENGL 342, ENGL 375, ENGV 360, FREN 245, FREN 245-CC, FREN 249, FREN 280, FREN 280-SA, FREN 282, FREN 282-CC, FREN 283, FREN 283-CC, FREN 284, FREN 284-CC, FREN 373, FREN 374, FREN 375, FTV 325, GER 242, GER 246, GER 273, GER 275, GER 276, GER 278, GER 312, GER 325, GER 371, GER 373, GER 375, GER 376, GER 379, GWS 200, GWS 317, GWS 330, GWS 342, GWS 373, HIST 224, HIST 247, HIST 277A, HIST 277B, HIST 278, HIST 372A, HIST 372B, HNRS 200, HNRS 208-SA, HNRS 208H, HNRS 209, HNRS 209-SA, HNRS 212, HNRS 212-SA, ITAL 230, ITAL 230-SA, ITAL 240, ITAL 240-SA, ITAL 250A, ITAL 250B, ITAL 250C, ITAL 250D, ITAL 330B, JPN 220, JPN 311, JUS 301, JUS 325, JUS 372A, JUS 372B, JUS 376, LAS 310, LAT 201, LAT 201- SA, LAT 202, LAT 202-SA, MENA 277A, MENA 277B, MENA 372A, MENA 372B, PHIL 210, PHIL 213, PHIL 220, PHIL 222, PHIL 260, PHIL 261, PHIL 262, PHIL 325, PHIL 325-SA, PHIL 330, RELI 210, RELI 211, RELI 212, RELI 220, RELI220A, RELI 220B, RELI 250, RELI 255, RELI 277A, RELI 300, RELI 304, RELI 350, RELI 363, RELI 367, RELI 372A, RELI 372B, RELI 379, RELI 381, RELI 385, RSSS 210, RSSS 304, RSSS 340, RSSS 345, RSSS 350, SPAN 210, SPAN 210-SA, (***) (###)

AND Tier II Individual & Societies R2778/L30)

Not Satisfied: Complete 1 course. Prerequisite course work in Tier 1 Individuals and Societies (INDV) must be completed prior to taking.

Courses: 1.00 required, 0.00 completed, 1.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

AED 210, AED 309, AED 408, AFAS 220, AFAS 220-CC, AFAS 223, AFAS 260, AFAS 340, AFAS 376, AFAS 444, AGTM 380, AGTM 380-SA, AIS 210, AIS 346, AIS 347, ANTH 202, ANTH 203, ANTH 204, ANTH 307, ANTH 314, ANTH 316, ANTH 320, ANTH 330, ANTH 346, ANTH 346-CC, ANTH 347, ANTH 347-CC, ANTH 380, ANTV 307, AREC350, CLAS 240, CLAS 305, CLAS 305-SA, CLAS 306, CLAS 306-SA, CLAS 362, CPH 310, CPH 387, CPH 387-SA, CPH 444, EAS 280, ECON 200, ECON 200-CC, ECON 201A, ECON 201A-CC, ECON 205, EDL 200, EDP 200, ESOC210, FCSC 302, FSHD 200, FSHD 347, GEOG 205, GEOG 210, GEOG 210-CC, GEOG 250, GEOG 251, GEOG 251-CC, GEOG 256, GEOG 270, GEOG 367, GEOG 380, GER 274, GER 274-SA, GPSV 365, GWS 240, GWS 260, GWS 323, GWS 328, GWS 362, HED 350, HIST 246, HIST 370A, HIST 370B, HNRS 204H, HNRS 205H, HNRS 206H, HNRS207H, HNRS 217, HNRS 221, HUMS 376, ISTA 263, ITAL 330D, JOUR 305, JUS 370A, JUS 370A-CC, JUS 370B, JUS370B-CC, LAR 350, LAS 204, LAS 251, LING 210, LING 211, LING 330, MAS 265, MAS 365, MENA 251, MENA 330, MENA 334, NESV 334, NSC 255, NURS 310, PA 205, PA 250, PA 323, PHIL 205, PHIL 211, PHIL 214, PHIL 223, PHIL 233, PHIL 241, PHIL 246, PHIL 250, PHIL 264, PHIL 323, PHIL 326, PHIL

345, PHIL 346, PHIL 347, PHIL 348, PLG 202, PLG 211, PLG 256, POL 201, POL 201-CC, POL 201-SA, POL 202, POL 202-CC, POL 202-SA, POL 203, POL 204, POL 204-CC, POL 250, PSY 200, PSY 240, PSY 240-CC, PSY 241, PSY 277, PSY 345, PSY 346, PSY 347, PSY 348, RCSC 204, RELI 233, RELI 305, RELI 306, RELI 315, RELI 323, RELI 326, RELI 334, RELI 360, RELI 370A, RELI 370B, RELV 334, RNR 256, RSSS 275, RSSS 315, RSSS 328, SERP 200, SLHS 255, SLHS 310, SOC 220, SOC260, SOC 260-CC, SOC 260-SA, SOC 280, SOC 357, SOC 367, SPAN 220, TLS 200, TLS 204, TLS 239, TLS 240, (***) (###)

Diversity Emphasis Course(R531)

Not Satisfied: One course must be taken that focuses on Gender, Race, Class, Ethnicity, Sexual Orientation or Non-Western Area Studies.

Courses used to fulfill this requirement may also be used to fulfill other requirements.

Diversity Emphasis Course(R531/L10)

Not Satisfied: General Education Diversity Emphasis Course: Gender, Race, Class, Ethnicity, Sexual Orientation or Non- Western Area Studies.

Courses: 1.00 required, 0.00 completed, 1.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

AED 408, AFAS 160A1, AFAS 160A1-SA, AFAS 160A2, AFAS 160A2-SA, AFAS 220, AFAS 220-CC, AFAS 222, AFAS 223, AFAS 230, AFAS 245, AFAS 245-CC, AFAS 249, AFAS 255, AFAS 260, AFAS 302, AFAS 304A, AFAS 304A-SA, AFAS 304B, AFAS 306, AFAS 310, AFAS 311D, AFAS 314, AFAS 318, AFAS 318-SA, AFAS 330, AFAS 330-CC, AFAS 340, AFAS 342, AFAS 365, AFAS 371, AFAS 373, AFAS 375, AFAS 381, AFAS 444, AFAS 467, AFAS 468, AIS 160A1, AIS 160A1-SA, AIS 210, AIS 346, AIS 347, AIS 381, AIS 467, ANTH 150A1, ANTH 150A1-SA, ANTH 160A1, ANTH 160A1-SA, ANTH 202, ANTH 203, ANTH 222, ANTH 307, ANTH 314, ANTH 316, ANTH 318, ANTH 320, ANTH 330, ANTH 346, ANTH 346-CC, ANTH 347, ANTH 347-CC, ANTH 375, ANTH 402, ANTH 450, ANTH 467, ANTV 307, ANTV375, ARH 203, CHN 245, CHN 251, CHN 275, CHN 276, CHN 276-CC, CHN 331, CHN 340, CHN 341, CHN 419, CHN420, CHN 429, CHN 468, CHN 475D, CHN 475E, CHN 482, CHN 483, CHN 483-SA, CLAS 362, CPH 387, CPH 387- SA, CPH 444, DNC 177C, DNC 177D, EAS 130, EAS 130-CC, EAS 160A1, EAS 160A1-SA, EAS 160A2, EAS 160A2- SA, EAS 160A3, EAS 160A3-SA, EAS 160A4, EAS 160A4-SA, EAS 160A5, EAS 160A5-SA, EAS 280, EAS 333, EAS 484A, EAS 484B, EAS 489, EAS 496C, EAS 496C-SA, ENGL 160A1, ENGL 160A1-SA, ENGL 230, ENGL 245, ENGL245-CC, ENGL 342, ENGL 429, FREN 160A1, FREN 160A1-SA, FREN 245, FREN 245-CC, FREN 249, FREN 373, FTV251, GEOG 205, GEOG 210, GEOG 210-CC, GEOG 251, GEOG 251-CC, GEOG 311D, GEOG 311E, GER 274, GER274-SA, GER 278, GER 373, GER 376, GWS 200, GWS 240, GWS 253, GWS 254, GWS 254-CC, GWS 260, GWS306, GWS 323, GWS 324, GWS 328, GWS 330, GWS 335, GWS 335-CC, GWS 342, GWS 362, GWS 373, GWS 402, GWS 427, GWS 448, GWS 459, GWS 468, GWS 489, HIST 160A1, HIST 160A1-CC, HIST 160A1-SA, HIST 160A2, HIST 253, HIST 253-CC, HIST 254, HIST 254-CC, HIST 272, HIST 275, HIST 276, HIST 277A, HIST 278, HIST 306, HIST 370A, HIST 370B, HIST 372A, HIST 372B, HIST 475D, HIST 475E, HIST 482, HIST 489, HNRS 204H, ITAL 330B, ITAL 330D, JPN 220, JPN 245, JPN 272, JPN 304, JPN 304-SA, JPN 310, JPN 311, JPN 396H, JPN 402, JPN 411, JPN 411-SA, JPN 412, JPN 446A, JPN 446B, JPN 447A, JPN 447B, JPN 485, JPN 486, JPN 489, JPN 495B, JPN 495B-SA, JPN 496A, JPN 496A-SA, JPN 496C, JPN 496C-SA, JUS 325, JUS 370A, JUS 370A-CC, JUS 370B, JUS370B-CC, JUS 372A, JUS 372B, JUS 376, LAS 251, LAS 310, LAS 337, LAS

362, LING 210, LING 304, LING 330, LING 402, LING 411, LING 412, LING 419, LING 420, LING 496C, MAS 160A1, MAS 160A1-SA, MAS 265, MAS 330, MAS 330-CC, MAS 332, MAS 332-CC, MAS 337, MAS 365, MAS 467, MENA 160A1, MENA 160A1-SA, MENA 160A2, MENA 160A2-SA, MENA 160A3, MENA 160A3-SA, MENA 251, MENA 277A, MENA 311E, MENA 330, MENA 334, MENA 372A, MENA 372B, MENA 375, MENA 375-SA, MENA 441, MIS 150B1, MIS 150B1-SA, MUS 109, MUS 231, MUS 334, MUS 334-CC, MUS 337, MUS 344, NESV 334, NESV 375, PHIL 222, PHIL 223, PHIL 325, PHIL 325-SA, PHIL 330, POL 160A1, POL 160A1-SA, POL 330, POL 330-CC, POL 332, POL 332-CC, POL 335, POL 335-CC, POL 441, POL 464, POL 464-SA, POL 468, POL 476, RELI 130, RELI 210, RELI 212, RELI 220, RELI 277A, RELI 323, RELI 324, RELI 331, RELI 333, RELI 334, RELI 350, RELI 360, RELI 363, RELI 370A, RELI 370B, RELI 372A, RELI 372B, RELI 381, RELI 483, RELI 484A, RELI 484B, RELI 485, RELI 486, RELI 489, RELV 334, RSSS 315, RSSS 328, RSSS 350, SOC 220, SOC 222, SOC 260, SOC 260-CC, SOC 260-SA, SOC 280, SOC 324, SOC 324-CC, SOC 325, SOC 357, SOC 362, SOC 362-CC, SOC 427, SOC 432, SOC 448, SOC 448-CC, SOC 450, SOC 450-CC, SOC 459, SOC 459-CC, SOC 459-SA, SOC 467, SPAN 210, SPAN 210-SA, TLS 150C1

Additional Coursework(RG521)

Courses listed in this section may include general elective credits, UA courses and transferable courses from other institutions. Consult with your advisor to determine if courses listed in this section may be used to fulfill a requirement or sub-requirement in your degree program.

Courses taken for Pass/Fail option can only count as elective credit. They cannot fulfill any General Education, Major, or Minor requirements.

BSBE in Biosystems Engineering(RG1744)

Overall Requirement Not Satisfied: BSBE in Biosystems Engineering. In order to take Advanced Courses in this major, a student must achieve Advanced Standing. This requires a GPA of 2.00 in the Foundation Coursework listed below.

Engineering Foundation Coursework(R15599)

Overall Requirement Not Satisfied: Departments require a specific GPA in Advanced Standing Requirement courses.

Math - Calculus I(R15599/L10)

Not Satisfied: Complete 3 units.

Units: 3.00 required, 0.00 completed, 3.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

MATH 122B, MATH 124, MATH 125, MATH 125-CC

Math - Calculus II(R15599/L20)

Not Satisfied: Complete 3 units.

Units: 3.00 required, 0.00 completed, 3.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

MATH 129, MATH 129-CC, MATH 250A

Science - Gen Chemistry I(R15599/L60)

Not Satisfied: Complete 4 units.

Units: 4.00 required, 0.00 completed, 4.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

CHEM 151, Approved Transfer Course, CHEM 103A, CHEM 103A-CC, CHEM 104A, CHEM 105A, CHEM 106A

Science - Gen Chemistry II(R15599/L70)

Not Satisfied: Complete 4 units.

Units: 4.00 required, 0.00 completed, 4.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

CHEM 152, Approved Transfer Course, CHEM 103B, CHEM 103B-CC, CHEM 104B, CHEM 105B, CHEM 106B

Science - Intro Mechanics Physics(R15599/L140)

Not Satisfied: Complete 4 units.

Units: 4.00 required, 0.00 completed, 4.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

PHYS 141, PHYS 161H

Science - Intro Elec & Magnetism Physics(R15599/L160)

Not Satisfied: Complete 4 units.

Units: 4.00 required, 0.00 completed, 4.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

PHYS 241, PHYS 261H

Science - Molecular and Cellular Biology OR Plant Science(R15599/L200)

Not Satisfied: Complete 4 units.

Units: 4.00 required, 0.00 completed, 4.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

MCB 181L, MCB 181R, Approved Transfer Course, MCB 184, PLS 240

Science - Microbiology OR PSIO I OR Ecology II(R15599/L240)

Not Satisfied: Complete 4 units.

Units: 4.00 required, 0.00 completed, 4.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

MIC 205A, MIC 205L, ECOL 182L, ECOL 182R, Approved Transfer Course, PSIO 201

Engineering Courses - Biosystems(R15599/L290)

Not Satisfied: Complete 8 units.

Units: 5.00 required, 0.00 completed, 5.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type
Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

ABE 201, ABE 205, ABE 284

Engineering Courses - Additional Courses I(R15599/L380)

Not Satisfied: Complete 3 units.

Units: 3.00 required, 0.00 completed, 3.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

ENGR 102A, ENGR 102B, ENGR 102

Engineering Courses - Biosystems Additional Courses II(R15599/L405)

Not Satisfied: Complete 3 units.

Units: 3.00 required, 0.00 completed, 3.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

CE 214

English Composition(R15599/L530)

Not Satisfied: Complete 6 units.

Units: 6.00 required, 0.00 completed, 6.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

ENGL 102, ENGL 104H, ENGL 108, ENGL 101, ENGL 101A, ENGL 103H, ENGL 107, ENGL 107A

OR English Composition(R15599/L540)

Not Satisfied: Complete 3 units.

Units: 3.0 required, 0.00 completed, 3.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

ENGL 109H

Biosystems Engineering Advanced Courses(R15606)

Overall Requirement Not Satisfied: Biosystems Engineering Advanced Courses

Biosystems Engineering Math(R15606/L10)

Not Satisfied: Complete 7 units. Complete 1 course from either MATH 250B or MATH 254

Units: 7.00 required, 0.00 completed, 7.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

MATH 223, MATH 223-CC, MATH 250B, MATH 254, MATH 254-CC

Biosystems Engineering Advanced Core Courses I(R15606/L20)

Not Satisfied: Complete 17 units. 17 units of Advanced Core units consist of the following: 3 units from ABE 221, 3 units from ABE 423, 3 units from ABE 447, 1 unit from ABE 496A, 3 units from ABE 498A, 3 units from ABE 498B, 1 unit from ABE 393. Additional units taken through ABE 393 may not be used to substitute for or replace those for the Advanced Core Courses II.

Units: 17.00 required, 0.00 completed, 17.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

ABE 221, ABE 393, ABE 393-SA, ABE 423, ABE 447, ABE 496A, ABE 498A, ABE 498B

Biosystems Engineering Advanced Core Courses II(R15606/L30)

Not Satisfied: Complete 3 units. Students must choose, in consultation with an BE Advisor, a 3 unit ABE 400 level course, or ABE 431, or ABE 432. Students will not be able to double dip with the BE major courses.

Units: 3.00 required, 0.00 completed, 3.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

ABE 422, ABE 426, ABE 427, ABE 428, ABE 452, ABE 452-SA, ABE 455, ABE 456, ABE 458, ABE 459, ABE 467, ABE 475A, ABE 479, ABE 481A, ABE 481B, ABE 482, ABE 483, ABE 486, ABE 487, ABE 488, ABE 489A, ABE 489B, ABE 492, ABE 497C, AME 431, AME 432

Biosystems Engineering Advanced Design Courses(R15606/L40)

Not Satisfied: Complete 9 units. Students will not be able to double dip with courses between the major. BE Design Electives should be chosen in consultation with an advisor.

Units: 9.00 required, 0.00 completed, 9.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

ABE 422, ABE 426, ABE 427, ABE 428, ABE 452, ABE 452-SA, ABE 455, ABE 456, ABE 458, ABE 459, ABE 467, ABE 475A, ABE 479, ABE 481A, ABE 481B, ABE 483, ABE 486, ABE 488, ABE 489A, ABE 489B, ABE 493, ABE 497C

Additional Engineering Courses I(R15606/L50)

Not Satisfied: Complete 9 units.

Units: 9.00 required, 0.00 completed, 9.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

ENGR 265, SIE 265, SIE 305, SIE 305-CC, SIE 305-SA, AME 324A

Additional Engineering Courses II(R15606/L60)

Not Satisfied: Complete 3 units.

Units: 3.00 required, 0.00 completed, 3.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

AME 331, BME 331, CE 218
Additional Courses(R15606/L70)
Not Satisfied: Complete 3 units.

Units: 3.00 required, 0.00 completed, 3.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

AGTM 422, ENGL 308, ENGV 308

Biosystems Engineering Technical Electives(R15607)

Not Satisfied: Biosystems Engineering Technical Electives

Biosystems Technical Electives(R15607/L10)

Not Satisfied: Complete 9 units. Students will not be able to double dip with courses between the major. BE Technical Electives should be chosen in consultation with an advisor.

Units: 9.00 required, 0.00 completed, 9.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Courses Available

ABE 422, ABE 426, ABE 427, ABE 428, ABE 452, ABE 452-SA, ABE 455, ABE 456, ABE 458, ABE 459, ABE 467, ABE 475A, ABE 479, ABE 481A, ABE 482, ABE 483, ABE 486, ABE 487, ABE 488, ABE 489A, ABE 489B, ABE 497C, ACBS 428L, ACBS 428R, ACBS 443, AGTM 497C, AIS 431A, AIS 441A, AME 301, AME 313, AME 320, AME 324B, AME 324L, AME 352, AME 430, AME 431, AME 432, AME 433, AME 442, AME 444, AME 445, AME 446, AME 455, AME 460, AME 462, AME 463, AME 466, AME 472, AME 473, AME 474, AME 483, AME 487, AME 488, AME 489A, AME 489B, ANTH 405A, ANTH 431A, ANTH 441A, ARL 441A, ASM 404, ATMO 423, BIOC 384, BIOC 385, BIOC 443, BIOC 448A, BIOC 462A, BIOC 462B, BIOC 463A, BIOC 466, BIOC 470, BIOC 471, BIOC 472, BIOC 473A, BME 330, BME 416, BME 417, BME 466, BME 480, BME 483, BME 485, BME 486, CE 301, CE 310, CE 323, CE 333, CE 334, CE 335, CE 343, CE 349, CE 363, CE 370L, CE 370R, CE 381, CE 389, CE 402, CE 408A, CE 410, CE 411, CE 422, CE 423, CE 426, CE 427, CE 429, CE 432, CE 433, CE 434, CE 435, CE 437, CE 438, CE 439, CE 440, CE 441, CE 442, CE 444, CE 445, CE 446, CE 448, CE 455, CE 456, CE 458, CE 460, CE 462A, CE 463, CE 464A, CE 465, CE 466, CE 468, CE 469, CE 473, CE 476A, CE 476B, CE 478, CE 484, CHEE 301A, CHEE 301B, CHEE 303, CHEE 305, CHEE 326, CHEE 370L, CHEE 370R, CHEE 370R-CC, CHEE 400A, CHEE 400R, CHEE 401A, CHEE 402, CHEE 413, CHEE 415, CHEE 420, CHEE 435, CHEE 436, CHEE 437, CHEE 442, CHEE 443, CHEE 471, CHEE 473, CHEE 476A, CHEE 476B, CHEE 477R, CHEE 478, CHEE 481A, CHEE 482, CHEE 488, CHEM 241A, CHEM 241B, CHEM 243A, CHEM 243B, CHEM 302A, CHEM 322, CHEM 323, CHEM 325, CHEM 326, CHEM 380, CHEM 400A, CHEM 400B, CHEM 401A, CHEM 404A, CHEM 404B, CHEM 412, CHEM 432A, CHEM 436, CHEM 437, CHEM 439A, CHEM 446, CHEM 447, CHEM 448A, CHEM 450, CHEM 470A, CHEM 470B, CHEM 480A, CHEM 480B, CHEM 481, CPH 484, CSC 401A, ECE 415, ECE 417, ECOL 410, ECOL 428L, ECOL 428R, ECOL 448A, ECOL 454, ECOL 456A, ECOL 474, ENGR 211P, ENGR 435, ENGR 436, ENGR 452, ENTO 436, ENTO 497C, ENTR 436, ENVS 305, ENVS 307, ENVS310, ENVS 316, ENVS 330, ENVS 340, ENVS 401, ENVS 404, ENVS 408, ENVS 410, ENVS 425, ENVS 426, ENVS428L, ENVS 428R, ENVS 430L, ENVS 430R, ENVS 431, ENVS

431A, ENVS 436, ENVS 440, ENVS 441A, ENVS 453, ENVS 454, ENVS 456A, ENVS 461, ENVS 462, ENVS 464, ENVS 470, ENVS 471, ENVS 474, ENVS 483, GEN 330, GEN 446, GEOG 330, GEOG 431A, GEOG 483, GEOS 330, GEOS 340, GEOS 410, GIST 483, HWRS 340, HWRS423, HWRS 427, HWRS 456A, HWRS 467, MATH 310, MATH 322, MATH 330, MATH 355, MATH 362, MATH 363, MATH 401A, MATH 402, MATH 407, MATH 413, MATH 415A, MATH 415B, MATH 422, MATH 424, MATH 425A, MATH 425B, MATH 432, MATH 443, MATH 445, MATH 446, MATH 447, MATH 454, MATH 454-CC, MATH 456, MATH 461, MATH 464, MATH 466, MATH 468, MATH 475A, MATH 475B, MATH 485, MCB 448A, MIC 425, MIC 426, MIC 428L, MIC 428R, MIC 440, MIC 443, MNE 411, MNE 484, MSE 302, MSE 303, MSE 304, MSE 331L, MSE 331R, MSE 345, MSE 360L, MSE 365, MSE 405A, MSE 411, MSE 412, MSE 414, MSE 415, MSE 435, MSE 437, NSC 484, PCOL 484, PHIL 401A, PHIL 427, PHYS 305, PHYS 321, PHYS 331, PHYS 332, PHYS 371, PHYS 381, PHYS 382, PHYS 405, PHYS 422, PHYS 426, PHYS 427, PHYS 430, PHYS 431, PHYS 433, PHYS 439, PHYS 440, PHYS 444, PHYS 445E, PHYS 460, PHYS 468, PHYS 469, PHYS 472, PHYS 473, PHYS 474, PHYS 476, PHYS 478, PHYS 480, PHYS 481, PHYS 483, PLG 462A, PLG 468, PLG 483, PLP 428L, PLP 428R, PLS 410, PLS 428L, PLS 428R, PLS 436, PLS 448A, PLS 475A, PLS 479, PLS 483, RAM 431A, RAM 441A, RNR 431A, RNR 436, RNR 441A, RNR 483, WFSC 431A, WFSC 441A, WFSC 454, WFSC 471, WFSC 474, WSM 330, WSM 426, WSM 431A, WSM 441A, WSM 456A, WSM467

Biosystems Engineering Graduation Requirements(R3034)

Overall Requirement Not Satisfied: Biosystems Engineering Graduation Requirements

Mid Career Writing Assessment(R3034/L20)

Not Satisfied: Complete 2nd semester English Composition with a B grade or higher. Students who do not earn a grade of B or higher in 2nd semester English Composition must also satisfy a college or department writing requirement. Consult your major advisor if you do not earn a grade of B or higher in 2nd semester English Composition.

Courses: 1.00 required, 0.00 completed, 1.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Major GPA(R3034/L40)

Satisfied: A minimum 2.0 GPA is required in the major coursework.

Units: 0.00 completed

GPA: 2.000 required, 0.000 completed

Major Residency(R3034/L50)

Not Satisfied: A minimum of 18 units in the major must be taken at the University of Arizona.

Units: 18.00 required, 0.00 completed, 18.00 needed

Term	Subject	Catalog Nbr	Course Title	Grade	Units	RptCd	RqDes	Type

Minor Optional(R1341)

Satisfied: A minor is optional for this major. Consult with your advisor to select a minor or discuss other options such as selecting a second major.

Appendix F. Biosystems Engineering Curriculum at previous ABET Review

Bachelor of Science in Biosystems Engineering (ABET Accredited) (2009-2010)

Biosystems engineers integrate mathematics, the biological, physical and engineering sciences with engineering design principles for producing and processing biological and agricultural products. These principles are applied to the design, analysis and construction of equipment, systems, and facilities for the efficient utilization of food, fiber and biochemical products. All programs utilize the latest in computer applications, sensor control systems, and biotechnology developments in their design objectives.

First Semester Course	Units	Second Semester Course	Units
Freshman Year (2009-2010)			
ENGR 102 (Intro to engineering)	3	MATH 129 (Calculus with applications 2)	3
MATH 125 (Calculus with applications 1)	3	CHEM 152 (General Chemistry II)	4
CHEM 151 (General Chemistry I)	4	PHYS 141 (Introductory mechanics)	4
ENGL 101 (First Year Composition 1)	3	ENGL 102 (First Year Composition 2)	3
INDV/TRAD*	3	INDV/TRAD*	3
Total	16	Total	17
Sophomore Year (2010-2011)			
ABE 296a (Seminar in BE).....	1	ABE 205 (Biosys Engin. Analt Skills Workshop)	3
CE 214 (Statics).....	3	AME 250 (Dynamics)	3
MATH 223 (Vector calculus).....	4	MATH 254 (Ordinary Differential Eqns).....	3
ABE 284 (Biosystems Transport Phen)	3	PHYS 241 (Intro. electricity and magnetism)	4
MCB 181R&L or PLS 130.....	4	MCB182 or MIC205A&L or PSIO 201	4
Total	15	Total	17
Junior Year (2011-2012)			
ABE 221 (Computer aided design).....	3	ABE 423 (Dynamics of biological systems).....	3
ABE 447 (Sensors and controls).....	3	ABE 484 (Advanced biosystems transport).....	3
CE 218 or AME 331 (Hydr. or Flu. mech.)	3	ABE Elective**	3
AME 324A (Mech of materials)	3	ENGL 308 (Technical writing).....	3
SIE 305 (Engin. Probability and Statistics)	3	ABE 393 (Internship).....	1
ENGR 211P (Engineering economics)	1	INDV/TRAD	3
Total	16	Total	16
Senior Year (20012-2013)			
ABE 496a (Seminar in Engr. Careers & Prof.).....	1	ABE 498b (Biosystems Engineering Design 2).....	3
ABE 498a (Biosystems Engineering Design 1).....	3	ABE Elective**	3
ABE Elective**	3	TECH Elective***	3
TECH Elective***	3	TECH Elective***	3
INDV/TRAD*	3	INDV/TRAD	3
INDV/TRAD*	3	Total	15
Total	16		

* INDV/TRAD courses must meet University general education requirements. One course must be recognized by the university as focusing on non-western culture, race, gender, or ethnicity. Tier 1 & 2 Ind. & Soc., Trad. & Cul., and GRCE course requirements are detailed on page 11.

**ABE Electives must contain elements of engineering design

***Technical electives depend upon area of emphasis and advisor's approval

Appendix G1. Example of Graduating Seniors Exit Survey

This Appendix contains only Q42. The full survey consists of 62 questions and will be available during the site visit if requested.

Q42 To what degree did your engineering education enhance your ability to:

	Not applicable (1)	Not well at all (2)	Less than adequately (3)	Adequately (4)	More than adequately (5)	Exceptionally well (6)
Apply your knowledge of mathematics. (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Apply your knowledge of science. (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Apply your knowledge of engineering. (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Design experiments using statistics. (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Conduct experiments. (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Analyze and interpret data. (6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Design a system, component, or process to meet desired needs. (7)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Function on multidisciplinary teams. (8)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Understand professional and ethical responsibilities. (9)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Communicate using oral reports. (10)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Communicate using written reports. (11)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Understand the impact of engineering solutions in a global/society context. (12)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Recognize the need to engage in life-long learning. (13)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Understand contemporary issues in your field. (14)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Use modern engineering tools. (15)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Build on knowledge from previous coursework. (16)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Build on skills from previous coursework. (17)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Address economic issues. (18)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Address environmental issues. (19)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Address sustainability issues. (20)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Address manufacturability issues. (21)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Address ethical issues. (22)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Address health and safety issues. (23)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Address social issues. (24)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Appendix G2. Example of Alumni Survey

Exit Survey for Biosystems Engineering Alumni



To improve the effectiveness of our degree programs, the College of Engineering has developed a continuous improvement process. One of the key portions of this process is program assessment. To this end, we need your help with the following questions. You may have filled out a similar questionnaire 3 years ago, but it will be appreciated if you will do it again so we can determine how perspectives change with time. Thank you in advance for your cooperation in this important matter. Please type the information requested in the spaces below and return your response as an e-mail attachment.

Name: _____ Graduation semester/year: _____

Please list any other degrees obtained since receiving your bachelor's degree: _____

What is your current position? _____

What Professional Societies do you participate in? _____

Based on your experiences in the College of Engineering (CoE) and your department, please respond to the following by checking the most appropriate number. Thank you in advance for your honesty and cooperation in this important matter.

If you are completing this form electronically, please follow these instructions to check the box that you would like to select as your answer:

1. Using your mouse cursor, double-click the check box you would like to mark
2. A dialog box will appear with some options; one option is a pair of radio buttons for *Checked* and *Not checked*
3. Select the button you prefer – *Checked* to mark the check box; *Not checked* to clear a box
4. Click *OK*

A. How satisfied were you with your education in the CoE at

The University of Arizona in helping your ability to:	highly	medium	unsatisfied
1. Apply required mathematics to engineering problems	5 <input type="checkbox"/>	4 <input type="checkbox"/> 3 <input type="checkbox"/>	2 <input type="checkbox"/> 1 <input type="checkbox"/>
2. Apply physics to engineering problems	5 <input type="checkbox"/>	4 <input type="checkbox"/> 3 <input type="checkbox"/>	2 <input type="checkbox"/> 1 <input type="checkbox"/>
3. Apply chemistry to engineering problems	5 <input type="checkbox"/>	4 <input type="checkbox"/> 3 <input type="checkbox"/>	2 <input type="checkbox"/> 1 <input type="checkbox"/>
4. Understand contemporary issues?	5 <input type="checkbox"/>	4 <input type="checkbox"/> 3 <input type="checkbox"/>	2 <input type="checkbox"/> 1 <input type="checkbox"/>

B. To what degree did your engineering education enhance your ability to:

	high	moderate	not at all
1. Analyze and interpret data?	5 <input type="checkbox"/>	4 <input type="checkbox"/> 3 <input type="checkbox"/>	2 <input type="checkbox"/> 1 <input type="checkbox"/>
2. Design experiments?	5 <input type="checkbox"/>	4 <input type="checkbox"/> 3 <input type="checkbox"/>	2 <input type="checkbox"/> 1 <input type="checkbox"/>
3. Conduct experiments?	5 <input type="checkbox"/>	4 <input type="checkbox"/> 3 <input type="checkbox"/>	2 <input type="checkbox"/> 1 <input type="checkbox"/>

- | | | | | | |
|--|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| 4. Function on multidisciplinary teams? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 5. Formulate engineering problems? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 6. Solve engineering problems? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 7. Understand ethical responsibilities of an engineer? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 8. Understand the impact of engineering solutions in a global context? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 9. Communicate via oral reports? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 10. Communicate via written reports? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 11. Recognize the need to engage in lifelong learning? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 12. Design a system component or process to meet a need? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |

C. To what degree did your design experience at the university

- | | | | | | |
|--|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| 1. Build on knowledge from previous coursework? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 2. Incorporate engineering standards? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 3. Address economic issues? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 4. Address environmental issues? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 5. Address health and safety issues? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 6. Address socio/political issues? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 7. Use techniques, skills, and tools encountered in modern engineering practice. | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |

D. To what degree did laboratory experiences at the university?

- | | | | | | |
|---|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| 1. Correlate with lecture courses? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 2. Allow you to learn to use modern tools in your field? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |
| 3. Enhance your understanding of basic operations or phenomena in your field? | 5 <input type="checkbox"/> | 4 <input type="checkbox"/> | 3 <input type="checkbox"/> | 2 <input type="checkbox"/> | 1 <input type="checkbox"/> |

E. Did your college experience meet your career needs? 5☐ 4☐ 3☐ 2☐ 1☐

What would you have changed?

F. What have you learned on the job that should have been included in your formal education?

It might be a good idea to discuss a few current journal articles in the class lectures once in a while, to relate what people are actually working on across the world (and what the problems are with these projects) with what the students are learning in their lectures.

G. Do you feel that at graduation you were adequately prepared for:

- | | | |
|-------------------------------|------------------------------|-----------------------------|
| 1. Initial career employment? | yes <input type="checkbox"/> | no <input type="checkbox"/> |
| 2. Graduate school? | yes <input type="checkbox"/> | no <input type="checkbox"/> |

Appendix H. ABE 2015-2016 Academic Program Review Report

Introduction

A Joint Internal/External Review Committee was invited to conduct an academic program review of the Department of Agricultural and Biosystems Engineering (ABE) at the University of Arizona. This seven- member Committee conducted an on- campus site visit during March 29 and 30, 2016. Based on review of the ABE self- study document and meetings with faculty, students, and staff, it is clear that the Department is committed to providing instruction, conducting fundamental and applied research, and delivering extension outreach for Arizona agriculture and beyond.

The Department currently has 14 tenure/tenure- track faculty including 9 full professors, 4 associate professors, and 1 assistant professor. In addition, the Department has 1 associate professor of professional practice whose primary responsibilities are teaching classes and running the senior design program. There is an undergraduate program for the B.S. degree in Biosystems Engineering and a graduate program in Agricultural and Biosystems Engineering granting M.S. (including an optional Accelerated Master's Program, AMP) and Ph.D. degrees. The emphasis areas of the Department are biometry and biosystems informatics; controlled environment agriculture; food, bioproducts, and renewable energy; and water resources. In 2015, the Department developed a defined Pre- Health Track four- year plan. A number of key events that occurred since 2009 have continued to impact the Department on its undergraduate and graduate enrollments and research funding: transferring the biomedical engineering students to the newly created Biomedical Engineering Department in the College of Engineering, transferring the Agricultural Systems Management degree in Yuma to the Agricultural Education Department in College of Agriculture and Life Sciences, and the departure of two senior faculty members to take positions in other universities. The latest enrollments, shown in the Self- Study Report, are 47 undergraduate students, 9 M.S. students, and 9 Ph.D. students. The Department has made a major effort in the development of its 2021 Strategic Plan. The Plan has four specific goals in the focus areas of bioenergy and bioproducts industry; biological information and sensors; production of safe food, feed, and fiber; and water resources engineering. For each goal, there are clearly stated faculty participants; the current situation and gaps between current situation and desired situations; strategies to achieve goals; actions; inputs needed to achieve each goal; and objective metrics that will be used to track progress towards attaining goals.

The Review Committee strongly recommends that the Department continues to clearly define its mission and identity. Having this framework in place will enable the Department to align its activities to achieve its goals. The results of the Review Committee evaluation are presented below in terms of perceived strengths (overall, programmatic, resources, and structure), weaknesses (overall, programmatic, resources, and structure), and recommendations to move forward.

Strengths

Overall

- The Department's significant investment in strategic planning processes using the logic model; this effort has produced some specific focus areas and planned actions. For example: build comprehensive teams, engage new partners, build infrastructure; obtain funding to support activities; perform innovative research and development and transfer to constituents; and educate students and communicate with the public (in Agricultural and Biosystems Engineering 2021 Strategic Plan, Strategic Goal One, Section C).
- The Department's involvement in numerous programmatic and functional activities, especially relative to the small size of the faculty and staff. A significant strength is the Department's commitment to increasing activities and initiatives, especially to recruit undergraduate and graduate students and garner research funding in new areas. As the Department is aware, key to its strength and reputation will be strong undergraduate and graduate programs.
- The strong position of the Department to address the two key aspects of any academic unit: sustainability and competitiveness.
- The strong alignment of the Department's abilities with the stated areas of emphasis at the University of Arizona. For example: Space Systems, Water and the Arid Environment, and Precision Health.
- The Department's strong public- private partnerships.
- The nationally and internationally visible and well- known research and outreach in areas of the Department (for example, controlled environment agriculture (CEA) and irrigation for semi- arid regions).
- The clear alignment of Departmental activities with the global initiatives of the American Society of Agricultural and Biological Engineers – Global Partnerships for Global Solutions: An Agricultural and Biological Engineering Global Initiative (<http://www.asabe.org/media/195967/globalinitiative.pdf>).
- The Department's national ranking, 19th in the nation; this is particularly impressive for a unit of their size and considering all of the changes they have experienced.
- The Department head's leadership and collaboration with leaders in the College of Agriculture and Life Sciences (CALS) and the College of Engineering (CoE).
- The focus of the Department's research, extension, and instruction activities in addressing critical needs in the State (e.g., water issues, CEA).

Programmatic

- The Department's Accelerated Master's Program which has the potential to significantly increase graduate student numbers and generate new revenue.
- The gender diversity in the Biosystems Engineering undergraduate program.
- The two undergraduate seminars offered by the Department; one at the sophomore level and one at the senior level.
- The Department's active participation in general education with their offering of two general education courses and one service class, all with high enrollments.

- The impressive hands- on learning opportunities for undergraduate and graduate students.
- The strong emphasis in the Department to integrate teaching, research, and extension activities.
- The Department's research facilities which are well equipped for conducting on- going projects as well as projects in emerging areas.
- The Department's strong extension/outreach activities as compared to many similar departments in the U.S.
- Additional strengths can be seen in the Department's 100% placement for undergraduate students, the significant number of honor students that are part of their program, their strong senior design program, and the access students have to the Department shop enabling them to "build anything".

Resources

- The Department's quality human and physical resources. Significant effort has been made to effectively utilize and manage all resources.
- The Department's clear faculty hiring plan: Professor of Practice for Controlled Environment Agriculture (60% I and 40%E), Irrigation Extension Specialist (70%E and 30%R), and Assistant Professor of Automation and Robotics (40%I and 60%R).

Structure

- The highly functioning procedures for Departmental administrative and faculty governance.
- The Department's ability to coordinate and manage highly diverse functional/programmatic activities and a complex organizational structure for its faculty and staff size.

Weaknesses

Overall

- The Department's lack of a strong identity and image; the result is that Departmental activities appear unfocused and dated.
- Faculty retention challenges in recent years; this has negatively impacted the Department's ability to carry out its mission.
- It is not clear in what way and to what extent the large number of jointly appointed faculty and designated campus colleagues contribute to the Department.
- The Department is very competitive in many ways; however, there are fundamental issues, especially related to its educational programs that need to be addressed to enhance its sustainability.
- Engagement of all faculty will be needed to strengthen the Department; leadership by senior faculty will be especially important.
- The website is outdated.

Programmatic

- One significant challenge for the Department's instructional activities is the low number of undergraduate and graduate students.

- The Department has targets for student numbers and ideas for how to achieve these targets; however, it is not clear what activities will be priorities as they move forward.
- The Department lacks focused plans to garner resources from both CALS and CoE.

Resources

- The Department has only one tenure- track assistant professor.
- The Department has no graduate teaching assistants, even for large classes.
- Staff support for student recruitment, retention and placement is inadequate.

Structure

- Department faculty and staff are spread over many buildings and geographic locations.
- Active and reasonably funded faculty research projects have not been able to impact graduate student enrollment.
- Department is not well aligned with CoE for undergraduate senior projects and misses opportunities to coordinate/learn with other engineering students.

Recommendations

1. Under the current funding climate for U.S. universities, it is necessary for every academic unit to develop a short list of the areas in which it can be “best at,” “must win,” and “can win”. These areas may already be in the Department's very comprehensive planning documents. A prioritization process will help produce focused, actionable insights for moving forward.
2. The Department's emerging emphasis on systems/informatics/analytics should be considered as a potential strong integrator of the Department's domains and core competencies.
3. The Department should develop a map of value- proposition/impact, outcomes, activities, expenditure/investment, and revenue/return to support budget management and resource generation for short- term decisions and long- term prioritization.
4. The Department should develop succinct and powerful communication materials, in partnership with CALS and CoE, based on their planning documents, to convey the Departmental vision story, value- propositions, domains, core competencies, instruction/research/extension activities, and impact.
5. The Department should increase development/advancement effort to raise funds. Clear and specific case statements will be needed for these activities.
6. The Department should explore a new administrative model that will enable it to be a full contributor in both CALS and CoE.
7. While carrying out visioning and identity activities, it will be important to consider ways to enable the leadership of the Department to be able to follow through with the recommendations selected to move forward (for example, including a facilitator for the visioning activities, strategic planning, and business plan development; and participation in leadership training programs such as the Food Systems Leadership Institute).
8. The Department must continue to develop an understanding of internal and external budget management and resource generation challenges and opportunities.
9. Once the Department has a clear mission and identity, additional tenure- track assistant professors will be needed to energize the Department and move it forward.

10. An additional 0.5 FTE staff position for student recruitment, retention, placement, and alumni relationships would strengthen the Department's undergraduate and graduate programs.
11. Create more visible and active professional development opportunities for graduate students.
12. Explore strategic alliances and joint recruitment activities with other departments in CALS and CoE.
13. Additional avenues for strengthening the Department's undergraduate and graduate programs should include: (1) identification of partnerships and pathways (e.g., community colleges, pre- vet/pre- med program) for student recruitment, (2) a focus on identifying and recruiting qualified students admitted to the CoE into the ABE, (3) participation in the upcoming vet- med program to provide an undergraduate home for pre- vet students and a graduate home for post- vet students, (4) a continued emphasis on engaging College ambassadors, and (5) development of a clear picture of the historical numbers of applications, admittances, and matriculating graduate students to identify another emphasis for recruitment efforts.
14. The Department should explore the feasibility of creating revenue generation Master's degree programs to fund doctoral research, teaching assistantships, and undergraduate recruitment scholarships.
15. The Department should create non- engineering degree options in partnership with other units in CALS. For example, develop a broader program between ABE (e.g., CEA) and Plant Sciences at the undergraduate and graduate levels for students with interests in systems and not necessarily engineering.
16. For all Departmental activities, the website should be updated to make it visible and attractive to students and potential partners and donors.

Appendix I1. Outcome Matrix based on individual courses in the curriculum.

ABET Outcome	<u>Foundation Courses</u> Outcomes	enr 102	math 125,129 , 223, and 254	chem 151, 152	biological science (8 credits)	general educ. require- ments	phys 141, 241	engineering science (ce 214, 218, sie 265, ame 331, 324a	engl 101, 102, 308 agtm 422	sie 305
a	Can apply mathematics, science and engineering principles to solve problems	H	H	H	H		H	H		H
b	Can design and conduct experiments and analyze and interpret data			H	H		H			H
c	Can design a system, component or process to meet desired needs within realistic constraints									M
d	Can function on multidisciplinary teams	H			M		L			L
e	Can identify, formulate and solve engineering problems							H		
f	Has an understanding of professional and ethical responsibility									
g	Can communicate effectively			M	M	M	M		H	
h	Has the broad education necessary to understand the impact of engineering solutions in global, economic, environmental and societal context	M				M				
i	Recognize the need for and the ability to engage in lifelong learning.	M				H				
j	Has a knowledge of relevant contemporary issues	M								
k	Can use the techniques, skills, and modern engineering tools necessary for engineering practices.	M		L	L		L			

ABET Outcome	<u>Required ABE Courses</u> Outcomes	abe 201	abe 205	abe 221	abe 284	abe 393	abe 423	abe 447	abeTechElec. orAME431 orAME432	abe 496a	abe 498a	abe 498b
a	Can apply mathematics, science and engineering principles to solve problems		H	M	H		H	L	H		H	H
b	Can design and conduct experiments and analyze and interpret data		H	L			H	H				
c	Can design a system, component or process to meet desired needs within realistic constraints			L				M			H	H
d	Can function on multidisciplinary teams	H	L	L			H	M			H	H
e	Can identify, formulate and solve engineering problems			M	H			L	H		H	H
f	Has an understanding of professional and ethical responsibility								L	H	M	M
g	Can communicate effectively	H		L				L		H	H	H
h	Has the broad education necessary to understand the impact of engineering solutions in global, economic, environmental and societal context	H				H			L	H		
i	Recognize the need for and the ability to engage in lifelong learning.	H				H			L			
j	Has a knowledge of relevant contemporary issues	H		M		H		L		H		
k	Can use the techniques, skills, and modern engineering tools necessary for engineering practices.		H	H			H	H	H		H	H

We will provide a portfolios for all of these required courses at the time of the site visit.

ABET Outcome	<u>Electives Courses</u> Outcomes	abe 426*	abe 452	abe 455*	abe 456	abe 458	abe 459	abe 479*	abe 481a*	abe 481b	abe 482	abe 483	abe 486
a	Can apply mathematics, science and engineering principles to solve problems	H		H	H	H	H	M	H	M	H	H	L
b	Can design and conduct experiments and analyze and interpret data	H			M	M	L	H	H		M	M	
c	Can design a system, component or process to meet desired needs within realistic constraints	H		H	H	H	H	H		M	M	M	M
d	Can function on multidisciplinary teams		H		M	M		H		M			M
e	Can identify, formulate and solve engineering problems	H	M	H	H	H	H	M	H	M	M	H	M
f	Has an understanding of professional and ethical responsibility		H		L	M	M	L		L			M
g	Can communicate effectively		H		M	M	M	M		L			L
h	Has the broad education necessary to understand the impact of engineering solutions in global, economic, environmental and societal context		H	L	M	M	M	L		L	L	L	
i	Recognize the need for and the ability to engage in lifelong learning.		H										M
j	Has a knowledge of relevant contemporary issues		H	L	L	M	H	M		H	L		H
k	Can use the techniques, skills, and modern engineering tools necessary for engineering practices.	H		H	H	H	M	H	M	M	H	H	M

* = Courses for which we will provide a portfolio at the time of the site visit

Appendix I2. Summary Outcome Matrix based on required courses in the curriculum

ABET Outcome	Required ABE Courses Outcomes	Total # of “H’s”	% of activity
a	Can apply mathematics, science and engineering principles to solve problems	6	14%
b	Can design and conduct experiments and analyze and interpret data	4	9%
c	Can design a system, component or process to meet desired needs within realistic constraints	5	11%
d	Can function on multidisciplinary teams	4	9%
e	Can identify, formulate and solve engineering problems	4	9%
f	Has an understanding of professional and ethical responsibility	2	5%
g	Can communicate effectively	4	9%
h	Has the broad education necessary to understand the impact of engineering solutions in global, economic, environmental and societal context	3	7%
i	Recognize the need for and the ability to engage in lifelong learning.	2	5%
j	Has a knowledge of relevant contemporary issues	3	7%
k	Can use the techniques, skills, and modern engineering tools necessary for engineering practices.	7	16%

Table above addresses the degree to which each outcome is covered in the required curriculum. Approximately 14% of the required curriculum provides activities for students increase their ability to apply mathematics, science, and engineering principles to solve problems. The next most address outcome provides students with experiences in using techniques, skills, and modern engineering tools necessary for engineering practice. Approximately 11% of the required ABE curriculum provides students learning activities with designing a system, component or process to meet desired needs within realistic constraints. About 9% of the required curriculum provides activities with designing and conducting experiments and analyze and interpret data. And about another 9% of the required curriculum enables learning on functioning on multidisciplinary teams. All outcomes are addressed in at least two of the required courses as a high level focus. Outcomes “f” and “i” are a high level focus for only two courses but in both of those courses, substantial curricular content is targeted to address this topical material.

Appendix J. Senior Degree Audit Worksheet

DEGREE AUDIT WORKSHEET

Please return to the Academic Affairs Office, Engr. Bldg. Rm. 200 for processing.
If submitted directly to Graduation Services your degree audit will be delayed.

Degree Awarded

NAME: _____			SID: _____
(Last)	(First)	(Middle)	
EXPECTED GRAD TERM: _____	DEGREE: _____	REQUIREMENT TERM: _____	
	(Program)	(Plan(s))	
Degree # <u> 1 </u> of <u> 1 </u> (List Other Degrees) _____			DATE INITIATED: _____

Advisor Comments or Notes - All Electives (Technical, Engineering & Additional, etc.) & Current Adjustments need to be listed below. All courses to be taken in the final semester must include term & be listed - Use Additional Space on back if needed.

		Course Substitutions	
		Term	
		Required Course	Substitute Course

MAJOR 1	Print Last Name / Campus Phone	Date
ADVISOR: _____	_____	_____
MAJOR 2	Print Last Name / Campus Phone	Date
ADVISOR: _____	_____	_____
MINOR	Print Last Name / Campus Phone	Date
ADVISOR: _____	_____	_____

HONORS COLLEGE (If Applicable): _____ DATE _____

COLLEGE APPROVAL: _____ DATE _____

Student Present: Yes _____ No _____
Student Signature: _____
EMAIL _____
PHONE _____

<u>Graduation Services Use Only</u>	

Appendix K. Advanced standing approval form

College of Engineering - Application for Advanced Standing: Biosystems Engineering Program 2014 and 2015

STUDENT INFORMATION		Date Submitted:	
Student Name:		Fall approval = Prior to Oct. 1, Spring approval = Prior to March 1	
Student UA Email address:		Advanced Standing Effective Term	
		Summer I	Fall
		Summer II	Spring
STUDENT ACADEMIC INFORMATION		ADVISOR CONTACT INFORMATION	
Student ID Number:		Advisor	Dava Jondall
Major:	BIOSYSTEMS	Email	dava.j@email.arizona.edu
Minor:		Phone number	520.621.1753
Cum GPA: (Advisement Report)		Bldg/Room#	Shantz Bldg-425C
Major GPA: (Advisement Report)		Lower Division Courses Completed	
Advanced Standing GPA	0.000	Student Signature Acknowledging Deficiency Requirements	
Total Units Completed:	55		
Adv Stndg Required by Dept.:	2.00		
Deficiency Courses To Be Completed in 1st Semester of Adv Standing			

2014 -2015 Catalog									
Courses	Semester	UA Grade	Units	Grade Pts	Total Pts	GRO	Y/N	Transfer Grade	
ENGL 101 (3) OR ENGL 107 (3)			3						
ENGL 102 (3) OR ENGL 108 (3)			3						
or ENGL 109H (3)									
MATH122A (1) & MATH122B (4) OR MATH 124 OR MATH 125			4						
MATH 122B (4)									
MATH 124 (5)									
MATH 125 (3)									
MATH 129 (3)			3						
MATH 223 (4)			4						
MATH 254 (3)			3						
ENGR 102 or ENGR 102A/B or ENGR 102 (3)			3						
(*Required for Freshman only) ENGR 102A (1)									
ENGR 102B (2)									
CHEM 151(3) or CHEM 105A(3) & CHEM106A(1)			4						
CHEM 105A (3)									
CHEM 106A (1)									
CHEM 152 (4)			4						
PHYS 141 (4) OR PHYS 161H (4)			4						
PHYS 141 (4)									
PHYS 161H (4)									
PHYS 241 (4) OR PHYS 261H (4)			4						
PHYS 241 (4)									
PHYS 261H (4)									
MCB181R (3) & MCB1(1) OR PLS240 R (3) & PLS 240L (1)			4						
MCB 181R (3))									
MCB 181 L (1)									
PLS 240 (4)									
MIC 205 OR PSIO 201 OR ECOL 182 R/L			4						
PSIO 201 (4)									
ECOL 182 R (3)									
ECOL 182 L (1)									
MIC 205 A (3)									
MIC 205 L (1)									
ABE 201 (2)			2						
ABE 205 (3)			3						
ABE 284(3)			3						
CE 214 (3)			3						

Total # of Units		58	ADV STD GPA		2.00
DEPARTMENTAL APPROVAL		COLLEGE APPROVAL			
Unconditional		Advanced Standing Granted			
Denied		Advanced Standing Denied			

Dept Head	Date	Dean	Date
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Academic Advisor	Date	
COMMENTS: To qualify for Advanced Standing students should complete all of the lower division course work listed above. The Average student will complete 58 units of lower division units at a 2.0 or higher to qualify of Advanced Standing. Honors Students who take ENGL 109H, should complete 55 units of lower division units at a 2.0 GPA or higher to qualify for Advanced Standing. Transfer Students must complete 12 units at the University with a GPA of 2.0 or Higher. Transcripts must be posted in UAcess, for Lower division course work completed at other institutions. Transfer course work must be completed with		TIER I - INDV - TIER I - TRAD - TIER II - ARTS/HUMS TIER II - INDV

Appendix L. Outline of ABET outcomes (a-k) assessment based on individual courses in the curriculum

a. Can apply mathematics, science and engineering principles to solve problems.

Assessed by ABE required Courses (205, 284, 423, 498a, 498b) and Electives (426, 455, 456, 458, 459, 483)

Performance Criteria	Level 5	Level 3	Level 1
Mathematical reasoning	Applies higher level mathematics (through differential equations) and or scientific principles of chemical, biological, physical systems to solve biosystems engineering problems	Can apply higher level mathematics with assistance to set up biosystems engineering problems	Poor skills in the use of higher level mathematics and in the connection between mathematical models and physical systems
Appropriate use of significant figures	Presents quantities with appropriate units and significant digits	Most quantities are expressed in proper units and with appropriate significance	Quantities often reported with incorrect or missing units and inaccurate significance
Utility of answers	Recognizes practical significance of answers (size, shape, rate are reasonable in number)	Usually provides a correct answer but does not readily check practicality	Poor understanding of interpretation of answers

Evaluated by

- a1 Performance on specific HW, quiz, and exam questions
- a2 Performance on specific HW, quiz, and exam questions
- a3 Performance on specific HW, quiz, and exam questions

b. Can design and conduct experiments and analyze and interpret data
Assessed by ABE required Courses (447) and Electives (426, 479)

Performance Criteria	Level 5	Level 3	Level 1
Information collection	Seeks information from multiple sources to solve new problems	Seeks information from the instructor, class material, and textbook to solve new problems	Seeks no additional information to solve new problems
Experimental design	Develops and implements logical experimental procedures	Experimental procedures are followed, but not consistently, leading to oversight and fixable mistakes	Experimental procedures are not followed; makes many mistakes
Error analysis	Is aware of measurement error and properly reports uncertainty	Is aware of measurement error but does not consistently report correctly	Is unaware of measurement error
Data interpretation	Interprets data correctly and draws reasonable and appropriate conclusions	Interprets data correctly but at times draws incorrect or over-reaching conclusions	Does not properly interpret data; consistently draws improper conclusions
Safety	Always observes laboratory safety procedures for self and others	Occasionally fails to follow laboratory safety procedures	Practices frequent unsafe behavior

Evaluated by

- b1 Performance based on lab report and results, and student class project
- b2 Performance in laboratory exercises, and student class project
- b3 Presentation of laboratory results, and student class project
- b4 Presentation of laboratory observations and interpretations and student class project
- b5 Faculty observation of student behavior in laboratory

**c. Can design a system, component or process to meet desired needs within realistic constraints
Assessed by ABE required Courses (498a, 498b) and Electives (426, 456, 458, 459, 479)**

Performance Criteria	Level 5	Level 3	Level 1
Design Process	Understands very well all aspects of the design process and applies them effectively	Has limited understanding of the design process	Has a poor understanding of the design process
Problem Definition	Able to very clearly define the design problem/need independently	Able to define the design problem/need but requires guidance	Not able to define the design problem/need
Information gathering	Is very well aware of other existing designs and how they work	Aware of existing designs but does not understand how they work	Has a poor understanding of the existing design and the thought process
Analysis, Evaluation and Decision Making	Able to consider, analyze and evaluate and select alternative solutions	Has some difficulty in considering, analyzing, evaluating and making selection of alternative solutions	Has great difficulty in considering, analyzing, evaluating and selecting alternative solutions

Evaluated by

- c1 Performance on specific homework, examinations, student design project report and presentation
- c2 Design project final report and presentation, performance on exam performance
- c3 Self and peer evaluation, performance on exam performance lab portion

d. Can function on multidisciplinary teams.

Assessed by ABE required Courses (201, 423, 498a, 498b) and Electives (452, 479)

Performance Criteria	Level 5	Level 3	Level 1
Contribution	Collects and relays all necessary information on time and without prompting	Collects and relays some basic information most of the time	Does not collect or relay any information
Taking Responsibility	Performs all duties offering a fair amount of information without being reminded	Performs some duties offering some relevant information rarely being reminded	Does not perform any duties assigned giving very little information, always relying on others to do the work
Value Teammate's Opinion	Listens and speaks when appropriate without argument, helps teammates in the decision making, and has constructive disagreements	Listens, but sometimes talk too much, arguing sometimes, and often siding with friends instead of considering all views	Always talking and arguing with teammates and must have his/her way without compromising

Evaluated by

d1 Design Project final report and presentation

d2 Participation, completion, and depth of understanding of ABE 498a and b. Final report and presentation

d3 Self and peer evaluation

e. Can identify, formulate and solve engineering problems

Assessed by ABE required Courses (284, 498a, 498b) and Electives (426, 455, 456, 458, 459, 483)

Performance Criteria	Level 5	Level 3	Level 1
Application of theory	Relates theoretical concepts and analytical solutions to practical problems through thought processes and computational and experimental tools	Connects theory to practice when prompted	Does not see the connection between theoretical foundations/analytical solutions and real-world problems
Use of assumptions	Independently sets up appropriate system boundaries and conditions hypotheses	Makes appropriate assumptions and determine the system boundaries and conditions	Makes poor assumptions based on inaccurate solution domain
Interpretation of solutions	Provides a correct solution and can fully interpret its meaning under ideal conditions and practical applications	Provides a correct solution	Provides an incorrect solution

Evaluated by

- e1 Performance on specific HW and exam questions.
- e2 Performance on specific HW and exam questions.
- e3 Performance on specific HW and exam questions.
- e4 Design project.
- e5 Self and peer evaluation.

f. Has an understanding of professional and ethical responsibility
Assessed by ABE required Courses (496) and Electives (452)

Performance criteria	Level 5	Level 3	Level 1
Code of ethics	Student understands the code of ethics and is able to apply this to real world situations	Student is aware that a code of engineering ethics exists	Student is not aware of codes of ethical behavior
Applies ethical behavior	Participates fully in exercises to demonstrate ethical behavior	Participates in exercises to demonstrate ethical behavior	Does not participate in exercises to demonstrate ethical behavior
Professional development	Regularly attends classes and professional activities	Sometime attends classes and professional activities	Never or sporadically attends classes and professional activities

Evaluated by

- f1 participation in presentation and discussions on engineering and codes of ethics, and student survey
- f2 participation in presentation and discussions on engineering and codes of ethics, and student survey
- f3 participation in presentation and discussions on engineering and codes of ethics, and class activities, and student survey

g. Can communicate effectively.

Assessed by ABE required Courses (201, 496, 498a, 498b) and Electives (452)

Performance criteria	Level 5	Level 3	Level 1
Language	Very clearly and effectively communicate ideas both in written and oral forms all the time	Clearly and effectively communicate ideas sometimes both in written and oral forms	Most of the time not clear and effective in communicating ideas in both written and oral forms
Organization	Very well organized using appropriate format consistently	Has basic organization with appropriate format with some inconsistencies	Poorly organized with very inconsistent or practically no format

Evaluated by

- g1 Student presentations.
- g2 Student reports

h. Has the broad education necessary to understand the impact of engineering solutions in global, economic, environmental, and societal context

Assessed by ABE required Courses (201, 496) and Electives (452)

Performance Criteria	Level 5	Level 3	Level 1
Awareness	Up to date with the current trends in biosystems engineering and its impact on society	Has some awareness of current trends in biosystems engineering and its impact in society	Unaware of current trends in biosystems engineering and its impact on society
History	Aware of the historical aspect of engineering solutions and their impacts on social and economic environment	Aware of the historical aspect engineering solutions but has no appreciation of their impacts globally	Unaware of historical impacts of engineering solutions
Periodicals	Reads and keeps/her/himself current with the literature on global and societal impacts of engineering	Aware of the existence of the literature but does not keep her/himself up with global issues dealing with engineering	Not familiar with any literature that addresses global and societal impact of engineering

Evaluated by

- h1 Exam questions on Globalization, senior/sophomore poster presentation, participation in ABE 201/496a joint seminars in which 496a students present professional activity
- h2 Exam questions on Globalization, senior/sophomore poster presentation, participation in ABE 201/496a joint seminars in which 496a students present professional activity
- h3 Exam questions on Globalization, senior/sophomore poster presentation, participation in ABE 201/496a joint seminars in which 496a students present professional activity

- i. **Recognize the need for and the ability to engage in lifelong learning.**
Assessed by ABE required Courses (201) and Electives (452)

Performance Criteria	Level 5	Level 3	Level 1
Learning outside structured environments	Demonstrates a concerted desire to learn from out of the classroom professional activities	Participates occasionally in out of classroom professional activities	Does not participate in out of classroom professional activities
Society participation	Participates and takes a leadership role in professional societies	Occasionally participates in professional societies	Never participates in professional activities
Professional development	Participates in professional development	Is aware of the need for professional development	Is not aware of the need for professional development

Evaluated by

- i1 Instructor interaction with students, and student survey
- i2 Instructor interaction with students, and student survey
- i3 Instructor interaction with students, and student survey

- j. **Has a knowledge of relevant contemporary issues ABE 393 and 496a**
Assessed by ABE required Courses (201, 496) and Electives (452, 481b, 486)

Performance Criteria	Level 5	Level 3	Level 1
Knowledge of current events	Has knowledge of current events in the engineering profession	Has some knowledge of current events	Is not engaged in issues in the world
Technology and society	Recognizes the role of technology in society	Is aware that technology impacts society	Has no awareness of technology's impact on society

Evaluated by

- j1 participation in ABE 201/496a joint seminars in which 496a students present professional activity, and Pro/Con presentation & written summary, exam questions, class term paper on significance & technical merit and commercialization plan
- j2 participation in ABE 201/496a joint seminars in which 496a students present professional activity, Pro/Con presentation & written summary, exam questions, class term paper on significance & technical merit and commercialization plan

- k. Can use the techniques, skills, and modern engineering tools necessary for engineering practices
Assessed by ABE required Courses (205, 221, 423, 447, 498a, 498b) and Electives (426, 456, 458, 479, 483)

Performance criteria	Level 5	Level 3	Level 1
Computer skills	Can effectively use computer software and hardware and other resources, at the skill level of a professional	Uses computer software and hardware and other resources occasionally for assignments and projects	Does not use computer software or hardware other resources for assignments and projects
Engineering tools	Able to learn and use simulation/modeling in problem solving and design analysis. Able to assemble and disassemble parts digitally.	Able to learn and use simulation/modeling in problem solving and design analysis but has difficulty understanding the assumptions, boundary conditions and the limitations. Able to construct complex design parts.	Unable to use simulation/modeling and does not understand assumptions, boundary conditions and the limitations
Prototyping and data analysis	Able to effectively use laboratory and shop instrumentation and equipment. Able to assess potential problems and identify ways to enhance the design via digital assembly.	Limited ability to use lab and shop instrumentation and equipment with some supervision. Capable of create and assemble parts digitally.	No ability to operate most instrumentation and shop equipment or does so with intense supervision

Evaluated by

k1 Homework, lab exercises and report, lab exams and student class project

k2 Design projects, lab exercises and report, lab exams

Appendix M. Outcomes assessment based on individual courses in the curriculum.

a) Can apply mathematics, science and engineering principles to solve problems				ABE 205 SP15/16		ABE 284 FA15		ABE 423 SP15/16		ABE 498a FA14		ABE 498b FA15	
				Assd by:	P. Waller	Assd by:	M. Kacira	Assd by:	P. Waller	Assd by:	P. Livingston	Assd by:	P. Livingston
Performance Criteria	Level 5	Level 3	Level 1	Wght avg	Total # stdnts	Wght avg	Total # stdnts	Wght avg	Total # stdnts	Wght avg	Total # stdnts	Wght avg	Total # stdnts
Mathematical reasoning	Applies higher level mathematics (through differential equations) and or scientific principles of chemical, biological, physical systems to solve biosystems engineering problems	Can apply higher level mathematics with assistance to set up biosystems engineering problems	Poor skills in the use of higher level mathematics and in the connection between mathematical models and physical systems	3.01	33	4.25	106	3.84	15	3.71	14	4.18	22
Significance of data	Presents quantities with appropriate units and significant digits	Most quantities are expressed in proper units and with appropriate significance	Quantities often reported with incorrect or missing units and inaccurate significance			4.45	109	4.21	14	5.00	14	5.00	22
Utility of answers	Recognizes practical significance of answers (size, shape, rate are reasonable in number)	Usually provides a correct answer but does not readily check practicality	Poor understanding of interpretation of answers			3.85	55	4.21	14	5.00	14	5.00	22

Weighted Average = 4.27

b) Can design and conduct experiments and analyze and interpret data				ABE 447 FA15	
				Assessed by:	JY. Yoon
Performance Criteria	Level 5	Level 3	Level 1	Weighted average	Total # students
Information collection	Seeks information from multiple sources to solve new problems	Seeks information from the instructor, class material, and textbook to solve new problems	Seeks no additional information to solve new problems	3.87	68
Experimental design	Develops and implements logical experimental procedures	Experimental procedures are followed, but not consistently, leading to oversight and fixable mistakes	Experimental procedures are not followed; makes many mistakes	3.87	68
Error analysis	Is aware of measurement error and properly reports uncertainty	Is aware of measurement error but does not consistently report correctly	Is unaware of measurement error	4.53	68
Data interpretation	Interprets data correctly and draws reasonable and appropriate conclusions	Interprets data correctly but at times draws incorrect or over-reaching conclusions	Does not properly interpret data; consistently draws improper conclusions	4.53	68
Safety	Always observes laboratory safety procedures for self and others	Occasionally fails to follow laboratory safety procedures	Practices frequent unsafe behavior		

Weighted Average = 4.20

c) Can design a system, component or process to meet desired needs within realistic constraints				ABE 498a FA14		ABE 498b FA15	
				Assessed by:	P. Livingston	Assessed by:	P. Livingston
Performance Criteria	Level 5	Level 3	Level 1	Weighted average	Total # students	Weighted average	Total # students
Design Process	Understands very well all aspects of the design process and applies them effectively	Has limited understanding of the design process	Has a poor understanding of the design process	4.86	14	4.82	22
Problem Definition	Able to very clearly define the design problem/need independently	Able to define the design problem/need but requires guidance	Not able to define the design problem/need	5.00	14	5.00	22
Information gathering	Is very well aware of other existing designs and how they work	Aware of existing designs but does not understand how they work	Has a poor understanding of the existing design and the thought process	4.50	12	5.00	22
Analysis, Evaluation and Decision Making	Able to consider, analyze and evaluate and select alternative solutions	Has some difficulty in considering, analyzing, evaluating and making selection of alternative solutions	Has great difficulty in considering, analyzing, evaluating and selecting alternative solutions	4.67	12	4.50	22

Weighted Average = 4.80

d) Can function on multidisciplinary teams				ABE 423 SP15/16		ABE 498a FA14		ABE 498b FA15		ABE 201 FA14	
				Assessed by:	P. Waller	Assessed by:	P. Livingston	Assessed by:	P. Livingston	Assessed by:	P. Livingston
Performance Criteria	Level 5	Level 3	Level 1	Weighted average	Total # students	Weighted average	Total # students	Weighted average	Total # students	Weighted average	Total # students
Contribution	Collects and relays all necessary information on time and without prompting	Collects and relays some basic information most of the time	Does not collect or relay any information	4.40	15	4.57	14	4.26	23	4.13	24
Taking Responsibility	Performs all duties offering a fair amount of information without being reminded	Performs some duties offering some relevant information rarely being reminded	Does not perform any duties assigned giving very little information, always relying on others to do the work	4.27	15	4.57	14	4.09	22	4.13	24
Value Teammate's Opinion	Listens and speaks when appropriate without argument, helps teammates in the decision making, and has constructive disagreements	Listens, but sometimes talk too much, arguing sometimes, and often siding with friends instead of considering all views	Always talking and arguing with teammates and must have his/her way without compromising	4.27	15	4.43	14	4.09	22	4.13	24

Weighted Average = 4.24

e) Can use the techniques, skills, and modern engineering tools necessary for engineering practices				ABE 284 FA15		ABE 498a FA14		ABE 498b FA15	
				Assd. by:	M. Kacira	Assd. by:	P. Livingston	Assd. by:	P. Livingston
Performance Criteria	Level 5	Level 3	Level 1	Weighted average	Total # students	Weighted average	Total # students	Weighted average	Total # students
Application of theory	Can relate theoretical concepts and analytical solutions to practical problems through thought processes and computational and experimental tools	Connects theory to practice when prompted	Does not see the connection between theoretical foundations/analytical solutions and real-world problems	4.71	49	3.57	14	3.50	22
Use of assumptions	Accurately determine the control volumes based on given conditions and independently set up appropriate hypotheses	Makes appropriate assumptions and determine the system boundaries and conditions	Makes poor assumptions based on inaccurate solution domain	3.92	110	5.00	14	3.50	22
Interpretation of solutions	Provides a correct solution and can fully interpret its meaning under ideal conditions and practical applications	Provides a correct solution	Provides an incorrect solution	4.69	54	4.57	14	3.50	22

Weighted Average = 4.28

f) Has an understanding of professional and ethical responsibility				ABE 496a FA15	
				Assessed by:	K. Farrell-Poe
Performance criteria	Level 5	Level 3	Level 1	Weighted average	Total # students
Code of ethics	Student understands the code of ethics and is able to apply this to real world situations	Student is aware that a code of engineering ethics exists	Student is not aware of codes of ethical behavior	4.83	46
Applies ethical behavior	Participates fully in exercises to demonstrate ethical behavior	Participates in exercises to demonstrate ethical behavior	Does not participate in exercises to demonstrate ethical behavior	4.83	46
Professional development	Regularly attends classes and professional activities	Sometime attends classes and professional activities	Never or sporadically attends classes and professional activities	4.83	46

Weighted Average = 4.83

g) Can communicate effectively				ABE 201 FA14		ABE 496 FA15		ABE 498a FA14		ABE 498b FA15	
				Assessed by:	M. Yitayew	Assessed by:	K. Farrell-Poe	Assessed by:	P. Livingston	Assessed by:	P. Livingston
Performance criteria	Level 5	Level 3	Level 1	Weighted average	Total # students	Weighted average	Total # students	Weighted average	Total # students	Weighted average	Total # students
Language	Very clearly and effectively communicate ideas both in written and oral forms all the time	Clearly and effectively communicate ideas sometimes both in written and oral forms	Most of the time not clear and effective in communicating ideas in both written and oral forms	4.67	24	4.88	112	4.71	14	4.05	22
Organization	Very well organized using appropriate format consistently	Has basic organization with appropriate format with some inconsistencies	Poorly organized with very inconsistent or practically no format	4.67	24	4.88	112	4.71	14	4.05	22

Weighted Average = 4.73

h) Has the broad education necessary to understand the impact of engineering solutions in global, economic, environmental, and societal context				ABE 201 FA14		ABE 496a FA15	
				Assessed by:	P. Livingston	Assessed by:	K. Farrell-Poe
Performan ce Criteria	Level 5	Level 3	Level 1	Weigh- ted average	Total # students	Weigh- ted average	Total # students
Awareness	Up to date with the current trends in biosystems engineering and its impact on society	Has some awareness of current trends in biosystems engineering and its impact in society	Unaware of current trends in biosystems engineering and its impact on society	5.00	24	4.87	69
History	Aware of the historical aspect of engineering solutions and their impacts on social and economic environment	Aware of the historical aspect engineering solutions but has no appreciation of their impacts globally	Unaware of historical impacts of engineering solutions	4.50	24	4.87	69
Current Events	Reads and keeps/her/hims elf current with the literature on global and societal impacts of engineering	Aware of the existence of the literature but does not keep her/himself up with global issues dealing with engineering	Not familiar with any literature that addresses global and societal impact of engineering	5.00	24	4.87	69

Weighted Average = 4.86

				ABE 201 FA14	
				Assessed by:	P. Livingston
i) Recognize the need for and the ability to engage in lifelong learning					
Performance Criteria	Level 5	Level 3	Level 1	Weighted average	Total # students
Learning outside structured environments	Demonstrates a concerted desire to learn from out of the classroom professional activities	Participates occasionally in out of classroom professional activities	Does not participate in out of classroom professional activities	5.00	24
Society participation	Participates and takes a leadership role in professional societies	Occasionally participates in professional societies	Never participates in professional activities	5.00	24
Professional development	Participates in professional development	Is aware of the need for professional development	Is not aware of the need for professional development	5.00	24

Weighted Average = 5.00

				ABE 201 FA14		ABE 496 FA15	
				Assessed by:	P. Livingston	Assessed by:	K. Farrell-Poe
j) Has a knowledge of relevant contemporary issues							
Performance criteria	Level 5	Level 3	Level 1	Weighted average	Total # students	Weighted average	Total # students
Knowledge of current events	Has knowledge of current events	Has some knowledge of current events	Is not engaged in issues in the world	5.00	24	4.91	46
Technology and society	Recognizes the role of technology in society	Is aware that technology impacts society	Has no awareness of technology's impact on society	5.00	24	4.91	46

Weighted Average = 4.94

k) Can use the techniques, skills, and modern engineering tools necessary for engineering practices				ABE 423 SP15/16		ABE 447 FA15		ABE 498a FA14		ABE 498b FA15	
				Assessed by:	P. Waller	Assessed by:	JY. Yoon	Assessed by:	JY. Yoon	Assessed by:	P. Livingston
Performance criteria	Level 5	Level 3	Level 1	Weighted average	Total # students	Weighted average	Total # students	Weighted average	Total # students	Weighted average	Total # students
Computer skills	Can effectively use computer software and hardware and other resources, at the skill level of a professional	Uses computer software and hardware and other resources occasionally for assignments and projects	Does not use computer software or hardware other resources for assignments and projects	4.53	15	3.75	68	3.29	14	4.59	22
Engineering tools	Able to learn and use simulation/modeling in problem solving and design analysis. Able to assemble and disassemble parts digitally.	Able to learn and use simulation/modeling in problem solving and design analysis but has difficulty understanding the assumptions, boundary conditions and the limitations. Able to construct complex design parts.	Unable to use simulation/modeling and does not understand assumptions, boundary conditions and the limitations	4.13	15	4.13	68	5.00	14	4.82	22
Prototyping and data analysis	Able to effectively use laboratory and/or shop instrumentation and equipment. Able to assess potential problems and identify ways to enhance the design via digital assembly.	Limited ability to use lab and shop instrumentation and/or equipment with some supervision. Capable of create and assemble parts digitally.	No ability to operate most instrumentation and shop equipment or does so with intense supervision			3.94	68	5.00	14	5.00	22

Continued below.

k) Can use the techniques, skills, and modern engineering tools necessary for engineering practices				ABE 205 SP15/16		ABE 221 FA15	
				Assessed by:	P. Waller	Assessed by:	M. Yitayew
Performance criteria	Level 5	Level 3	Level 1	Weighted average	Total # students	Weighted average	Total # students
Computer skills	Can effectively use computer software and hardware and other resources, at the skill level of a professional	Uses computer software and hardware and other resources occasionally for assignments and projects	Does not use computer software or hardware other resources for assignments and projects	4.53	15	4.74	135
Engineering tools	Able to learn and use simulation/modeling in problem solving and design analysis. Able to assemble and disassemble parts digitally.	Able to learn and use simulation/modeling in problem solving and design analysis but has difficulty understanding the assumptions, boundary conditions and the limitations. Able to construct complex design parts.	Unable to use simulation/modeling and does not understand assumptions, boundary conditions and the limitations			4.74	135
Prototyping and data analysis	Able to effectively use laboratory and/or shop instrumentation and equipment. Able to assess potential problems and identify ways to enhance the design via digital assembly.	Limited ability to use lab and shop instrumentation and/or equipment with some supervision. Capable of create and assemble parts digitally.	No ability to operate most instrumentation and shop equipment or does so with intense supervision				

Weighted Average = 4.42

Appendix N. Biosystems Engineering Flyer

BIOSYSTEMS ENGINEERING

**ENGINEER A SUSTAINABLE FUTURE
FOR THE NATURAL WORLD.**

Biosystems engineering is a collaborative program between the Colleges of Engineering and Agriculture & Life Sciences that applies design and analysis concepts to living systems, their range of scale from microorganisms to complex ecosystems. The students and faculty in Biosystems engineering work on creating a sustainable future for the natural world. The University of Arizona is dedicated to improving the environment in which we live. Whether that is by trying to recreate a contained ecosystem that can be deployed on the moon and provide food on Earth or by optimizing existing natural processes, biosystems engineering is leading the charge.

Areas of study include Bioenvironment & One Health, Controlled Environment Agriculture, Food Security & Safety, Renewable Energy and Bioproducts, and Water Resources. Students can tailor their courses to fit almost any need as they solve the agricultural and biological engineering problems we face today, while looking ahead to tomorrow. The flexibility of the program allows any student to develop programs and research projects specifically suited to their interests. Biosystems is preparing engineers to work in biotechnology and bioenergy, water and environmental resources, biomedical fields, controlled environments, and organizations dedicated to ensuring reliable access to clean water and high-quality nutritious food.



▶▶ RESEARCH HIGHLIGHTS

The Biosystems Engineering Department is diagnosing and treating world epidemics utilizing smartphone and cloud-based diagnostics, lab-on-a-chip biosensors, and nanotechnology based sensing and therapeutics. We are creating innovative and resource-efficient technologies to feed the people on Earth, and to grow food in outer space using controlled environment agriculture technology. We are designing cutting-edge technologies and processes to create greener bioproducts from diverse biological feed stocks including algae, green waste, oil, and sugars. Operating in a desert environment has made the Biosystems Engineering Department a world leader in managing, protecting, and sustaining our finite water resources.

UNDERGRADUATE FOCUS AREAS
Biosystems ▼ Water Resources ▼ Pre-Health

GRADUATE PROGRAMS
Accelerated and Traditional M.S. in Agricultural and Biosystems Engineering
M.Eng. in Agricultural and Biosystems Engineering
Ph.D. in Agricultural and Biosystems Engineering

STUDENT CLUBS AND ORGANIZATIONS
Biosystems Engineering Club (ASABE Student Chapter)
Controlled Environment Agriculture Student Association (CEASA)

ENGINEERING.ARIZONA.EDU/FUTURE ◀◀◀

College of Engineering
Recruiting and Admissions
520.621.6032
enr-admissions@email.arizona.edu
[engineering.arizona.edu]

College of Engineering

Biosystems Engineering
Departmental Advising
520.621.1733
abe@email.arizona.edu
[cals.arizona.edu/abe]

College of Agriculture
& Life Sciences

Appendix O. ABE Advisory Council Members and Affiliation

NAME	TITLE	AFFILIATION	MEMBERSHIP
Steve Pokrzywka	Chair (Alumni)	Salt River Pima/Maricopa Indian Community	1998
Loren Acker	Member	Sebra (Retired)	1996
George Cairo	Member (Alumni)	Cairo Engineering	1998
Crystal Diaz	Secretary (Alumni)	Ventana Roche	2010
Mike Kazz	Member (Alumni)	Zelen Environmental	1998
Michael Kostrzewski	Member	Pima County Wastewater	2011
Ty Morton	Member (Alumni)	HDR Inc.	2009
John Replogle	Member	USDA-ARS (Retired)	1996
Nadia Sabeh	Member (Alumni)	GB Engineering	2011
Kelly Thorp	Member	USDA-ARS	2010
Murat Kacira	Faculty member	ABE Department	2015
Soohee Cho	Student member	BSE Student (Ph.D.)	2015
Ashley Hanno	Student member	BSE Student (UG)	2011

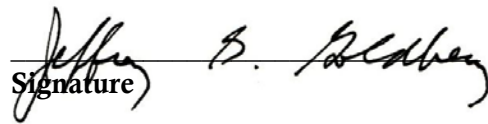
Signature Attesting to Compliance

By signing below, I attest to the following:

That the Biosystems Engineering Program has conducted an honest assessment of compliance and has provided a complete and accurate disclosure of timely information regarding compliance with ABET's *Criteria for Accrediting Engineering Programs* to include the General Criteria and any applicable Program Criteria, and the ABET *Accreditation Policy and Procedure Manual*.

Jeffrey B. Goldberg, Ph.D.

Dean, College of Engineering
University of Arizona
Tucson, AZ


Signature

June 28, 2016
Date