AC 2010-496: THE MARYLAND ASSOCIATE'S OF SCIENCE IN ELECTRICAL AND COMPUTER ENGINEERING: OUTCOMES-BASED TRANSFER DEGREES

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The Maryland Associate of Science in Engineering: Outcomes-Based Transfer Degrees in Electrical Engineering and Computer Engineering

Abstract

The Maryland Higher Education Commission (MHEC), citing a study that indicates a severe shortage of graduates in the electrical and computer engineering disciplines in the state, initiated an effort to develop an Associate of Science in Engineering (ASE) degree that would be accepted by all four-year institutions in the state without further review, removing the need for course-by-course articulation agreements for ASE graduates. Representatives from public and private institutions with electrical and/or computer engineering programs were invited to participate in the effort to define the ASE degree in these two disciplines. Early in the process, there was a consensus that an outcomes-based approach would allow the individual institutions to maintain their autonomy and diversity and that a course-by-course requirement would not, so the former approach was adopted. The degree has been defined and the regulation approved by MHEC. The effective date of the ASE is October 19, 2009. All four-year schools in Maryland have agreed to accept the ASE articulation agreement to facilitate graduates into their electrical engineering and computer engineering programs.

This paper describes the process for reaching consensus on critical outcomes and other requirements for state-wide transfer into electrical and computer engineering Bachelor's degree programs in Maryland, both public and private. While the present requirements were determined by consensus, there were natural concerns regarding consistency of the level of outcomes across institutions, quality control, and the ability of this process to efficiently and effectively incorporate potential changes in outcomes being considered for implementation by individual four-year schools. The faculty committee met monthly for two years to discuss engineering, mathematics, physics, chemistry, and computer programming content that would allow incoming community college students to successfully compete with native engineering students in their junior year. Other issues such as admission requirements and block transfer of credits were addressed and agreed upon. Community college graduates with the ASE degree will have their credits transfer to participating institutions as a block, without subject to further course-by-course review. The student will then have more flexibility in selecting a four-year institution. To respond to changes in curricula, a continuous review committee comprised of faculty was created to review outcomes annually and facilitate communication among institutions. This paper will present details on: the process developed to identify the critical outcomes and indicators; the mechanism developed to adapt to changes in curricula; the application process for two-year schools; and feedback received from institutions with resulting adaptations to the ASE criteria.

Background

In the United States, the transfer path from the community college to the four-year university is taken by a significant fraction of the graduating BS engineering students. This path is generally quite inefficient due to the fact that the interface between two-year and four-year institutions is generally defined by a course-by-course transfer, with differing requirements for each university.

Four-year schools tend to have limited coordination with two-year schools regarding the content of their lower level STEM courses. The larger the state, in terms of the number of students and/or the number of institutions, the bigger the problem is. This paper presents a process initiated in Maryland that defines an outcomes-based associate's degree in electrical engineering and computer engineering that could be used for seamless and efficient transfer between participating institutions around the country.

To address statewide workforce needs, the Maryland Higher Education Commission (MHEC) initiated an effort to develop an Associate of Science in Engineering (ASE) degree that will be accepted by all four-year institutions in the state without further review, removing the need for course-by-course articulation agreements for ASE graduates. It is felt that this will result in a more efficient system, in that community college students would be more likely to pursue this pathway and persist to graduation since the degree is designed for them to complete the last two years of the BS degree in the same amount of time as native four-year students. Representatives from all of the public and private institutions with electrical and/or computer engineering programs were invited to participate in the effort to define the ASE degree in these two disciplines. An outcomes based approach was selected, modeling an existing statewide teaching degree. This approach is in line with recommendations on improving engineering education and changes in engineering accreditation criteria over the last decade.

In Enhancing the Community College Pathway to Engineering Careers[1], the authors detailed conclusions reached by fifty participants from two-year and four-year institutions in a National Science Foundation sponsored workshop held in 2004. One conclusion was that articulation agreements must be supported by partnerships between two-year and four-year colleges to achieve seamless transfers of students from the two-year schools. In addition, student outcomes and competencies should be used for articulation instead of courses. The workshop participants also suggested further evaluation of the transfer process using such criteria as assessment of learning outcomes and competencies. In Educating the Engineer of 2020 [2], one of the 14 recommendations of a project sponsored by the National Academy of Engineering is that four-year institutions should be responsible for insuring seamless transitions with "their" two-year programs. In coming to this conclusion, the committee cited the importance of the community college pathway - a pathway taken by about 40% of all BS graduates, including many lower-income students and many students from underrepresented groups within engineering.

While the engineering criteria for ABET accreditation shifted to an outcomes-based approach in 2000 [3], these program outcomes are not discipline specific and are not sufficient to define the outcomes for the first two years in engineering. In addition, there does not appear to be a defined list of learning outcomes for electrical or computer engineering students who have completed the first two years of courses. The move to use course outcomes to facilitate transfer from community colleges to four-year institutions is groundbreaking. There is limited information in the literature to guide the transition or to evaluate the process. In the following sections, the ASE degree will be presented followed by a discussion of a statewide committee to facilitate changes to the degree. A discussion of assessment and sustainability criteria for the degree will also be discussed.

The ASE Degree

The ASE aims to smooth the pathway between Maryland associate and baccalaureate degrees in engineering. Community college students across Maryland are interested in earning baccalaureate degrees in engineering; however, they confront a series of challenges when trying to transfer into four-year engineering programs. Maryland two-year and four-year engineering programs differ greatly from institution to institution in courses required, and courses that transfer to one institution may not transfer to another. Articulation agreements are such that students need to have a clear idea of which four-year program they aspire to transfer into before beginning their associate degree. Changing their intended four-year program can result in significant delays in progress toward the BS degree. The ASE uses critical outcomes to articulate programs across the state so as to assist students as they move from one degree level to the next, helping to ensure that they are critically prepared to compete as juniors, maximizing the amount of credit that is transferable into the four-year major, and enhancing the students' ability to choose among Maryland four-year programs.

The main tenet of the ASE degree is that the program requires student competence in all of the key STEM outcomes from the first two years of an undergraduate program that are needed in order to be successful in the final two years of the BS program. When the ASE degree is obtained, transfer to a four-year institution occurs when the student meets the admissions requirements of the four-year school, "without further review." This means that the transferring student receives credit for all first and second year technical courses at the four-year institution (plus general education courses), unless a course has been changed; such a change would introduce a new key outcome not included under the ASE program requirements. This approach represents a major paradigm shift from the international standard of the course-by-course transfer approach, with articulation agreements between education partners. One of the main shifts is with respect to quality control. Under the course-by-course system, the four-year schools are responsible for quality control in that they decide if a potentially transferable course has the required content at the required level. Under the outcome system, the two-year institutions are responsible for quality control – they decide if the students have achieved the technical outcomes at the required level of complexity. During the development of the outcomes, the committee contacted ABET regarding the impact of this new degree on the accreditation of the four-year institutions. The ABET representative reinforced their focus on program outcomes and process and encouraged flexibility in the approach.

At the current time, outcomes for the ASE in electrical engineering (EE)[4] and computer engineering (CE)[5] are specified for math, physics, chemistry, computer science, and engineering. There are a total of 20 required outcomes in EE and 22 required outcomes in CE from the "engineering courses" in the curriculum. These outcomes are usually dispersed in courses with titles like: "Introduction to Engineering Design, Basic Electric Circuits, Basic Digital Circuits, Computer Programming, Numerical Methods for Engineers, Introduction to Systems and Discrete Structures." The outcomes cover the areas of project development and engineering design, teamwork and communication skills, laboratory and data reduction skills, ethics awareness, computer programming and simulation, digital and analog circuits, and linear systems concepts. Although both disciplines share 16 common outcomes in chemistry, the content areas and outcomes for physics and mathematics vary for CE and EE. For physics, the three CE

content areas are mechanics, electricity & magnetism, and heat & thermodynamics. In addition to those three areas, the EE content includes optics & waves and modern physics. For mathematics, the two disciplines differ in content areas related to multivariable functions and vectors.

In addition to the definition of each outcome, recommended performance indicators, suggested assessment types, and sample assignments were developed by the committee to provide guidance to two-year institutions. Table 1 shows the supporting information provided for one of the engineering outcomes[5].

Table 1: Sample engineering outcome with indicators, assessment type and assignments

Outcome—Computer Engineering (CE)	Recommended Indicators	Suggested Assessment Type	Sample Assignments
9. Know the relations between basic electrical quantities and be able to generate all equations needed to solve any general electric circuit.	For a given circuit (both time and frequency domains): a. Correctly determine how many equations are needed to solve the problem b. Write the necessary KVL and KCL equations c. Write the necessary terminal relationships for the components	• Brief Response • Problem Solving	• Given the following series circuit: A 10k ohm resistor, a 37 mH inductor and a 100 kHz - 1 V source, calculate the steady state current through and the voltage across each component. • Write the complete set of differential equations needed to solve for all voltages and currents in a 5-node complex RLC circuit using two voltage sources. • Write the complete set of sinusoidal steady state equations for a parallel combination of a resistor, inductor, and capacitor connected to a sinusoidal current source. • Given a complex circuit diagram, identify the number of nodes and meshes in the circuit.

The ASE degree has been added to the MHEC regulations; details about the outcomes, application process for two-year colleges, the continuous review committee and frequently asked questions are found on the MHEC-maintained website (http://www.mhec.maryland.gov/ASE/).

The first part of the regulations describes the degree[6], while the continuous review process is defined in a separate section[7]. The degree is defined as follows:

> (6-1) "Associate of Science in Engineering (A.S.E.)" means a degree that recognizes a mastery in engineering and that:
> (a) Meets the lower-level degree academic content, outcomes, and requirements for engineering education, similar to the first 2 years of a parallel baccalaureate program in engineering education;
> (b) Requires at least a 2.0 on a 4.0 grade scale in all courses required by the degree program in computer science, engineering, mathematics, and the physical and natural sciences; and
> (c) If conferred, transfers without further review or course-by-course match by Maryland public and participating independent 4-year institutions into a parallel baccalaureate program, except that transfer students may be treated like native students with regard to credits earned through Advanced Placement (AP), International Baccalaureate (IB), and transcripted credits.

The Continuous Review Committee is defined as follows:

> A. The Commission shall convene a continuous review committee for each ASE degree area, such as electrical engineering. Each continuous review committee shall be composed of faculty with relevant expertise in that area of study from Maryland 2-year and 4-year public and independent institutions with approved engineering programs.
> B. Outcomes for each ASE degree area shall be reviewed by the appropriate continuous review committee to ensure that outcomes are consistent with current standards. The committees shall meet at least once a year for the purpose of conducting this review.
> C. The president or president's designee of a Maryland independent 4-year institution that wishes to participate in the Statewide articulation agreement shall submit a letter to the Secretary stating that the ASE shall transfer to its institution without further review or course-by-course match, except that credits earned through Advanced Placement (AP), International Baccalaureate (IB), or transcripted credit, may be treated as they would be with native students at the institution.

The ASE Process and Statewide Oversight Committee

The ASE degree was initiated by MHEC, but developed over a two-year period entirely by a committee of faculty from two-year and four-year colleges within the state. In 2006, the Transfer and Access Committee of the Joint Leadership Council of the University System of Maryland (USM) and the Maryland Association of Community Colleges (MACC) endorsed the concept of a statewide engineering transfer degree and asked MHEC to develop a process for this initiative. MHEC convened an ASE Oversight Council, requesting nominations from the higher education segments and other stakeholders. In 2007, an Electrical and Computer Engineering (ECE)

Faculty Disciplinary Committee was convened, composed of faculty from a representative group of two-year and four-year institutions offering approved programs with an ECE focus. This faculty group was charged by the ASE Oversight Council to develop a common core of degree requirements for the ASE.

Early in the process, there was a consensus amongst the faculty to move away from a course-by-course requirement in favor of an outcomes-based approach that would allow the individual institutions to maintain their autonomy and diversity. The outcomes-based approach had been successfully developed for an Associates of Arts in Teaching (AAT) degree. This degree has since become the most common transfer degree for future teachers around the state. The mathematics, physics and chemistry content and outcomes for the AAT were the starting point for the science outcomes for the ASE. Most of the monthly meetings were spent developing the engineering outcomes and associated details. A decision was made to have separate outcomes for CE and EE due to the differing competencies expected by the end of the sophomore-level courses. The degree outcome requirements were defined and submitted for statewide review. A broad structure was proposed to maintain the degree in the inherently dynamic environment of the engineering profession and update the outcomes as necessary. On March 13, 2009, the ASE Oversight Council approved the Electrical and Computer Engineering (ECE) Faculty Disciplinary Committee's recommendation on ASE statewide outcomes and an accompanying continuous review process. The Maryland Higher Education Commission approved the regulation at a public meeting on May 20, 2009. After a public comment period in which no substantive objections were registered, the degree was codified in October 2009. Two-year schools may begin to offer the degree in 2010, upon approval by MHEC.

Since all four-year accredited electrical engineering programs have their own unique rubrics to measure their student outcomes, it is challenging to develop a set of outcomes that ensure that ASE graduates would meet all the outcomes at all the four-year schools at the appropriate level of sophistication without requiring an undue number of credits for the ASE degree. The Maryland approach required compromise and consensus to arrive at a list of the critical outcomes deemed necessary to allow ASE diploma holders to successfully perform as upper-class undergraduates at their chosen BS institutions. The committee focused of the outcomes that were most critical to student success. A continuous review committee (CRC) was conceived to provide a mechanism to propose changes to the outcomes and evaluate the success of students and the ASE degree. A separate CRC committee has been created for CE and EE and is expected to meet at least annually. Membership in the CRC committee is required for all two-year and four-year schools with approved programs in the state[8].

As the ASE was being developed over the last two years, statements were made and questions were posed, some of which had the potential to derail the exceptionally intimate and delicate collaboration that was being developed. The faculty working group moved past and put aside some of these questions, trusting that the leadership would follow through on doing the work to answer some of the questions. The questions posed by involved faculty and administrators from four-year and two-year schools across the state fell into several broad categories; 1) The effectiveness of the proposed continuous review process in responding to changes in the curriculum at four-year universities, 2) The impact of the ASE degree on the number of transfer students, student performance to matriculation and student satisfaction with the transfer process,

3) Whether the identified outcomes are sufficient and necessary for student success at a four-year schools, and 4) How to maintain the levels of critical outcomes at two-year schools. Many of these questions will be answered over the next few years as students matriculate through the programs.

Assessment and Sustainability

The ASE degree is promising because it is modeled after a successful predecessor, the AAT. There was consensus about the most important outcomes after over a year of careful deliberation by stakeholders within the state. While the present requirements were determined by consensus, there were natural concerns regarding consistency of the level of outcomes across institutions, quality control, and the ability of this process to efficiently and effectively incorporate potential changes in outcomes being considered for implementation by individual four-year schools. The ASE Oversight Council established an Electrical Engineering Continuous Review Committee to review ASE outcomes, student performance data, and any other relevant issues at least once annually. The first meeting of the CRC occurred in October 2009. It is expected that the work of the committee and at the four-year schools will provide data to assess the success of the ASE degree.

Conclusion

The ASE degree attempts to tackle a national problem related to making an efficient coupling to a very dynamic and blurry interface between two-year and four-year Electrical Engineering (EE) and Computer Engineering (CE) programs. The field of electrical engineering is evolving at a rate better measured in months than in years or decades, and the institutions of higher learning all adjust their curricula to reflect these changes on their own schedules, related to their unique collection of needs and abilities. The shift to an outcomes-based transfer degree is a potentially very innovative step.

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