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A SUCCESSFUL EAC-ABET ACCREDITED UNDERGRADUATE PROGRAM IN MODELING AND SIMULATION ENGINEERING (M&SE)

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ABSTRACT

The first undergraduate degree program in modeling and simulation engineering recently was implemented at Old Dominion University. The program awards the Bachelor of Science Degree in Modeling and Simulation Engineering and was designed to meet the ABET accreditation requirements for general engineering programs. This paper describes the design and implementation of a continuous improvement process for the program. The department mission statement and the program educational objectives are presented. The student outcomes are stated and an assessment process for evaluating student achievement is described. Finally, the continuous improvement process for the program is presented. Recommendations from the initial ABET accreditation visit are summarized.

1 INTRODUCTION

Fifty-five years ago, computer science was just beginning to gain acceptance as a growing academic discipline and computer science departments were rare at universities although many faculty were utilizing computers and software to enhance their teaching and research. A similar situation occurred for computer engineering approximately thirty-five years ago. We believe that modeling and simulation (M&S) now is on a similar path. In recent years, there has been growing interest in recognizing M&S as a discipline. Several national leadership groups have identified the importance of simulation in engineering and science and have advocated for developing M&S academic programs (NSF 2006; NRC 2006). Congress even has attempted to address these pressing needs by passing legislation for establishing grant programs to help fund M&S degree program startups (Congressional Record 2007). However, in spite of these efforts, development of M&S programs at universities has been limited primarily to masters-level programs and is progressing slowly.

Old Dominion University has been one of the early leaders in developing M&S academic programs. Master's Degree programs were started in 1998 and a Doctoral Degree program was established in 2000. Then in 2010, an undergraduate degree program was initiated. This program awards the Bachelor of Science Degree in Modeling and Simulation Engineering (BS-M&SE). Simultaneously, the Department of Modeling, Simulation and Visualization Engineering (MSVE) was established within the College of Engineering and Technology to administer all M&S academic programs. The first BS-M&SE degrees were awarded in May 2013 and the initial ABET accreditation visit for the program occurred in fall 2014.

The establishment of an M&S academic department and the development of an undergraduate M&S program have been described in the literature. The department organization and its contribution to the overall mission of the university are described in (Mielke et al. 2011). The initial planning for the undergraduate program is described in (Leathrum and Mielke 2011), curriculum development is presented in (Leathrum and Mielke 2012), and preparation for the initial ABET accreditation review is presented in (McKenzie 2015).

The purpose of this paper is to present the continuous improvement program evaluation process that was developed for the BS-M&SE program and then to describe the changes to this process that were recommended at the initial ABET accreditation visit. It is our hope that this information will be useful to others planning to implement undergraduate programs in Modeling and Simulation Engineering. In Section 2, the ABET accreditation requirements (ABET 2011) are summarized briefly. These requirements are stated in the form of eight criteria that must be addressed by all engineering programs. In Section 3, the department mission statement and the program educational objectives for the M&SE program are stated. The student outcomes for the M&SE program are presented in Section 4. In Section 5, the continuous improvement process developed for the M&SE program is described. This section includes a discussion of the assessment inputs and processes as well as a description of the program enhancement plan. Conclusions are presented in Section 6. This section includes a brief summary of the results of the program's initial ABET accreditation visit.

2 EAC-ABET ACCREDITATION REQUIREMENTS

ABET accreditation under the Engineering Accreditation Commission (EAC) requires that programs are evaluated against eight criteria, common to all engineering programs, and against any program-specific criteria. The BS-M&SE program was reviewed as a General Engineering program since Modeling and Simulation Engineering is not recognized currently as a distinct engineering discipline. There are no program-specific criteria for General Engineering. *Criterion 1 - Students* is directed towards program students and seeks to establish that admission standards are appropriate and uniformly enforced, students demonstrate and are evaluated against a minimum level of competency as they progress through the curriculum, and students receive adequate advising and follow the university-approved curriculum. *Criterion 2 – Program Educational Objectives* focuses on the relevancy of Program Educational Objectives (PEOs). PEOs are broad statements that indicate what graduates of the program will be expected to have accomplished within the first few years after graduation. *Criterion 3 – Student Outcomes* identifies the knowledge and skills that students are expected to have at graduation. Student Outcomes (SOs) are related directly to successfully achieving the PEOs and so SOs are the subject of significant assessment within courses, surveys, portfolio reviews, and other Student Learning Measures (SLMs). A program is required to have well-defined SOs and a process whereby the adequacy of curriculum coverage for each outcome can be assessed and, if necessary, remediated. This process must rely on multiple mechanisms to assess student achievement of SOs and have a systematic process for assembling assessment results that demonstrate overall success and enables the identification of specific areas for program improvement.

Criterion 4 - Continuous Improvement perhaps is the most important in that it requires that there is a systematic process in place for utilizing the assessment results to identify and address needed improvements in the program. Areas that require improvement must be tracked and re-evaluated at a later time to determine if prescribed fixes have, in fact, made positive impacts. Thus, it is Criterion 4 that "closes the loop" for the continuous program improvement process. *Criterion 5 - Curriculum* identifies broad curricular guidelines that help to ensure adequate coverage of the basic sciences, mathematics, engineering incorporating design, and general education. Additionally, this criterion mandates that the program of study for each student culminates in a significant engineering design experience that incorporates multiple realistic constraints. Criteria 6-8 relate to the adequacy of program faculty, program facilities, and the institutional support provided to the program.

The focus of this paper is on the implementation of Criterion 2, Criterion 3, and especially Criterion 4 for the BS-M&SE program. We state the Program Educational Objectives (PEOs), present the Student Outcomes (SOs), and then describe the continuous improvement Program Evaluation Process (PEP).

3 MISSION AND EDUCATIONAL OBJECTIVES

The program must have published PEOs that are consistent with the mission of the university and the needs of the program's various constituencies. In addition, there must be a documented and effective process, involving program constituencies, for periodic review and revision of these PEOs. We first present the mission statements for the university and the department.

Old Dominion University's Mission Statement, published in the Old Dominion University Catalog 2013-2014, is stated in the following.

> Old Dominion University, located in the City of Norfolk in the metropolitan Hampton Roads region of coastal Virginia, is a dynamic public research institution that serves its students and enriches the Commonwealth of Virginia, the nation and the world through rigorous academic programs, strategic partnerships, and active civic engagement.

The Mission Statement for the MSVE Department, that is published in the University Catalog and on the MSVE website, is presented next.

> MSVE serves the public globally with education and research in modeling and simulation through the following:
>
> - Provide high quality undergraduate and graduate modeling and simulation engineering curricula via on-campus and distance learning.
> - Conduct cutting edge research in modeling, simulation, and visualization engineering.
> - Promote the discipline of modeling and simulation and its use in real-world practical applications.

Next, we identify the program educational objectives for the BS-M&SE program. The PEOs describe the achievements that program graduates are expected to attain during the first few years following graduation. The educational objectives of the modeling and simulation engineering program, established with the participation of program constituencies, are consistent with the mission of Old Dominion University and the Department of Modeling, Simulation and Visualization Engineering.

The program educational objectives of the Modeling and Simulation Engineering program are as follows.

> Within a few years after graduation, Modeling and Simulation Engineering alumni will have:
>
> a) Established themselves as practicing professionals in modeling and simulation engineering or related areas or have engaged in graduate study;
> b) Demonstrated their ability to work successfully as members of a professional team and to function effectively as responsible professionals; and,
> c) Demonstrated their ability to adapt to changing situations, evolving technologies, and new career challenges.

The PEOs clearly are consistent with and support the mission statements of the university and the department. Student outcomes (SOs), described in the next section, are developed to prepare students to attain the PEOs.

4 STUDENT OUTCOMES

Student outcomes are defined as statements that describe what students are expected to know and be able to do by the time of graduation. The program curriculum must be designed to continually advance students toward achieving the desired outcomes. The student outcomes are derived from two sources. ABET specifies a set of eleven student outcomes that are common to all engineering programs; these outcomes are presented in (ABET 2011) and summarized in Table 1 for convenience. The ABET student outcomes are broad statements that identify knowledge and skills required of all engineers. In addition, the M&SE program faculty has defined a set of essential knowledge and skills that they believe form the technical foundation for the discipline of modeling and simulation engineering. These are the concepts, principles, and methods that anchor the M&SE curriculum; they represent the fundamentals that every M&SE graduate must know and be able to use. The M&SE essential knowledge and skills are stated as a set of nine student outcomes that focus on the technical components of the M&SE curriculum.

The M&SE program adopted the eleven ABET student outcomes directly. These outcomes are stated in Table 1.

Table 1: EAC-ABET student outcomes.

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(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
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The program student outcomes that address technical knowledge and skills specific to the M&SE program are presented in Table 2. The MSVE faculty thought it important to identify these student outcomes because collectively they indicate the capabilities and skills of a new and perhaps unfamiliar engineering discipline. It is our hope that these program student outcomes will help perspective employers and other interested parties understand the capabilities and value that M&SE graduates can bring to their organizations. The program student outcomes add resolution to the statement of ABET student outcome (k) for Modeling and Simulation Engineers.

This section concludes with a description of the procedure for measuring student achievement relative to the student outcomes. For each student outcome, three-to-five performance measures are defined. The performance measures must be observable through investigation of normal course activities such as problem assignments, exam questions, term papers, laboratory exercises, student presentations, and term projects. Performance measures typically add resolution and meaning to the student outcomes. Next, a rubric is defined to evaluate the degree of student achievement in each performance measure. A four point scale is used and performance is labeled as unacceptable, acceptable, good, or excellent. Additionally, specific course content modules are identified as locations where a particular performance measure can be observed. It then is a straight forward procedure to associate a numerical score with each performance measure. Forming a weighted average of all performance measures for a given student outcome yields a numerical value indicating level of achievement for each student outcome.

Table 2: M&SE Program student outcomes.

(P-1) an ability to communicate designs across technical and non-technical boundaries
(P-2) an ability to model systems from different domains
(P-3) an ability to develop an input data model based on observed data
(P-4) an ability to select and apply appropriate simulation techniques and tools
(P-5) an ability to develop simulations in software
(P-6) an ability to apply the experimental process to acquire desired simulation results
(P-7) an ability to apply visualization techniques to support the simulation process
(P-8) an ability to use appropriate techniques to verify and validate models and simulations
(P-9) an ability to analyze simulation results to reach an appropriate conclusion

The department has developed a schedule for assessing the student outcomes. All twenty student outcomes are evaluated every two years. Each student outcome achievement score is determined by a minimum of three independent (different course or different instructor) samples. The samples include homework problems, exam problems, writing assignments, laboratory exercises, and course projects. Each outcome is accompanied by a rubric to provide a level of consistency between instructors and assessments. A two-year moving average is utilized to produce annual results for each student outcome. Each student outcome is assigned a threshold achievement score; performance above the threshold score indicates satisfactory student achievement while performance below the threshold score indicates a potential problem area that must be investigated more closely.

5 CONTINUOUS IMPROVEMENT PROCESS

ABET Criterion 4 states that a program must regularly use appropriate, documented processes for assessing and evaluating the extent to which both the program educational objectives and the student outcomes are being attained. The results of these evaluations must be systematically utilized as input for the continuous improvement of the program. The purpose of this section is to describe the continuous improvement process implemented for the BS-M&SE program.

The continuous improvement process utilized for the M&SE program is illustrated in Figure 1. At a high level, the process consists of the following steps: (1) gathering and assessing data concerning student achievement on student outcomes; (2) gathering and assessing additional program data obtained from program constituents and department databases; (3) utilizing these data to develop a program evaluation; (4) developing a program enhancement plan to remediate problem areas identified in the program evaluation; and (5) implementing the program enhancement plan. This continuous improvement process is conducted annually based on a moving two-year average of assessment data. The program enhancement plan based on current data is implemented in the next academic year. The impact of these changes is then assessed in the next assessment cycle. It often may take several assessment cycles to fully understand the effect of a program change.

Resolution is added to this high level description of the continuous improvement process in the following subsections. In Subsection 5.1, the assessment activities leading to the development of a program evaluation are described. Then in Subsection 5.2, the development and implementation of a program enhancement plan are explained.

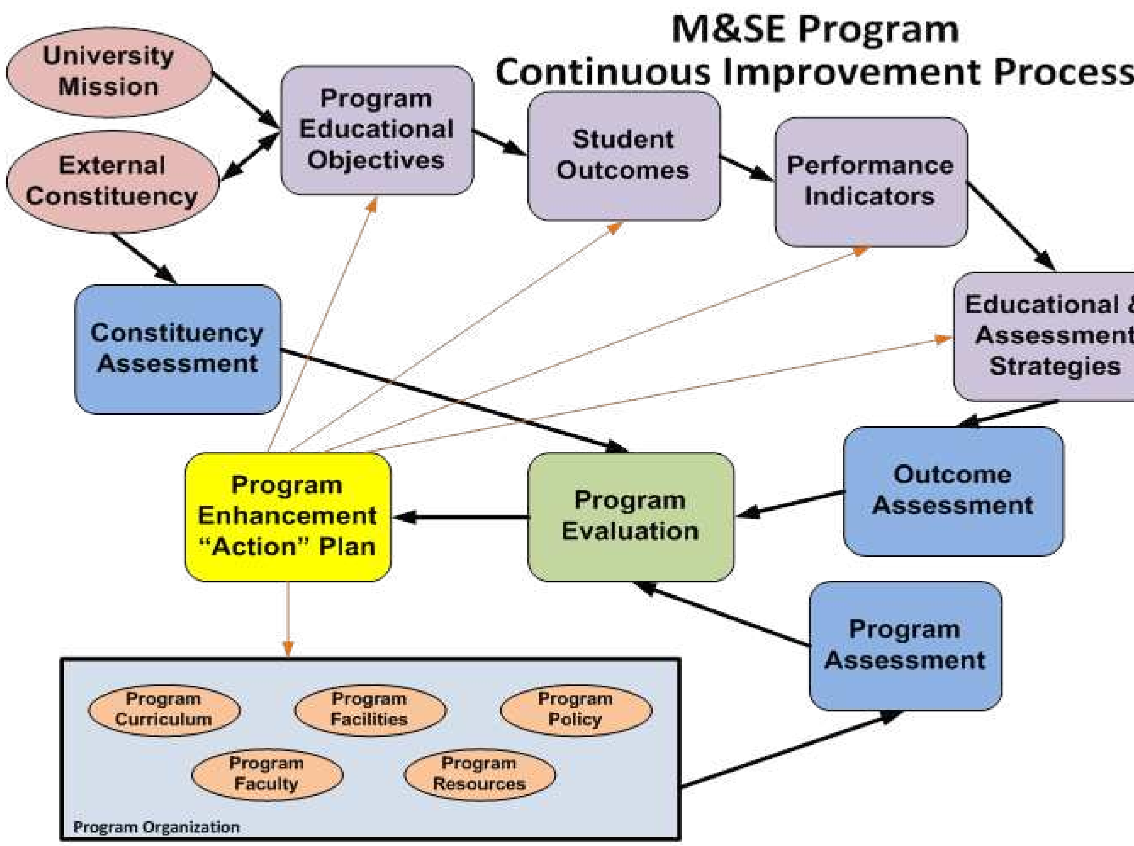

Figure 1: Continuous improvement process for the BS-M&SE Program.

5.1 Assessment Inputs and Processes

The assessment data resulting from evaluating student achievement of the student outcomes are a primary input for development of a program assessment. Any student outcome having an achievement score below the assigned threshold value is identified as a problem issue and will be addressed further during the development of the program enhancement plan. However, a number of other sources of input data also are utilized. These inputs are identified in this subsection.

MSVE regularly seeks input from program constituents. Each year, the department conducts exit interviews with graduating seniors. In addition, these students complete a written exit survey. These inputs result in a student evaluation of student outcome achievement as well as the identification of new potential problem issues. Every third year, the department surveys program alumni and employers of program alumni. These surveys provide additional evaluations of student outcome achievement as well as data concerning the success of program graduates. The department also maintains a Department Industrial Advisory Board (IAB). The IAB consists of community and industry leaders who have knowledge of and interest in modeling and simulation. The IAB meets at least twice each year and provides important guidance to the department on future directions and opportunities. The IAB participates in the department's major tri-annual program reviews. Their input provides additional data concerning achievement of student outcomes and program educational objectives. The department also encourages informal input from regional M&S employers and accepts this input on a continuous basis.

Still another source of input to the development of a program evaluation comes internally from the MSVE faculty. The Teaching Portfolio Review Committee reviews teaching portfolios prepared by department faculty. The purpose of this review is to provide feedback to the MSVE faculty members concerning the quality and effectiveness of their teaching materials and methods. Tenure-track faculty are reviewed annually while tenured faculty are reviewed every third year. The portfolio reviews are especially useful in the core courses to make sure that content is delivered as prescribed in the M&SE curriculum plan. In addition, the Undergraduate Committee regular assesses the appropriateness and condition of curriculum, facilities, policies, and resources for the undergraduate program. A summary of assessment inputs and processes is presented in Table 3.

Table 3: Summary of assessment inputs and processes.

Process or Activity	Actor(s)	Input	Frequency	Output
Student Outcome Assessment	MSVE Faculty MSVE Assessment Committee	Outcome Performance Measures	Annually	Student Outcome Achievement Assessment
Constituency Assessment	MSVE Assessment Committee MSVE Faculty	Senior Exit Survey	Annually	Survey Summaries PEO and SO Achievement Assessments Informal Feedback
		Alumni Survey	Tri-Annually	
		Employer Survey	Tri-Annually	
		IAB Minutes	Tri-Annually	
		Informal Feedback	Continuously	
Program Assessment	Teaching Portfolio Review Committee	Faculty Portfolios	Annually Tri-Annually	Teaching Portfolio Evaluations
	MSVE Undergraduate Committee MSVE Assessment Committee	Course/Curriculum Policy Facilities Resources WEAVE Report	Continuous Annually	Current Status
Program Evaluation	MSVE Assessment Committee Department Chair	All Assessment Output	Annually	Performance Evaluation Summary Identified Issues

The primary purpose of the assessment activity is to provide the input data needed to develop a program evaluation. The program evaluation is prepared by the MSVE Assessment Committee. This evaluation provides an annual checkup for the department; it indicates those areas where the department is having success and also indicates areas or issues where the department might improve. Of course, a primary output of the program evaluation is the identification of the student outcomes in which student achievement is below the target threshold. The MSVE Assessment Committee presents this report to the department chair and to the MSVE faculty. The program evaluation is the main input for development of the program enhancement plan.

5.2 Program Enhancement Plan

The final component of the continuous improvement process is the development and implementation of the program enhancement plan (PEP). The PEP considers each of the problem areas or issues identified in the program evaluation. For each problem or issue, the PEP prescribes a plan of action to address these issues. This plan is prepared initially by the MSVE Assessment Committee. The Assessment Committee often must work in conjunction with the Undergraduate Committee, especially when changes to the curriculum are involved, or with the department chair, especially when resource commitments must be made. Once a draft plan is produced, it is presented to the department chair and the MSVE faculty. This often is done at a special faculty meeting or faculty retreat several weeks prior to the start of the new academic year. The draft plan of action is discussed, perhaps modified, and then accepted for implementation. It is the actual implementation of the plan of action that closes the feedback loop in the continuous improvement process. At that point, adjustments to program delivery are made, usually in time for the new academic year.

The issues identified for remedial action at the close of one academic year are then tracked carefully in following academic years. A few issues are easily addressed and a solution is completed over the next academic year. However, most issues require longer time frames for observation and assessment of the full impact of a change. The structure of the continuous improvement process easily facilitates tracking ongoing issues, either until a solution is validated or until a decision is made to try a different remediation approach.

At the time this paper was being prepared, the department was conducting the third complete cycle of the continuous improvement process. In each of the two previous cycles, four issues were identified for remedial action. For example, a particular issue was identified in the Continuous Simulation course, both through the Teaching Portfolio Review and through Student Outcome Assessment. Changes to the course were proposed and implemented, involving reallocating the time allotted to topics within the course to strengthen areas of student weakness. The student outcomes are being monitored and are showing an improvement. The process seems to detect issues that should be addressed, and the process of developing and implementing a PEP appears to be a reasonable way to initial program change. At this time, we are pleased with the continuous improvement process that we have developed.

6 CONCLUSION

The first ABET accreditation visit to the M&SE program was conducted in October 2014. We are currently waiting for the official outcome of our accreditation evaluation during summer 2015. However, from our perspective, the accreditation visit went very well. We were somewhat concerned because, while we felt well prepared, this was the first time that a Modeling and Simulation Engineering program was evaluated.

The main recommendation from our visiting team was to reduce the number of program-specified student outcomes utilized in our assessment process. The MSVE Assessment Committee now is working to reduce the number of program student outcomes from nine to two or three. ABET also is considering adjustments to the eleven ABET-specified student outcomes; therefore, we will not make any final changes until we have more information from ABET.

A second minor issue concerns the selection of ABET visitors. The main engineering disciplines each have a sponsoring professional organization or society. ABET works with the sponsoring organization to identify appropriate visiting team members. Of course, M&SE presently is not identified as a specific engineering discipline and there is no sponsoring M&S organization. As the number of undergraduate M&SE programs begins to grow, it would be helpful for an M&S organization or society, such as the Society for Modeling and Simulation International (SCS), to become the sponsoring organization and assist in the selection of appropriate team visitors.

A secondary feedback used to assess the students' ability to perform in future employment is the senior capstone design project. The project is a year-long effort where the students execute a project from the proposal stage to the delivery of a prototype. Each project enlists the participation of an external "customer"; past projects have utilized Newport News Shipbuilding and the Eastern Virginia Medical School. These project have been very successful and resulted in job offers to the graduating seniors.

The MSVE Department at Old Dominion University would be pleased to assist other institutions interested in initiating new M&S academic degree program. We encourage you to contact the authors or the MSVE Department.

REFERENCES

ABET – Engineering Accreditation Commission. 2012-2013. "Criteria for Accrediting Engineering Programs." Accessed May 18, 2015. http://www.abet.org.

Leathrum, J. F., and R. R. Mielke. 2012. "Outcome-Based Curriculum Development for an Undergraduate M&S Program." In *AutumnSim 2012, Conference on Education and Training Modeling and Simulation (ETMS'12)*, edited by A. Abhari and M. Davoudpour, 48-53. San Diego, CA: Society for Modeling and Simulation International.

McKenzie, F. D. 2015. "Preparing for the EAC-ABET Visit for a Novel Undergraduate Program in Modeling and Simulation Engineering." In *Proceedings of the 13th Latin American and Caribbean Consortium of Engineering Institutions (LACCEI) Conference*, Santo Domingo, Dominican Republic: Latin American and Caribbean Consortium of Engineering Institutions.

Mielke, R. R., J. F. Leathrum, and F. D. McKenzie. 2011. "A Model for University-Level Education in Modeling and Simulation." *M&S Journal.* 6(3): 14-23.

National Research Council. 2006. *Defense Modeling, Simulation, and Analysis: Meeting the Challenge.* Washington, DC: The National Academies Press.

National Science Foundation. 2006. "Simulation-Based Engineering Science." *Report of the National Science Foundation Blue Ribbon Panel on Simulation-Based Engineering Science.*

Scott, R. C. 2007. "HR 4165 – To Provide Grants to Encourage and Enhance the Study of Modeling and Simulation at Institutions of Higher Education." *The Congressional Record*.

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