# Continuous Improvement for a Unique Modeling and Simulation Engineering Program

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## Abstract

The modeling and simulation (M&S) engineering (M&SE) program at Old Dominion University satisfies the program criteria for general engineering in the ABET Engineering Accreditation Commission (EAC) and also declares discipline-specific student outcomes that can be utilized as a template for future up-and-coming M&SE and similar computational science and engineering programs. M&S is a discipline focused on advancing and using the theories and practices of selecting appropriate modeling techniques, creating associated models, executing models dynamically over time, utilizing visualizations for verification and validation (V&V), and evaluating a range of possible solutions through analytical techniques. We have an educational curriculum that provides students with a well-rounded foundation that can be used either to advance M&S theories or apply such methodologies to virtually any domain. This paper describes our efforts to evaluate our program in attaining these goals through the process of continuous improvement of general engineering and discipline-specific outcomes.

## Keywords

ABET, modeling, simulation, engineering, education.

## Introduction

As we waited with bated breath for nearly a whole year, on Tuesday, September 1, 2015 at 2:24 PM, the first engineering undergraduate program in modeling and simulation (M&S) received notification of successful accreditation from the Accreditation Board for Engineering and Technology (ABET). This accreditation is an important recognition of engineering programs that work towards student attainment of learning outcomes that conform to engineering disciplines and have a process for measuring attainment and continuous improvement.

The Bachelor of Science (B.S.) in Modeling and Simulation Engineering (M&SE) degree program began in 2010 while M&S programs at the graduate level have existed at Old Dominion University (ODU) since 1998. Because of the significant history of M&S at ODU, an established cadre of motivated faculty, administrators, and M&S stakeholders were readily available to draw upon in the establishment of the undergraduate program and a Modeling, Simulation and Visualization Engineering (MSVE) Department to support the undergraduate students that were to come. ODU's sojourn into graduate modeling and simulation programs was initially administered by Dr. Ralph Rogers who, a year earlier, had headed a workshop[1] on the subject while at the Department of Industrial Engineering and Management Systems at the University of Central Florida. His arrival at ODU spurred on the establishment of the first PhD program in M&S in the USA in the year 2000 and the first PhD graduate in M&S in 2003. A year after Dr.

Rogers' workshop, teaching M&S at the undergraduate level was the theme at a 1998 National Science Foundation (NSF) workshop in Vancouver, Canada[2]. Inspiringly, Sarjoughian and Zeigler (2001) broached the subject of teaching M&S as an undergraduate discipline. Later, in 2006, the NSF Blue Ribbon Panel on Simulation-Based Engineering Science (SBES)[4] stated that "seldom have so many independent studies by experts from diverse perspectives been in such agreement: computer simulation has and will continue to have an enormous impact on all areas of engineering, scientific discovery, and endeavors to solve major societal problems."

More than a decade after pioneering a successful graduate program and building significant M&S infrastructure, we became the first in the world M&S department established specifically to support a B.S. program in the M&S discipline. Other similar programs have grown under the broader moniker of Computational Science and Engineering (CSE) but encompass more computer science aspects of high performance computing and parallel algorithms. The Science part of CSE focuses on the modeling and simulation of the natural sciences (biology, chemistry, physics) while the Engineering part of CSE focuses on the design, modeling, simulation, and analysis of complex, typically physical, systems. ODU's M&S programs focus on advancing and using the theories and practices of selecting appropriate modeling techniques, designing and creating associated models, executing models dynamically over time, utilizing visualizations for verification and validation (V&V), and evaluating a range of possible solutions through analytical techniques; then, applying this knowledge in different domains. Several universities have developed tracks or concentrations focusing on narrow areas of modeling and simulation as part of other degree programs; however, to date, no ABET-accredited engineering program in modeling and simulation has been fully implemented until now.

At the outset, ODU's undergraduate M&SE program has been designed to meet four sources of program content and goals[5,6]: the ABET criteria for accrediting engineering programs; the literature defining an M&S body of knowledge[7,8]; discipline-specific student outcomes identified by program faculty; and university general education requirements. The result is a curriculum that teaches the fundamental principles and theoretical foundations of M&S and prepares students to enter the workforce as entry-level engineers with the talent for design and the M&S skills that can prove the benefits of such designs. Aptly put by one of our industry advisors, "When I hire one of your graduates, I get three people in one – an engineer, a simulationist, and an analyst."

The M&SE program at Old Dominion University satisfies the program criteria for general engineering in the ABET Engineering Accreditation Commission (EAC) and also declares discipline-specific student outcomes that can be utilized as a template for future up-and-coming M&SE and similar computational science and engineering programs. M&SE graduates are also prepared for certification via the Certified Modeling & Simulation Professional (CMSP) examination (www.simprofessional.org) and licensure as an Engineer in Training (EIT).

We view this discipline as having broad engineering appeal that can be harnessed to find creative solutions to a wide variety of problems. Underlying the techniques and tools is a foundation in mathematical and statistical theories. Such theories bridge the gap between science and engineering and enable the exploration of solution spaces for problems that may be too complex, too costly, or too dangerous to explore by utilizing the real systems themselves. We have an educational curriculum to provide students with a well-rounded foundation that can be used

either to advance M&S theories or apply such methodologies to virtually any domain. This paper describes our efforts to evaluate our program in attaining these goals through the process of continuous improvement of general engineering and discipline-specific outcomes.

## Continuous Improvement

In this section we discuss our systematic continuous improvement process with its actors and inputs, the two-year data cycle for annual Program Enhancement Plans (PEPs) with identified actions, results of initial changes made (closing the loop), and future program improvement plans.

Assessment of the achievement of Student Outcomes (SOs) is done on an annual basis using the student learning measure (SLM) instruments such as test problems, quizzes, homework, and projects. The analysis of the assessment is done by the Chair of the MSVE Department and the MSVE Assessment Committee. The results of the assessment and recommended actions are presented to the faculty at faculty meetings and/or yearly retreats. Upon approval by the MSVE Department Faculty, the Department implements the proposed actions by the committee. The first column in Table 1 shows the assessment and evaluation activities in our continuous improvement process.

The first row in the table addresses Constituency Assessment, which is important in maintaining the relevancy of our Program Educational Objectives (PEOs). SOs are mapped to the established PEOs to indicate the mechanism by which program objectives are to be achieved. Although not required by ABET, assessment of the attainment of PEOs may also be part of the Constituency Assessment process. Since this is important to us, our surveys include questions about both relevancy and attainment. As indicated in the table, this process is primarily carried out triennially with surveys of alumni and their employers and at our biannual Industry Advisory Board (IAB) meetings. If there were suggested updates to our PEOs, the Program Evaluation activity, discussed later, would determine what effects any updates would have and identify any necessary changes to SOs that would result from an updated PEO. Additionally, it is possible that program evaluations suggest a change to the PEOs that would result in an action within the annual Program Enhancement Plan (PEP).

For Student Outcome Assessment, each SO rubric identified topics and/or performance indicators along with guidelines that allowed faculty to gage the extent to which each topic/indicator was achieved. These achievable performance levels were used to map SLMs that faculty choose at their discretion. A possible action in the PEP could be the recommendation to make changes to Educational & Assessment Strategies that could affect educational practices and/or strategies for assessment; for example, a change in the SLM utilized for a particular SO.

Program Assessment involves the consolidation of course assessment and constituency assessment results into an overall view of the program's performance on student achievement of the student outcomes in a particular year of assessment. This is the current status of the program as can be determined based upon the sample set of students, alumni, and employers that were assessed for that year. This information is put in context during the Program Evaluation activity by averaging over two years of assessment and tracking the two-year moving window trends of the SOs as recorded in our WEAVE assessment management tool.

**Table 1. M&SE Systematic Assessment Processes and Inputs**

| Process / Activity | Actor | Input | Frequency | Output |
|---|---|---|---|---|
| **Constituency Assessment** | MSVE Assessment Committee, MSVE Faculty | Alumni Survey | Triennially | Survey Summaries, Revalidated or Revised PEOs, MSVE IAB and Informal Feedback |
| | | Employer Survey | Triennially | |
| | | IAB Minutes | Biannually | |
| | | Informal Feedback (VMASC IA and Others) | Continuous | |
| **Student Outcome Assessment** | MSVE Faculty, MSVE Assessment Committee | SO Rubrics, Course SLMs | Annually | Outcome Assessment Reports (OARs), Cross Course Assessments |
| **Program Assessment** | Teaching Portfolio Review Committee | Faculty Teaching Portfolios | Annually, Triennially | Faculty Teaching Portfolio Evaluation |
| | MSVE Undergraduate Committee, MSVE Assessment Committee | Cross Course Assessments, Alumni Survey Summary, Employer Survey Summary, Faculty Teaching Portfolio Evaluation, Curriculum | Continuous | Current Status, PERs |
| **Program Evaluation** | MSVE Assessment Committee, Department Chair | Revised PEOs, PERs, WEAVE Report, Policy, Facility, Resources | Annually on Two-Year Data | PERs Summary with identified SO issues, Program Enhancement Plan (PEP), WEAVE Report |

The purpose of the Program Evaluation activity is for the MSVE Assessment Committee and the Department Chair to evaluate the results of the assessment activities (including Program Assessment) and determine if there are issues associated with PEOs or SOs. Issues are identified if established Performance Targets for particular SOs are not met. A Performance Target may be described as having 75% of our students achieve a good or excellent in a particular SO. During the Program Evaluation process, the MSVE Assessment Committee determines if these issues identify any gaps, strengths or weaknesses in the program which need to result in recommended actions in the PEP. The Department Chair participates in the Program Evaluation process and approves any actions requiring financial resources. PEP actions are discussed with associated faculty by the Chair and other MSVE Assessment Committee members as needed for feedback and final update to the PEP. The actions proposed by the MSVE Assessment Committee are also presented to the MSVE Faculty at the MSVE Faculty Retreat at the beginning of the Fall semester. Other actions that may be in the PEP could address program organizational components such as curriculum, facilities, policy, faculty, and resources. Upon approval during the faculty retreat, affected faculty will be asked to implement the actions during the current

academic year, if possible. To close the loop, all instituted actions from the PEP are evaluated during subsequent cycles until assessment data shows evidence of satisfactory improvement and the action is then closed.

## Summary

Our plan for continuous improvement of this novel program is applicable to any engineering program. We were able to take advantage of the luxury of planning its accreditation from the very start of the program and put in place a systematic plan for continuous improvement utilizing many of the processes and activities that were already in place in the college. As part of this continuing improvement process, we are able to shift performance targets to ensure that outcomes that are most in need of improvement are able to be addressed. Therefore, there will always be at least one outcome that will be evaluated for improvement. We believe this plan allows for not only continuous improvement but also continuous discussion and engagement from our faculty.

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