Assessing ABET Outcome 7 through a Fluid Systems Simulation

Dr. Gloria Guohua Ma, Wentworth Institute of Technology

Gloria Ma is a Professor in the Mechanical Engineering program at Wentworth Institute of Technology. She is actively involved in community services of offering STEM workshops to middle- and high-school girls. Her research interests include dynamics and system modeling, geometry modeling, project based engineering design, and robotics in manufacturing, artificial intelligent in Manufacturing, and engineering education.

Assessing ABET Outcome 7 through Simulation-Based Modeling of a Fluid System

Abstract

ABET Outcome 7 emphasizes a student's ability to acquire and apply new knowledge as needed, using appropriate learning strategies. This paper presents an instructional and assessment framework for evaluating Outcome 7, through a simulation-based fluid systems project implemented in a senior level Electromechanical Systems course. The project centers on a modular two-tank fluid system designed to introduce students to dynamic modeling and system simulation. Students derive mathematical models, identify system parameters, and validate system behavior through simulation. Because most students have limited prior exposure to fluid system dynamics and control, the project intentionally requires independent acquisition of new theory and computational tools. Assessment results indicate that the module promotes self-directed learning, interdisciplinary reasoning, and increased student confidence in applying newly acquired knowledge to unfamiliar engineering problems.

1. Introduction

Modern engineering practice requires graduates to continually adapt to emerging technologies and unfamiliar problem domains. In response, ABET Outcome 7 explicitly emphasizes lifelong learning and the ability to acquire and apply new knowledge using appropriate strategies [1]. Despite its importance, Outcome 7 remains challenging to assess traditional examinations or tightly structured laboratory exercises.

ABET Student Outcome 7 is most commonly assessed in senior design courses, where students are expected to independently acquire and apply new knowledge to open-ended design problems. While senior design courses provide a natural environment for observing independent learning, relying on a single course limits opportunities for formative assessment and systematic continuous improvement. Effective evaluation of Student Outcome 7 requires assessment at multiple points throughout the curriculum. At Wentworth Institute of Technology, the electromechanical engineering program provides a distinctive interdisciplinary curriculum in which students complete both mechanical and electrical core coursework. The senior-level Electromechanical Systems course, a required course for all electromechanical students, was intentionally selected as an additional assessment point for Student Outcome 7. This course focuses on modeling and simulation of dynamic mechanical, electrical, fluid, and thermal systems. Students analyze system behavior using mathematical modeling and computational tools, and multiple simulation software packages are utilized in laboratory activities to reinforce theoretical concepts. The course carries four credits and includes three hours of lecture and two hours of laboratory per week.

Simulation-based learning environments offer a promising approach to addressing this assessment challenge. By placing students in open-ended settings that require independent exploration, simulation-based projects promote self-directed learning and conceptual integration [2], [3]. This paper presents a simulation-based fluid systems module designed to provide a suitable context for evaluating students' ability to acquire new technical knowledge using appropriate learning strategies.

2. Related Work

ABET Outcome 7 has been widely interpreted as a measure of lifelong learning, adaptability, and the ability to independently acquire new knowledge beyond formal instruction [1], [4]. Previous studies have emphasized the importance of project-based and inquiry-driven learning environments for evaluating this outcome [5].

Unlike outcomes that emphasize technical correctness or design performance, Outcome 7 requires assessment approaches that capture self-directed learning, adaptability, and engagement with unfamiliar content. As a result, engineering educators have explored a range of project-based, survey-based, and rubric-driven strategies to operationalize and assess this outcome.

Mynderse [6] presents one of the most direct efforts to assess Outcome 7 through a Measurement Systems course. In this work, students complete open-ended projects requiring engagement with unfamiliar instrumentation and data analysis concepts. The study demonstrates that projects involving unfamiliar technical domains provide a practical and observable mechanism for assessing students' ability to acquire new knowledge independently.

Ayasoufi et al. [7] take a complementary approach by using the Learning and Study Strategies Inventory (LASSI) to quantify students' independent learning behaviors associated with Outcome 7. Their longitudinal study measures changes in students' learning strategies across the curriculum, providing indirect evidence of Outcome 7 attainment. While this approach offers validated psychometric insight into learning behaviors, it does not directly link assessment to discipline-specific technical tasks.

Broader assessment frameworks are discussed by Battistini and Kitch [8], who present a streamlined rubric-based approach for assessing all seven ABET student outcomes. Their work emphasizes the importance of clarity, consistency, and faculty adoption in outcome assessment, highlighting the need for projects that naturally elicit evidence aligned with specific outcomes. Similarly, Szatmary [4] reviews comprehensive tools for assessing ABET outcomes in mechanical engineering, particularly within capstone design, underscoring the value of open-ended, multidisciplinary experiences for evaluating higher-order learning outcomes.

Building on this body of work, the present study contributes a discipline-specific, simulation-based assessment of Outcome 7 through a fluid systems modeling project embedded in an electromechanical systems course. Unlike using instrumentation [6] and psychometric surveys [7], the proposed approach evaluates students' acquisition of new knowledge through direct evidence of modeling, simulation in a domain with limited prior student exposure.

3. Simulation-Based Fluid System Project

To assess ABET Student Outcome 7, a structured project was designed that requires students to acquire and apply new technical knowledge beyond prior coursework to complete a complex modeling and simulation task. Students are expected to consult a variety of learning resources, including textbooks, peer-reviewed literature, and credible online materials, to obtain information not explicitly provided in class. Evidence of learning is demonstrated through the correct application of this newly acquired knowledge in the project deliverables.

The fluid systems project is implemented as a multi-week assignment with learning objectives that emphasize both technical competency and the process of independent learning. Students are required to develop dynamic models of a coupled fluid system, implement numerical simulations, and identify and apply additional theoretical or computational tools as needed to complete the assignment. These objectives align directly with the intent of ABET Student Outcome 7.

The project is adapted from an end-of-chapter problem in *System Dynamics* by Ogata [9] and is based on a modular two-tank fluid system that serves as a representative dynamic system, as shown in Figure 1. Students are required to clearly state and justify modeling assumptions, including incompressibility, flow behavior, and system linearization. Prior to assigning the project, modeling of liquid-level systems is introduced during lecture to establish foundational concepts.

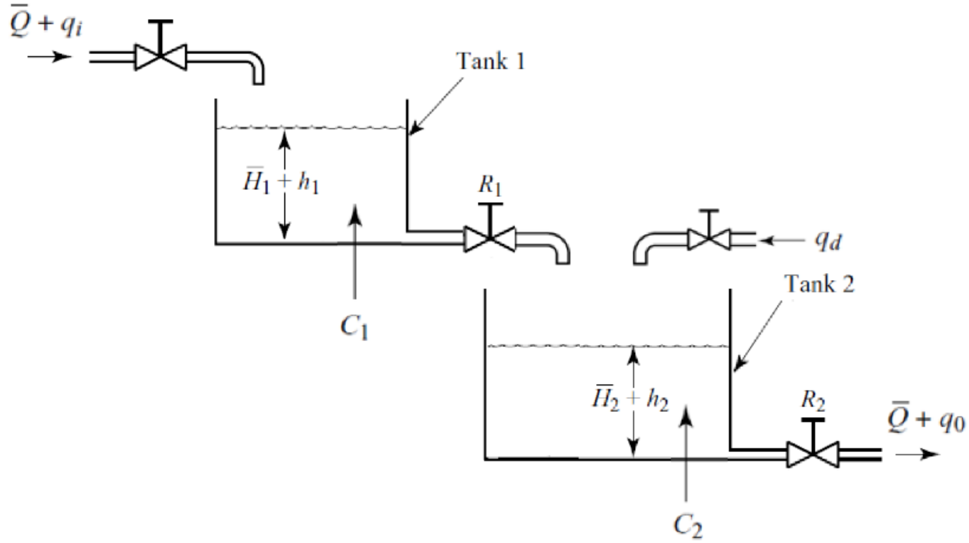

Figure 1. Project used to assess ABET Student Outcome 7.

The project task requires students to develop a mathematical model of the two-tank system and construct a simulation to predict system behavior. However, when working on simulation. Students must determine and specify the values of the flow resistances $R_1$and R_2. Since these parameters are not directly available, students are required to describe the process used to identify or estimate them. The system is assumed to start from rest, with both tanks initially empty at $t = 0$. The first tank has a diameter of 0.4 m, the second tank has a diameter of 0.5 m, and both tanks have a height of 1.2 m. The connecting pipes have a diameter of 0.1 m. Students construct a Simulink model to simulate system response with and without disturbances, displaying the liquid levels in both tanks. The inlet flow q_i is modeled as a step input with a magnitude of 0.035 cm³/s, and the disturbance flow q_d is modeled as a step input with a magnitude of 0.0025 cm³/s.

During simulation development, the values of $R_1$and $R_2$are required but not explicitly provided. As a result, students must independently consult external resources to identify appropriate modeling approaches and parameter estimation methods, providing direct evidence of their ability to acquire new knowledge using appropriate learning strategies.

Evidence of students' ability to apply newly acquired knowledge was evaluated through the correctness and completeness of the developed mathematical models and simulation results. Specifically, student work was assessed based on the appropriate incorporation of estimated system parameters, including flow resistances R_1 and R_2, the implementation of governing equations in the simulation environment.

4. Assessment Methodology

Assessment of student learning related to ABET Student Outcome 7 was conducted using multiple direct assessment artifacts, including written project reports and simulation results. Two performance indicators are developed based on SO7: ability to acquire new knowledge using appropriate learning strategies and ability to apply that knowledge to system modeling and simulation tasks. A rubric-based evaluation approach was employed to assess evidence of the two performance indicators.

Rather than evaluating technical correctness alone, the assessment emphasized how students identified, obtained, and integrated external resources, as well as how newly acquired knowledge informed model development and refinement. This approach aligns with recommendations in the engineering education literature for assessing lifelong learning related outcomes through observable student work rather than self-reported measures [4], [5].

The mapping from the sub-outcomes to ABET specific rubric dimension is shown in Table 1. Assessment Rubrics for sub-outcomes are listed in table 2 and table 3.

Table 1. Mapping of sub-outcomes to ABET-specific rubric dimensions

Sub-outcomes	ABET specific Rubric Dimension
Acquire new knowledge using appropriate learning strategies	Obtain and cite external sources to identify resistance models or estimate the resistance values
Apply new knowledge	implement the resistance values in the mathematical model and simulation to produce valid system behavior.

Table 2. SO-7A: Acquire new knowledge using appropriate learning strategies

Unsatisfactory (1)	Relies primarily on course materials; unfamiliar concepts are incorrect or missing; external references are absent, irrelevant, or improperly cited.
Developing (2)	Attempts to use unfamiliar concepts and external references, but understanding is incomplete; references are weakly aligned with the technical task and may be inconsistently or partially cited.
Satisfactory (3)	Correctly acquires unfamiliar technical concepts using relevant, properly cited external references that support modeling assumptions or methods
Exemplary (4)	Demonstrates strong understanding of unfamiliar concepts and intentionally selects high-quality external resources; references are consistently and properly cited

To implement the required simulations in Simulink, several system parameters needed to be determined but were not explicitly provided. As a result, students were required to independently consult external sources to identify appropriate modeling relationships and parameter estimation methods. This requirement provided direct evidence of knowledge acquisition.

Table 3. SO-7B: Application of new knowledge to system Modeling and Simulation

Unsatisfactory (1)	Resistance values are missing or incorrect, resulting in an unrealistic or incorrect model.
Developing (2)	Resistance values are applied with limited justification or inconstantly implemented in the system model, producing partially correct system behavior.
Satisfactory (3)	Resistance values are appropriately determined and applied, integrated correctly with the system model, producing reasonable system behavior.
Exemplary (4)	Resistance values are well justified and implemented correctly with the system model, with system behavior verified through response analysis or explored under disturbances

Application of newly acquired knowledge was directly assessed through students' determination and use of the flow resistance parameters $R_1$and R_2in the system model. These parameters were not provided and required students to apply externally sourced fluid mechanics relationships and modeling approaches to estimate physically reasonable values. Students demonstrated application of new knowledge by incorporating the estimated resistance values into the governing equations and implementing them correctly within the simulation environment.

5. Results and Discussion

Based on the rubric-based evaluation, the overall distribution of student performance demonstrates strong attainment of ABET Student Outcome 7. As shown in the assessment results (Figure 2), 76.9% of students achieved performance at or above satisfactory level.

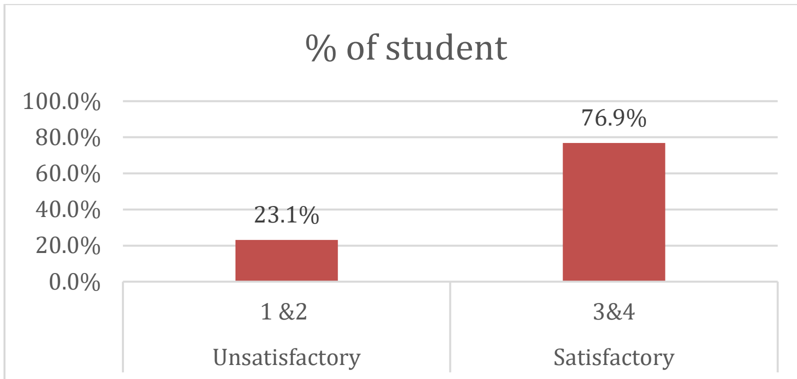

Figure 2. Assessment results

The results indicate that a structured modeling and simulation project situated within an unfamiliar technical domain can effectively generate direct evidence of ABET Student Outcome 7. By requiring students to work with fluid system concepts not previously covered in depth, the project created an authentic need for independent knowledge acquisition while preserving consistent expectations across all teams. Importantly, the project was not fully open-ended; only selected components required students to investigate new material. This balance made the assignment more manageable and helped build students' confidence in their ability to complete the work successfully.

Optional project extensions, such as implementing a feedback control system, provided additional opportunities for demonstrating Outcome 7 among more advanced teams. These extensions served as enrichment rather than requirements for outcome attainment, enabling differentiation in student performance without compromising the overall structured nature of the assessment.

Overall, the use of exclusively direct assessment artifacts strengthened the credibility of the evaluation and minimized dependence on subjective or self-reported evidence. The streamlined rubric supported consistent scoring while still capturing meaningful variations in how effectively students met the expectations associated with Outcome 7.

6. Conclusion and Future Work

This paper introduced a structured fluid-systems modeling and simulation project as a direct assessment tool for ABET Student Outcome 7 in a senior-level electromechanical systems course. The project requires students to identify, acquire, and apply unfamiliar knowledge related to fluid dynamics, mathematical modeling, and numerical simulation, all within a clearly defined set of objectives and deliverables. By selecting a technical domain with which students have limited prior experience, the assignment naturally motivates independent learning and the use of appropriate technical resources.

Student achievement of Outcome 7 was evaluated using a streamlined, four-level rubric. The rubric focused on two performance indicators: students' ability to acquire new technical knowledge using appropriate learning strategies, and their ability to apply that knowledge to modeling and simulation tasks. The assessment used only direct evidence from student work, including written reports, properly cited external references, and simulation results. This approach avoids reliance on self-reported learning. It also provides a transparent and reproducible method suitable for both course-level and program-level evaluation.

The results suggest that the structured project design effectively supports assessment of Student Outcome 7. The optional extensions such as feedback control design allow advanced students to further demonstrate independent learning without jeopardizing consistency in evaluation.

Future work will focus on refining the assessment rubric, incorporating limited physical validation, and extending the simulation-based framework to additional courses. The presented approach is readily adaptable to other engineering domains and provides a scalable method for evaluating Student Outcome 7.

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