# The Assessment Process for ME 321 Mechanical Experimentation II: A Second Course in Experimentation

**Geriel A Ettienne-Modeste**
*George Mason University, Department of Mechanical Engineering*

## Abstract

This paper describes the process adopted by the Department of Mechanical Engineering at George Mason University (GMU) to demonstrate the levels achievement of course learning outcomes and students outcomes, and reports initial results for an undergraduate mechanical engineering experimentation course, ME 321 Mechanical Experimentation II. ME 321, which introduces students to real world applications in fluid mechanics, heat transfer and thermodynamics, is the second of a two-course sequence offered during the junior year of the mechanical engineering curriculum. ME 321 has five course learning outcomes that have been mapped into four student outcomes to assess student learning. The levels of attainment for the course learning (CLO) and student outcomes (SO) are documented using the Mechanical Engineering Assessment Report (MEAR), specifically in the course assessment form (CAF). For this initial implementation of the process, evaluation of course learning outcomes for two sections are consistent, indicating that the largest percent difference between the levels achievement and attainment occurs for outcome 2 and the smallest occurs for outcome 4.

**Keywords: Student outcomes assessment, course learning outcomes assessment, assessment methods, evaluation of outcomes, mechanical experimentation,**

## I. Background

In the fall of 2014, George Mason's Volgenau School of Engineering launched the mechanical engineering program with three faculty and fourteen students. Since then the Department of Mechanical Engineering was established, the curriculum has been revised, new facilities added and the faculty and student-body have grown in number to 15 and 342, respectively. In preparation for its initial program accreditation through the Engineering Accreditation Commission of ABET, Inc., the department drafted program educational objectives, adopted student outcomes and developed its process for the assessment and evaluation of course learning and these student outcomes.

The program educational objectives of the mechanical engineering program are [1]:

- Graduates have demonstrated success as a mechanical engineer or their chosen career field;
- Graduates have advanced their educational pursuits through graduate education, professional registration, or similar means;
- Graduates have advanced their careers by engaging in professional society participation and community service outreach.

The program has adopted ABET's a- k as its student outcomes [2].

ME 321 is a one credit laboratory course offered during the spring semester of the junior year. The course catalog description reads

> *Experimental measurements in fluid mechanics and heat transfer. Involves technical report writing. The objective of the course is to provide the student with a working knowledge of the theory and practical considerations associated with contemporary experimental procedures, methods and design strategies. Emphasis will be placed on statistical experimental methods, uncertainty of measurements, instrument responses, computer aided data reduction, evaluation of system performance through experimentation and modeling, and elements of report writing.*

ME 321 has five course learning outcomes which were first developed when the program was started and later revised in the spring of 2015. The course learning outcomes are

- *An ability to use experimental methods to characterize fluid thermal systems,*
- *Understand and perform the analysis of experimental data using probabilistic and statistic methods,*
- *Understand how to design experiments based on expected outcomes,*
- *Understand the importance of standards in experimental methods,*
- *Understand how to communicate effectively by written report and oral presentation.*

Each course is assigned a course director, appointed by the department chair, who responsible for the development of the curriculum as well as the documentation of the assessment and evaluation of student learning. In addition, the course director has complete authority selecting which student outcome(s) the course addresses. Dr. Geriel A Ettienne-Modeste is the course director for ME 321, and the following four students outcomes have been adopted for assessment and evaluation:

- *(b) an ability to design and conduct experiments, as well as to analyze and interpret data*
- *(f) an understanding of professional and ethical responsibility*
- *(g) an ability to communicate effectively*
- *(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.*

In the sections which follows an overview of the assessment and evaluation process is presented. Specific details for ME 321 Mechanical Experimentation II class are discussed. The assessment results in this report are based on data collected for two semesters, spring 2017. There was a total of 16 students in spring 2017 Sec 201 and 24 students in spring 2017 Sec 202. The data in this paper represents first and second generation college students along with college students whose GPA range from a 2.5 to 3.5 from a 4.0 scale.

## II. Assessment of Required Courses

The process to determine the level of achievement of the student outcomes consists of direct periodic assessment and evaluation of quantitative data collected from course learning outcomes, and indirectly surveying graduating seniors each spring. Table 1 list the process elements and principals involved.

| Table 1. Assessment and Evaluation of Student Outcomes | | |
|---|---|---|
| | Principals Involved | |
| Process Element | Course Director | Student |
| Assessment Process | Course Assessment Form (CAF)<br>Mechanical Engineering Assessment Report (MEAR) | Senior Exit Surveys |
| Frequency of Assessment | Prescribed by Assessment Schedule | Every Spring |
| Frequency of Evaluation | Generate Student Outcomes Achievement Report Every Two Years | Every Two Years |
| Expected Level of Attainment | 90% in the top 3 performance levels | 90% of top two performance levels |
| Results of Evaluation | Document Student Outcomes below Expected Level of Attainment and develop a plan for continuous improvement | Document Student Outcomes below Expected Level of Attainment and develop a plan for continuous improvement |
| Documentation | Department Shared Files<br>TK20 | Department Shared Files<br>TK20 |

Each course director is required to produce a historical record of what was taught and how it was taught in her/his course. The Mechanical Engineering Assessment Report (MEAR) documents this evidence and includes the Course Assessment Form (CAF) containing assessment of course learning and student outcomes. Also included in the MEAR is the course syllabus, list of instructors, copies of all common assessment instruments, and a discussion of the results for the CLOs as well as recommendations for course improvement. The Student Outcomes Assessment Report (SOAR) is generated every two years for all SOs. For this paper, assessment collected during the 2017 is presented. Generating the SOAR requires mapping student outcomes across required courses, and then preparing the MEAR for each course, most importantly completing the CAF form. Only then is it possible to aggregated data for student outcomes and compare these results with the expected level of attainment. The expected level of attainment is a process element which measures how well the student success for a given course learning outcome.

Assessment of the CLOs for ME 321 occurs each spring semester it is offered. Required in this assessment are rubrics for each CLO. Table 2 is a representative sample used when grading student work. It consists of performance indicators that identify abilities students are expected to demonstrate and four achievement levels; namely unsatisfactory, developing, satisfactory and exemplary. Actual achievement of a particular CLO is computed by determining the percentage of students' work that fall into the satisfactory and exemplary categories while the expected attainment level is set for each CLO by the course director. Table 3 presents composite results for all five learning outcomes using the four achievement levels, and the established attainment levels for two sections offered in spring 2017. For example, in CLO-1 the Unsatisfactory criteria represent students who does not understand how to calculate, perform or conduct information for the respective performance indicator and achieved a grade less than 70%. Results for achievement of student outcomes are shown in table 4. Although these results are presented, they are only meaningful if ME 321 was the sole course used to measure them.

**Table 2. Grading Rubric of CLO1 for ME 321**

**Course Learning Outcome 1 - an ability to use experimental methods to characterize fluid thermal systems**

| Performance Indicators (PI) | Unsatisfactory (1) | Developing (2) | Satisfactory (3) | Exemplary (4) |
|---|---|---|---|---|
| Knows how to demonstrate that the force on a vane from a combination of its surface shape and the properties of the jet directed from the vane | Unable to demonstrate that the force on a vane from a combination of its surface shape and solve Bernollui's equation to determine the jet fluid flow properties | Performs correct calculations to determine the force on a vane (i.e., for a combination of its surface shape) and determine the jet flow properties using Bernollui's equation | Performs correct calculations but does not use consistent notation | Performs correct calculations for the force on a vane using Bernollui's equation |
| Applies analytical techniques to determine the coefficients of discharge, velocity and contraction at a fixed flow rate for the sharp-edged orifice and show how the coefficient of discharge varies with flow | Unable to write appropriate techniques to determine the coefficients of discharge, velocity and contraction at a fixed flow rate for the sharp-edged orifice and show how the coefficient of discharge varies with flow | Uses correct equation to determine the coefficients of discharge, velocity and contraction at a fixed flow rate for the sharp-edged orifice but incorrectly shows how the coefficient of discharge varies with flow | Uses correct equation to determine the coefficients of discharge, velocity and contraction at a fixed flow rate for the sharp-edged orifice and finds solution with minor mistakes | Uses correct equation to determine the coefficients of discharge, velocity and contraction at a fixed flow rate for the sharp-edged orifice and finds correct solution |
| Understand how to determine the discharge of incompressible fluid using different Flow Measurement apparatus (i.e., a Venturi meter, an orifice plate meter and a rotameter) to formulate the Steady-Flow Energy Equation and Bernoulli's Equation that can be plotted as a function of Head losses associated with each meter | Uses incorrect equations, or provides wrong justifications or interpretations of results | Uses correct equations to determine the discharge of incompressible fluid using different Flow Measurement apparatus without justification and provides no interpretation of the results | Uses the correct equations to determine the discharge of incompressible fluid using different Flow Measurement apparatus but does not provide a complete justification or interpretation of the results | Clearly justifies assumptions and approximations, uses appropriate equations, and provides correct interpretation of results to determine the discharge of incompressible fluid using different Flow Measurement apparatus |
| Understand how to test the Pelton Turbine at different loads and spear valve settings and produce curves that show the turbine performance and the effect of different spear valve settings | Uses incorrect equations to determine the turbine performance, or provides wrong justifications or interpretations of results | Uses correct equations to determine the turbine performance without justification and provides no interpretation of the results | Uses the correct equations to determine the turbine performance but does not provide a complete justification or interpretation of the results | Clearly justifies assumptions and approximations, uses appropriate equations, and provides correct interpretation of results to determine the turbine performance (i.e., show the performance curve for the torque, power, and efficiency vs the speed of the turbine) |

| | Table 3. Composite Course Learning Outcomes Results | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unsatisfactory | | Developing | | Satisfactory | | Exemplary | | Achievement | | Expected Attainment |
| CLO | Sec 201 | Sec 202 | Sec 201 | Sec 202 | Sec 201 | Sec 202 | Sec 201 | Sec 202 | Sec 201 | Sec 202 | |
| 1 | 14 | 31 | 14 | 26 | 20 | 35 | 80 | 68 | 78.1% | 64.4% | 90% |
| 2 | 36 | 51 | 31 | 56 | 39 | 80 | 86 | 101 | 65.1% | 62.8% | 95% |
| 3 | 17 | 25 | 26 | 36 | 47 | 57 | 102 | 106 | 77.6% | 72.8% | 95% |
| 4 | 6 | 12 | 15 | 15 | 47 | 45 | 60 | 120 | 83.6% | 85.9% | 90% |
| 5 | 12 | 26 | 23 | 36 | 67 | 52 | 186 | 176 | 87.8% | 78.6% | 95% |

| | Table 4. Composite Student Outcomes Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Unsatisfactory | | Developing | | Satisfactory | | Exemplary | | Achievement | |
| SO | Sec 201 | Sec 202 | Sec 201 | Sec 202 | Sec 201 | Sec 202 | Sec 201 | Sec 202 | Sec 201 | Sec 202 |
| B | 19 | 49 | 55 | 77 | 142 | 138 | 328 | 376 | 86.4% | 80.3% |
| F | 33 | 33 | 20 | 29 | 23 | 55 | 52 | 43 | 58.6% | 61.3% |
| G | 2 | 4 | 4 | 8 | 4 | 18 | 54 | 66 | 90.6% | 87.5% |
| K | 31 | 63 | 34 | 62 | 51 | 75 | 140 | 152 | 74.6% | 64.5% |

## III. Results from the Course Assessment Form

In this section of the paper, the results from the Course Assessment Form will be discussed. For both sections of ME 321 in Spring 2017 the results for all five CLOs was reported. Table 3, indicates that Section 201 had a higher level of achievement than Section 202 for all CLOs.

Results in Table 3 also indicate that cumulative sum of CLO5 had the largest number of students with an Exemplary performance indicator compared to the cumulative sum of CLO1 which produced the lowest number of students who performed Exemplary for both sessions of ME 321. CLO5 measured "the ability to communicate effectively by written report and oral presentation."

The high expected level of attainment was attributed to this was the very first time we implemented the expected level of attainment in the ME 321 course and we artificially set the course expected level of attainment very high. Moreover, this high expected level of attainment for the ME 321 course is based on student's response and interpretation of data obtained from their experiments; thus, formal training on how to write an effective report as well as mentoring and practice on public speaking and strong presentation skills were placed as high importance for the course and this again was the first time we implemented the expected level of attainment in the course. Furthermore, CLO2 produced the lowest achievement level for both sections of ME 321. CLO2 measured "the ability to understand and perform the analysis of experimental data using probabilistic and statistic methods." One of the reasons CLO2 produced the lowest achievement level may be attributed to the fact that this was the first time we implemented the expected level of attainment in the course. In the future, the expected level of attainment will be measured by the mean of the actual achievement levels. The next paragraph shows how the CLOs were mapped into the SO outcomes.

Table 5 shows the mapping of the CLOs into the SO outcomes. The data from Table 5 showed that the CLOs and the SO were used to measure student performance.

Table 5. Mapping of the CLOs into the SO outcomes

| | **Course Learning Outcomes** | | | | | |
|---|---|---|---|---|---|---|
| **Student Outcomes** | (1) | (2) | (3) | (4) | (5) | |
| (a) | | | | | | |
| (b) | | | X | X | X | |
| (c) | | | | | | |
| (d) | | | | | | |
| (e) | | | | | | |
| (f) | | X | X | | | |
| (g) | X | X | X | X | X | |
| (h) | | | | | | |
| (i) | | | | | | |
| (j) | | | | | | |
| (k) | X | X | | | | |

**IV. Conclusions**

In this paper we were able to provide assessment data collected during Spring 2017 for ME 321. We showed that the expected level of attainment was a process element used to measure the student success for a given course learning outcome. The Mechanical Engineering Assessment Report (MEAR) documents a historical record of what was taught and how it was taught in a course. The Course Assessment Form (CAF) contains assessment of course learning and student outcomes. Table 5, showed a mapping of the CLOs into the SO outcomes. Overall, the results reported in this paper provides an effective means of assessment for student's achievement.

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