Increasing and Assessing Technical Argument Integration into Mechanical Engineering ME395: Laboratory 1

Pre-Assessment Results

Investigators: Kenn Oldham and Volker Sick, Mechanical Engineering;
Thomas Bowden and Kelly Rohan, Technical Communications; Sakib Elahi, Biomedical Engineering

I. Background

ME395: Laboratory I is the Mechanical Engineering Department's core laboratory course for juniors (110-160 students). It combines laboratory experiments drawn from across the department's technical curriculum with over-arching instruction on laboratory analysis and technical communication. During a typical semester, students perform eight or nine experiments in teams of three or four. The goals of each experiment are introduced through a task letter from a fictitious company. These task letters provide scenarios in which a group of consultants (the student teams) are asked to perform a set of experiments and report back their findings and conclusions. Subject matter and engineering theory are drawn from courses on dynamics and vibrations, mechanics of materials, thermodynamics, and fluid dynamics.

Stretching across laboratories and subject areas, overarching instruction focuses on two primary topics:

- Error analysis and interpretation: Students are instructed on identifying sources of error in experimental measurements (precision, resolution, and accuracy errors) and evaluating their impact on calculated results. Conclusions drawn from experimental outcomes are expected to be compatible with uncertainty of final results.
- Technical report writing: Students are instructed on the elements of an effective written technical report. While report format is standardized to an executive summary followed by procedure, findings, and conclusions, with accompanying instruction, additional lectures are dedicated to topics such as task letter interpretation, organization, effective use of figures, readability, and communication best practices.

The first individual lab reports in ME395 (Lab 4), typically performed at approximately week 5, cover tensile and fracture testing of aluminum.

II. Project Goals

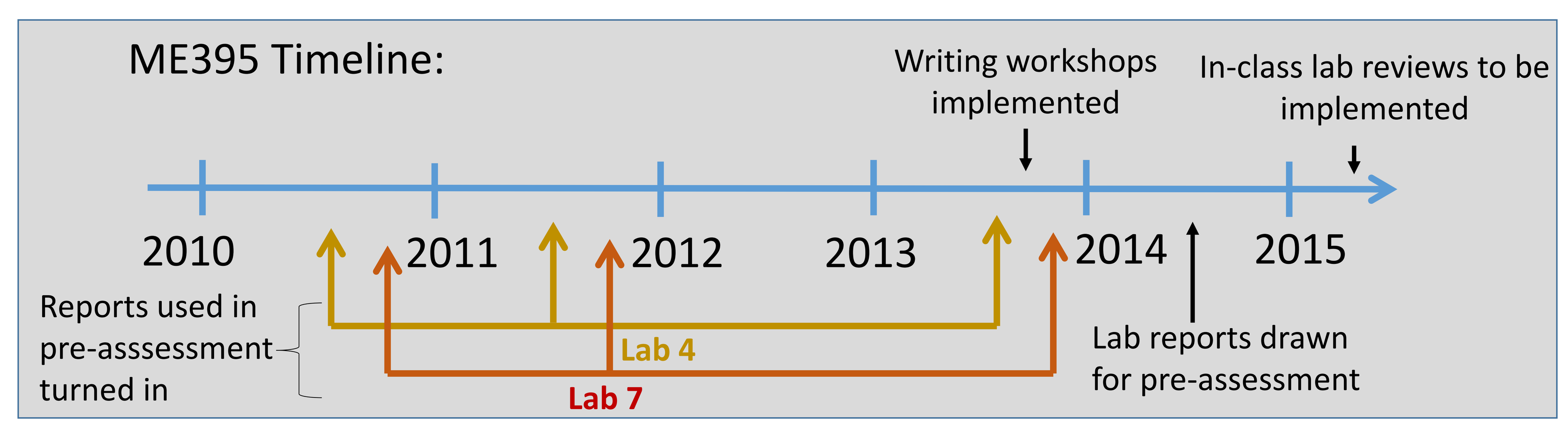
The goal of ongoing curriculum development in ME395 is to improve the teaching of technical arguments through discrete changes to course structure, and to assess the impact of these changes by reviewing laboratory reports before and after curriculum changes.

Traditionally, ME395 instruction is lecture-based and forward looking with:

- Technical communication topics introduced through a series of largely self-contained lectures.
- Engineering topics introduced as required by upcoming labs, with minimal review of past labs.

Support from a University of Michigan Whitaker Fund teaching grant is being used to perform course assessment and resulting curriculum development required to:

- (Primary) Convert a portion of technical communications instruction to a **writing workshop** format, in which students actively apply the theory discussed to real-world writing tasks.
- (Secondary) Include in-class **reviews of students' prior experiment interpretation** to discuss effective approaches to technical argumentation.



III. Project Status

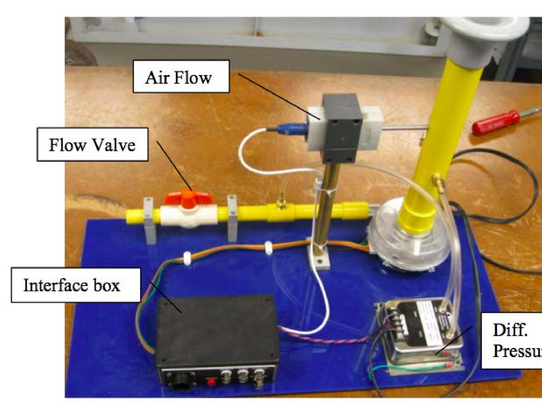
Results presented in this poster are drawn primarily from pre-assessment of technical argument instruction in ME395. A selection of student reports have been reviewed for student effectiveness in several aspects of technical argument, drawing from three semesters in which the authors co-taught the course:

1. Fall 2010: Traditional format
2. Fall 2011: Traditional format
3. Fall 2013: Writing workshops first introduced

Full incorporation of proposed curriculum changes will be implemented in Fall 2015, with review of additional student reports to be completed for comparison to older reports.

For the purposes of pre-assessment, laboratory reports are drawn from the course's two individual labs, Lab 4 and Lab 7. Although task letters vary between semesters, the scenarios are similar in content and permit head-to-had comparison between reports from the same cohort of students. In particular, Lab 4 and Lab 7 require similar logical progressions relating engineering theory to experimental results, from which proper conclusions are highly subject to experimental uncertainty. Lab 4, on fracture of aluminum, requires assessment of whether fracture specimens have entered a regime of plane strain, while Lab 7, on fluid dynamics of a blower, requires assessment of whether self-similar behavior is present.

The second individual lab reports in ME395 (Lab 7), typically performed at approximately week 13, cover similarity in fluid flow in a blower.



IV. Pre-Assessment Methods

A total of 42 laboratory reports have been reviewed, with 7 reports for each of ME395 Lab 4 and Lab 7 drawn from each of the three prior years of instruction. Reports were drawn from students evenly distributed in grade rank between years, representing A to C+ grades in the course. Students belonging to the same team in either Lab 4 or Lab 7 were also excluded to avoid overlap in laboratory results. Once selected, reports were anonymized and read by an independent post-graduate reviewer, Dr. Sakib Elahi (former UM graduate student and ME395 GSI).

Traditional report grades combine evaluation of basic technical and communication activities (i.e., proper use of equations, informative figure preparation) with more advanced technical argument content (i.e. interpretation of results in context of uncertainty, justifying conclusions or recommendations). An excerpt of a typical grading rubric is shown below:

7. Procedure to obtain inlet velocity clear	0	1			
8. Procedure to obtain flow rate clear	0	1			
9. Procedure to obtain outlet velocity clear	0	1			
10. Other aspects of procedure clear including effect of pressure zero	0	1	2	3	
11. Definition of dimensionless numbers used	0	1	2		
12. Head coefficient-flow coefficient plot correct	0	1	2	3	4
13. Error bars included	0	1			

Standard ME395 grading criteria include a progression from task-oriented items, such as those shown in an excerpt for Lab 7, to items that require more critical thinking and the ability to put tasks in context.

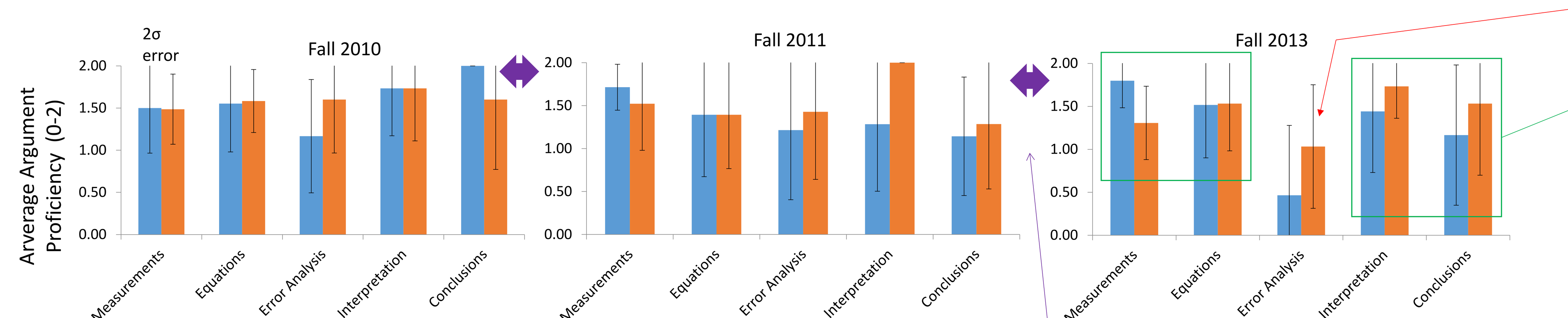
For the purposes of assessing the effectiveness of technical argument instruction, re-review was focused on critical thinking elements, isolating five questions identified as having commonality across lab reports over multiple years and important to forming effective arguments:

1. Procedure/Findings: Do students clearly indicate how experimental measurements are used in later calculations?
2. Findings: Do students explain the why specific equations are important for obtaining desired information?
3. Findings: Do students describe their approach to error analysis and indicate dominant sources of error?
4. Findings/Conclusions: Can students clearly justify an argument about their experimental results that requires assimilating laboratory and theoretical knowledge?
   - Lab 4, Aluminum Fracture: Students must determine whether fracture toughness reaches conditions of plane strain, based on their own experimental results and criteria set forth in an ASTM standard.
   - Lab 7, Fluid Dynamics: Students must determine whether a self-similar relationship between pressure and head coefficients is present, and recognize that this enables additional performance predictions to be made.
5. Findings/Conclusions: Are conclusions from (4) consistent with the level of uncertainty present in their measurements and calculated outcomes?

Student performance under each question was assessed as proficient, partial, or absent/incorrect.

V. Results

Review of reports based on the criteria in Section IV enabled us to compare effective versus ineffective communication strategies employed by students. 2 = high proficiency; 1 = moderate proficiency; 0 = proficiency not demonstrated.



	Examples of High Proficiency Arguments	Examples of Moderate Proficiency Arguments
Ties **measurements** to objectives: Attempts to justify experiments vs. merely describes actions.	"In order to determine the validity of scaling the results of this experiment, enabling us to calculate the flow rate and pressure rise, we need to know how these relate. If the values are related by other values that are known to be consistent for similar geometries, we can scale the experimental results to obtain the desired projections."	"In order to collect the raw data necessary to calculate the flow rate I connected an Omega PX653 pressure transducer on either side of the blower to record the pressure drop across the blower … I performed five separate trials of collecting data in which I would enter a selected blower speed into LabVIEW. "
Explains importance of **equations**: Attempts to introduce importance of equations vs. merely step through calculations.	"Known parameters and dimensional analysis of turbomachines provide engineers with four dimensionless coefficients that can be used to describe the system; I will focus on the head coefficient, Ψ, and the flow coefficient, Φ … If it can be shown that the head coefficient only depends on the geometric term then the system can be successfully scaled..."	"We can relate this to the flow rate, Q, through the unit-less head coefficient, ψ, and the unit-less flow coefficient, ϕ, as seen in Eqs. 2, 3, and 4, where ω is the angular velocity of the impeller and DI is the diameter of the impeller."
Describes **error analysis**: Evaluates dominant sources of error and summarizes calculations?	"Uncertainties in the ψ- and ϕ-values are mostly due to precision errors during data acquisition, with some accuracy errors due to the instrumentation."	Moderate proficiency rare; typically, lower proficiency students fail to recognize importance of error origin or treatment, and thus fail to report
Interpretation of results: Draws on knowledge or experimental evidence to explain results?	"We can see in the plot that for changing speed, the values determined fall within error of each other. This indicates self-similar behavior with regard to flow coefficient, or flow rate, and hydrostatic head coefficient."	"However, we can still note that when the valve position was not varied, the values for different speeds were very similar. Therefore, the results obtained for the model can be applied when scaled to the full scale pump."
Conclusions under uncertainty: Conclusions are consistent with error analysis?	"The spread of the performance curves is taken into account in the uncertainty, as marked as dotted lines. With the exception of the lowest rpm, the uncertainty accounts for all points within the measured performance curves."	"The densities inherently have uncertainty associated with them and thus modeling as system with them will add to the overall uncertainty." – non quantitative, vague.

VI. Conclusions

1. Despite in-class emphasis, explanations of where error originates and its influence on calculated results remains the lowest-performing element of reviewed reports.

2. Significant improvement in argument details between the first and second individual labs was not observed, despite an overall improvement in most grades over the duration of the course:

	F2010		F2011		F2013	
	ME	TC	ME	TC	ME	TC
Lab 4	80.3	80.2	84.1	86.8	80.0	76.0
Lab 7	83.8	84.9	82.0	85.6	86.3	83.8
Change	+3.5	+4.7	-2.1	-1.2	+6.3	+7.8

Some possible interpretations:

- Students' basic organization skills improved, and greater attention was given to the mechanics of report writing, but higher-level critical thinking was little influenced by current teaching practices.
- Large number of topics encountered within class obscure overarching themes across labs and across reports.
- Pre-assessment methods based on limited differentiation (3-level) of proficiency lead to large relative error margins in pre-assessment results.

3. Similarly, we did not observe significant changes in student performance following the first use of the writing workshops (Fall 2013).

VII. Future Work

Based on our analysis thus far, further curriculum development will focus on opportunities to:

1. Expand discussion of error analysis steps related to specific lab questions, to increase the number of examples of error analysis procedures seen by students.
2. Review key points and elements of argument after report completion, drawing on examples of well-argued and poorly-argued reports .
3. Investigate student performance at placing arguments in context of clients' problems, which was not addressed in review of reports across years using different task letters.

Acknowledgements

The investigators thank the Center for Research on Learning and Teaching and UM Whitaker Fund for support of ongoing curriculum development opportunities.