Standards-Based Grading In Introductory Physics Laboratory Courses

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Background

- Assessing student learning is a key component to education.
- Traditional score-based grading system uses multiple individual assignment scores to produce a cumulative overall grade.
- Problems of traditional grading methods in introductory physics lab courses:
  - Failure in mastering certain basic lab skills in spite of repeated learning opportunities, yet earning a passing grade
  - Misunderstanding or lack of understanding of what need to learn in labs
  - Minimal incentive to learn from mistakes
- Standard-based grading (SBG) is an assessment method that relies on students demonstrating mastery of learning objectives (also called standards). There three key elements of SBG:
  - A clear set of learning objectives (LOs) that can be re-assessed throughout the course of teaching
  - The feedback/grading should be linked to students' degree of mastery of the LOs, and not be confounded with other variables such as showing up in class, good effort in completing assignment, etc.
  - Students should be permitted to remedy their deficiencies, poor performance on an early assignment should not forever weigh down the overall grade
- Is SBG a more effective assessment approach to help students with developing basic laboratory skills in physics? The answer to this question may have implications to other disciplines in education or can make us re-examine the current methods in assessing student learning in general.

Methods

- Pre/post assessments were administered in two sections of Physics I lab, one with traditional grading and one with SBG grading , using
  - Measurement Uncertainty Quiz (MUQ), a tool that assesses students' understanding of a threshold concept of physics labs, namely measurement uncertainty
  - 'The Colorado Learning Attitudes about Science Survey for Experimental Physics (E-CLASS), a tool that evaluates if a student's mindset when doing experiments is more like an expert's or a novice's in experimental physics
- The lab reports in the traditional grading section were graded with a generic grading rubric for all eleven labs. This generic grading rubric has many elements that overlap with the LOs in the SBG section.
- Four major learning objectives, each with specific sub-objectives were identified as shown in Table 1 for the SBG section. The lab instructions were revised to let students know what specific learning objectives are being assessed when answering certain questions in a lab report.
- For each lab report, students are given feedback on the mastery of each of the LO assessed using the EMRN rubric, where E stands for exemplary, M stands for meet expectations, R stands for revision needed, and N stands for not assessable. A numerical conversion of the grades is set up such that E=4, M=3, R=1, and N=0.
- A learning mastery gradebook was kept using online Learning Management System Canvas as shown in Figure 1. A 70/30 decaying average was used to calculate the grade, where the most recent score takes up 70% of the weighted average and all the previous scores take up only 30%.

Table 1 Learning Objectives in SBG Section

LO1 Measure real phenomena and apply physical model in observations	a) Describe the purpose of an experiment or a problem to be investigated
	b) Identify theoretical model applicable to the experiment
	c) Construct an experimental set-up, troubleshoot it, and collect data
LO2 Understand experimental error and measurement uncertainty	a) Identify sources of error and estimate measurement uncertainties
	b) Be able to propagate uncertainty in calculations, i.e. given several measured quantities with their uncertainties, find the uncertainty of another quantity that is computed from their values
LO3 Understand how to analyze data	a) Display data in graphical or tabular form with appropriate labels and units
	b) Perform calculations with data
	c) Be able to identify linear functional relationship between physical quantities
	d) Be able to linearize nonlinear function using variable substitution and perform linear regression analysis on the linearized data
LO4 Be able to summarize and communicate results	a) Report measurement results with uncertainties with correct format
	b) Make comparisons between experimental data and theoretical predictions
	c) Draw inferences and conclusions from experimental data

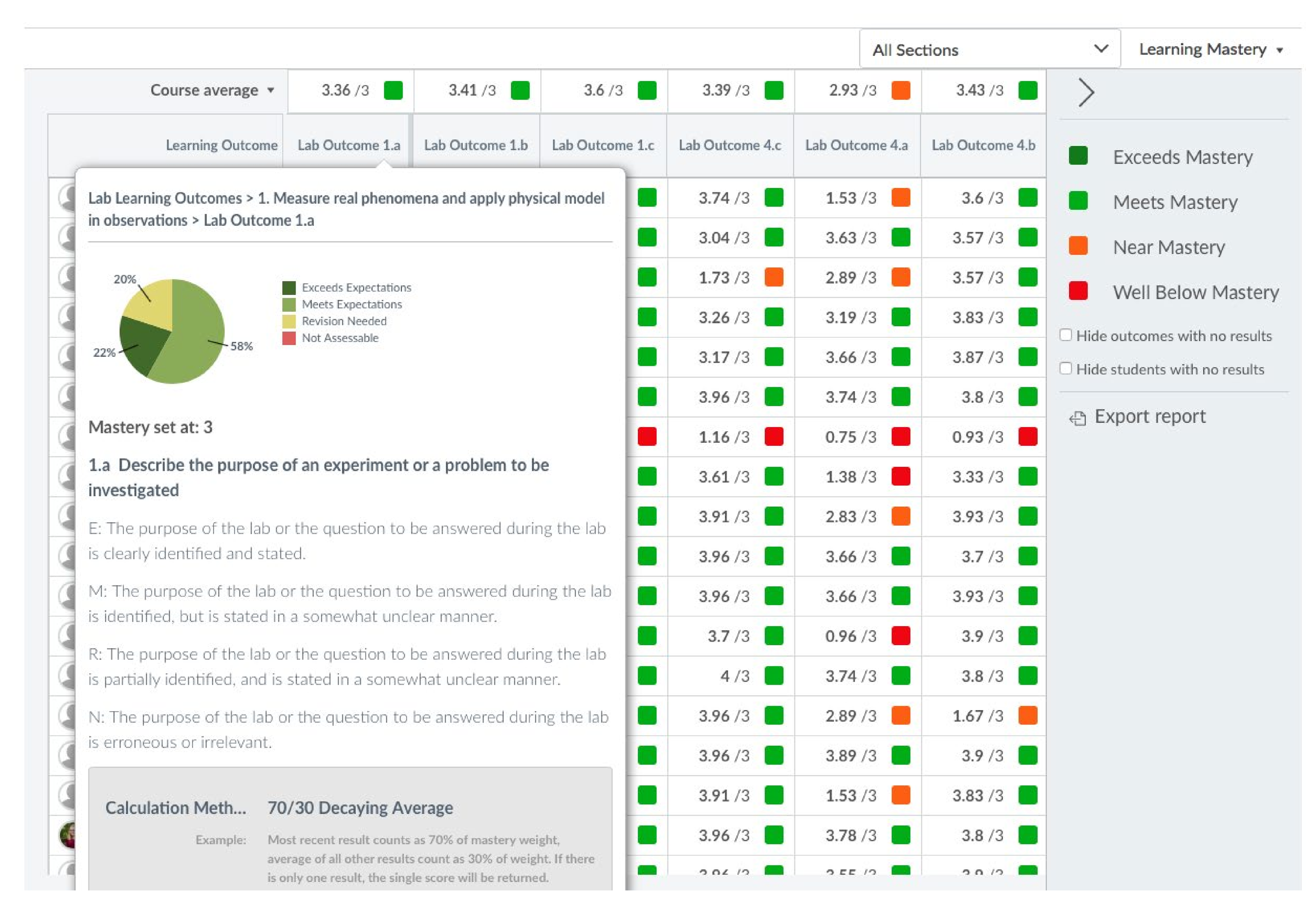

Figure 1 Screenshot of the Learning Mastery Gradebook on Canvas in SBG section in the middle of a semester.

Results

- The learning gain measures the percentage of responses that start off wrong in pre-test (WR and WW) turn to the right answer in post-test (WR). MUQ assessment in Figure 2 shows that the learning gain is 53% and 45% in SBG section and traditional section, respectively.

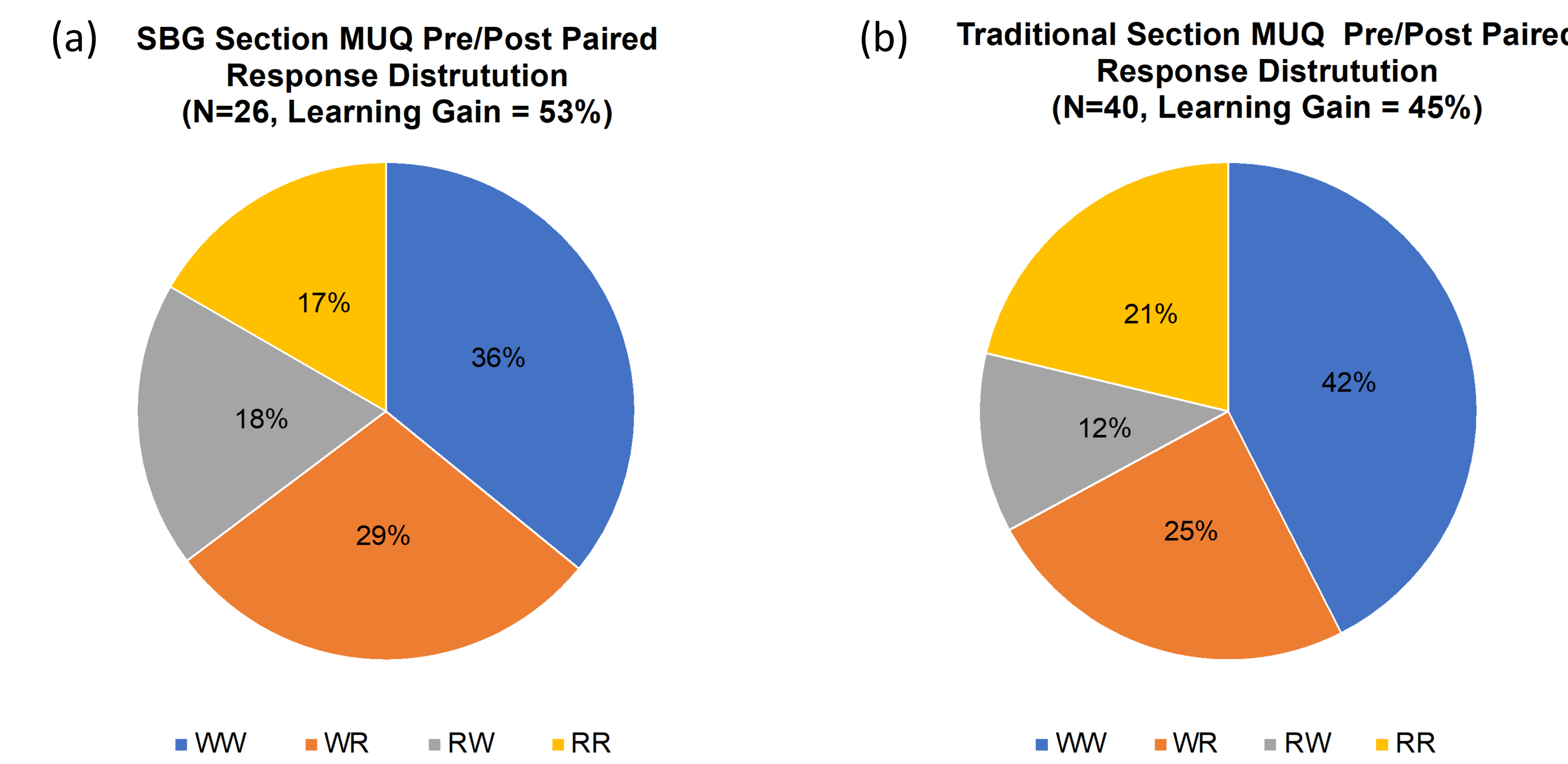

Figure 2 Percentage distribution of the four possible transitions (WW=wrong in pre-test and post-test, WR= wrong in pre-test, right in post-test, RW, and RR) of answers between the pre-test and post-test groups in the SBG Section (a) and the Traditional Section (b). N is the number of paired tests.

- As shown in Figure 3, the SBG section had an average expert-like fraction of 0.65±0.05 and 0.66±0.05 in pre-instruction survey and post-instruction survey, respectively. The traditional section had an average expert-like fraction of 0.59±0.04 and 0.53±0.04 in pre-instruction survey and post-instruction survey, respectively.

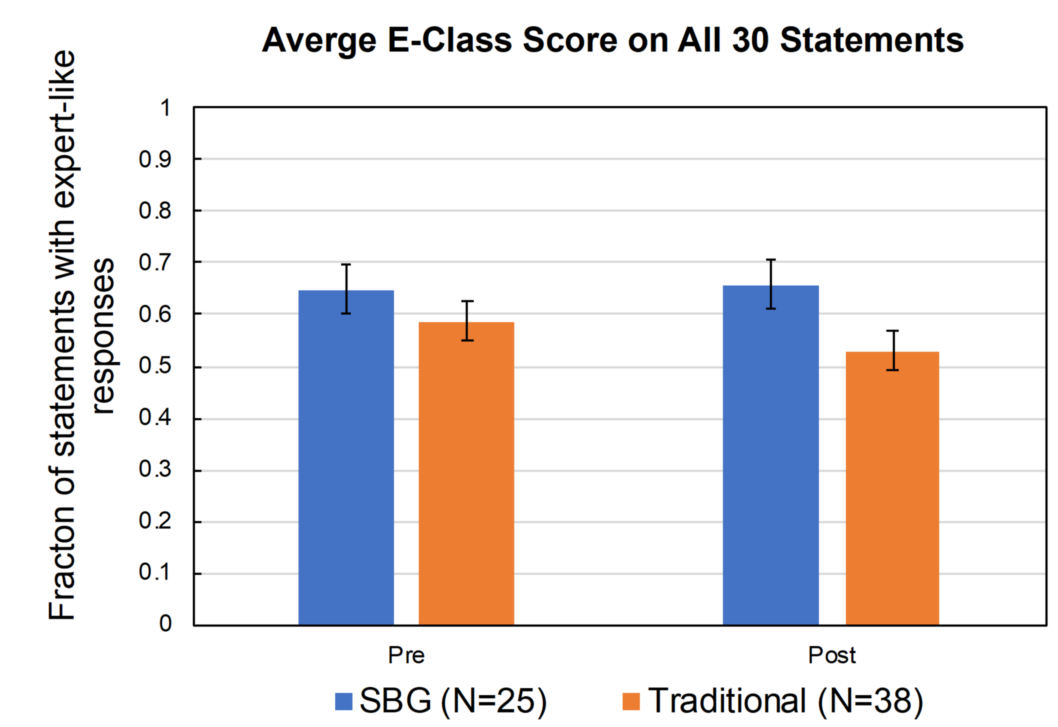

Figure 3 Comparison between the SBG section and the traditional section in pre and post E-Class scores.

Conclusions and Future Work

- Preliminary results indicate that standard based grading (SBG) has a positive impact to student learning in introductory physics lab. Compared to traditional grading methods, it helps students in developing skills that relate to threshold concepts such as measurement uncertainty. It also does a better job at maintaining students' attitudes in doing experiments in an expert-like manner.
- The study assumes that student population are of random nature in each section and the data presented here is only from one semester. More data collection is needed to generalize the conclusion to introductory lab courses.

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