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Standards-based Grading: An Alternative to Score-based Assessment

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Standards-based Grading: An Alternative to Score-based Assessment

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Abstract

Standards-based grading involves assessment of student development towards achieving the course objectives throughout the duration of a course. Final course grades are then determined based on students' overall development towards achieving the course objectives. There have been no studies to date that investigate this specific system for undergraduate science, technology, engineering and mathematics (STEM) education. This groundbreaking study involves the implementation of standards-based grading in a sophomore-level undergraduate course in Mechanics of Materials. The goals of this study are: 1) to obtain insight in how to best implement standards-based grading in an undergraduate STEM course, and 2) to obtain a sense of how students respond to standards-based grading. Students (N=30) were asked two questions at the end of the course: 1) if the standards-based grading system is more conducive to learning than the traditional, summative score-based grading system, and 2) if they prefer standards-based grading to the traditional grading system. The preliminary results suggest that the vast majority of the students, at a minimum, agree that standards-based grading is more conducive to learning (89.3%) and that they prefer standards-based grading (85.7%). Student comments also support the quantitive results. In addition, this study provides significant insight regarding implementation of standards-based grading for undergraduate courses in STEM.

Introduction

Course grading systems have been used to determine whether or not students are meeting relevant academic goals within their courses since the late 1700s[1]. Grading systems have since evolved into a measure of how well students can perform on various assignments, rather than an indicator of how students are developing towards achieving the course objectives. Most science, technology, engineering, and mathematics (STEM) educators within higher education use traditional, summative score-based grading, as shown in Table 1. These grading systems rely on assigning scores to multiple student assignments, which are subsequently summed and issued as a final course grade according to a predetermined scale. Course objectives are in essence unconnected with this process and typically not mentioned beyond the course syllabi[2]. This grading approach often inherently fails to meet the conditions for sound assessment of complex student work[2-4]. The resulting final course grades only display how well students perform on completing a number of separate course assignments.

Table 1: Snapshot example of a traditional, summative score-based grade book

Traditional, Summative Score-Based Grade Book						
Student	***Homework Total (%)***	***Quiz Total (%)***	***Midterm Exam (%)***	***Final Exam (%)***	***Total (%)***	***Final Course Grade***
John	70	80	75	83	77	C+
Bill	50	60	90	87	72	C-
Susan	100	95	62	65	81	B-
Felicia	70	90	85	95	85	B
Jane	95	100	90	85	93	A

An alternative approach is to directly measure the quality of students' proficiency towards achieving well-defined course objectives through standards-based grading. Standards-based grading was first developed during the 1990s when all US states reformed public K-12 education by setting academic standards for what students should know and be able to do[5-6]. Standards-based grading utilizes a standards achievement report, shown in Table 2, to provide meaningful feedback regarding student learning. Student progress towards achieving the course objectives is tracked throughout the duration of a course rather than assigning one-time individual scores to student work. Final course grades are then determined based on progress towards achieving the course objectives.

Table 2: Snapshot example of a standards-achievement for a course in Mechanics of Materials

Standards Achievement Report					
Development Towards Achieving the Course Objectives	***John***	***Bill***	***Susan***	***Felicia***	***Jane***
1A: Analyzing the normal stress, strains, and deformations of a body composed of elements	+	*N*	✓	✓	+
1B: Understanding the elastic properties, stress limits, and stress-strain responses of materials	✓	✓-	✓	✓	+
1C: Analyzing shear stresses and strains of a body composed of elements	✓	*N*	✓-	✓	✓
Final Course Grade	A-	F	B-	B	A
Progress Level: + *Strong performance* ✓ *Appropriate development* ✓- *Approaching appropriate development* *N* *Needs practice and further support*					

When educators directly assess student proficiency towards achieving course objectives, they gain the advantages listed in Figure 1. The benefits of standards-based grading stem from clear, meaningful, and personalized feedback provided to students regarding their proficiency towards achieving specific course objectives. Judgments are made about the quality of student work in regards to well-defined course objectives that students are made aware of at the beginning of a course[2]. This provides fairness and transparency by grading each student on the basis of the quality of their current work alone regardless of how other students in the course perform or the student's previous level of performance[2]. It promotes the encouragement of student learning and continuous improvement by directly placing the responsibility for learning on the students themselves[5]. It can also provide feedback for maintaining academic rigor and for assessing with great precision courses, curricula, and institutional programs.

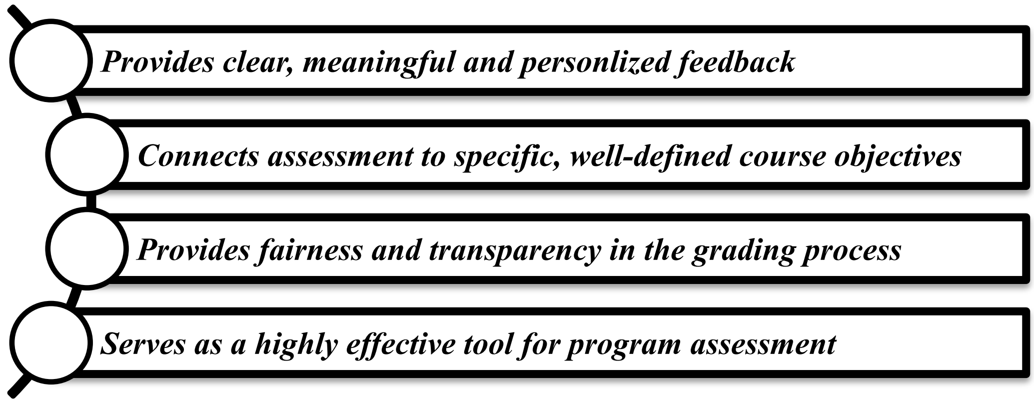

Figure 1: Some of the observed benefits of standards-based grading

The reported benefits of standards-based grading in K-12 learning environments provide a foundation for our investigation of the impact it can have on undergraduate STEM education. Although standards-based grading has gained popularity at the K-12 level, there have been no studies to date that analyze the implementation of this specific system for undergraduate STEM education. A pilot study was conducted in a sophomore-level course in Mechanics of Materials during the spring semester of 2011. The standards-based grading system was first implemented halfway through the semester. The goals of this study were: 1) to obtain insight in how to best implement standards-based grading in an undergraduate STEM course, and 2) to obtain a sense of how students would respond to standards-based grading.

Development and Implementation of the Standards-Based Grading System

1. Establish Well-Defined Course Objectives

Four major steps were taken to develop and implement the standards-based grading system. The first step was to establish well-defined course objectives and list them on the course syllabus. These course objectives are somewhat general in scope and limited to approximately three or four to maintain simplicity. For this course in Mechanics of Materials, the established course objectives are listed in Figure 2. These established course objectives provided the basis for the entire course and for developing and implementing the standards-based grading system.

Course Objectives
Upon successful completion of this course, students will be able to demonstrate proficiency in:

1. *Understanding the effects of forces and deformations within an elastic body.*
2. *Analyzing the three fundamental patterns of deformation: axial, torsion, and bending.*
3. *Determining deflection and the tendency for failure when multiple patterns of deformation occur in combination.*

More specific descriptions of the course objectives are provided on the course Standards Achievement Report.

Figure 2: Established course objectives for a course in Mechanics of Materials

2. Develop a Complete Standards Achievement Report

The second step is to develop a complete standards achievement report and to share it with the students at the beginning of the course. The standards achievement report replaces the traditional grade book and is used to keep track of student development towards achieving the courses objectives. It is also used as a means to provide direct feedback to the students regarding their progress and learning. The standards achievement report used for this course is shown in Figure 3. This was shared with the students on the course syllabus at the beginning of the class. As a result, the students were aware of exactly what skills and knowledge they needed to develop throughout the course. A spreadsheet was generated and a column was created for each student who was registered for the course. Assessment of student work was conducted weekly using a confidential, up to date standards achievement report.

3. Establish a Clear Course Grading Policy

The course grading policy describes how final course grades are issued to the students. Final course grades depend on the overall development of the students towards achieving the course objectives listed on the standards achievement report. The grading policy as described on the syllabus for this course is shown in Figure 4.

Standards Achievement Report

Development Towards Achieving the Course Objectives	***Student***
1. Understanding the effects of forces and deformations within an elastic body	
1A. Analyzing normal stresses, strains, and deformations of a body composed of elements	
1B. Understanding the elastic properties, stress limits, and stress-strain responses of materials	
1C. Analyzing shear stresses and strains of a body composed of elements	
1D. Analyzing shear and bearing stresses in pin joints	
2. Analyzing the three fundamental patterns of deformation: axial, torsion, and bending	
2A. Analyzing stresses, strains, and deformations of members subjected to axial forces	
2B. Analyzing stresses, strains, and deformations of members subjected to torsion	
2C. Analyzing stresses, strains, and deformations of members subjected to bending	
3. Determining deflection and the tendency for failure when multiple patterns of deformation occur in combination	
3A. Determining internal stresses, strains, and deflections for combinations of deformation patterns	
3B. Understanding stress transformations, maximum and minimum stress values, and Mohr's circle	
3C. Applying failure criteria to design members against material failure	
3D. Understanding the influence of geometric stress concentrations	
3E. Analyzing buckling of axially loaded members and designing for axial compression	

Progress Level	
+	*Strong development*
✓	*Appropriate development*
✓-	*Approaching appropriate development*
N	*Needs practice and further development*

Figure 3: Detailed standards achievement report for a course in Mechanics of Materials

Grading Policy

Your grade in this course will be determined using standards-based grading. This involves directly assessing your development towards achieving the course objectives and tabulating the results in the standards achievement report. Assessments will be conducted using homework and examinations. Confidential standards achievement reports will be provided to you throughout the semester as a means to provide feedback regarding your development towards achieving the course objectives. Your final grade in the course will be determined according to the table below. Note that course grades of A, B, and C may be modified by a plus (+) *or minus* (–) *suffix if appropriate.*

Final Course Grade	***Development Towards Achieving the Course Objectives***
A	*The student has demonstrated appropriate development on all course objectives and strong development on some objectives.*
B	*The student has demonstrated appropriate development on all course objectives.*
C	*The student has demonstrated appropriate development on the majority of the course objectives.*
F	*The student has failed to demonstrate appropriate development on one-half of the course objectives.*

Figure 4: Established grading policy for a course in Mechanics of Materials

4. Establish Clear Assessment Rubrics and Guidelines

Assessment rubrics and guidelines inform the students of development expectations and describe how their work will be assessed. The assessment rubrics and guidelines as described on the syllabus for this course are shown in Figure 5.

Assessment Rubrics and Guidelines

Assessment of all student work will be based on the scale and rubrics presented in the table below. A list of guidelines regarding the assessment of student work is also provided.

Level	***Development Towards Achieving the Course Objectives***
+	*Strong development. In addition to exhibiting appropriate development, demonstration of in-depth inferences and proficiency with applications that go beyond what was taught in class.*
✓	*Appropriate development. No major errors or omissions regarding any of the information and/or processes (simple or complex) that were explicitly taught. Work is presented in a clear, organized and professional manner.*
✓-	*Approaching appropriate development. No major errors or omissions regarding the simpler details and processes, but major errors or omissions regarding more complex ideas and processes.*
N	*Needs practice and further development. A partial knowledge of some of the simpler and complex details and processes.*

1. All homework and examination problems must be completed individually.
2. Students can reach a maximum level of appropriate development (✓) for course objectives through consistent, multiple evaluations of homework problems at that level. Students can request a reevaluation of course objectives by turning in additional, unassigned homework problems.
3. Students can reach a level of strong development (+) for course objectives by performing at that level during the examinations.

Figure 5: Established assessment rubrics and guidelines for a course in Mechanics of Materials

Student Responses to Standards-Based Grading

Students were anonymously asked two questions at the end of the course: 1) if the standards-based grading system was more conducive to learning than traditional, summative score-based grading, and 2) if the students preferred standards-based grading to traditional grading. A response rate of 93% (N=30) was obtained for these two questions. The results shown in Figure 6 conclude that the vast majority of the students, at a minimum, agreed that standards-based grading was more conducive to learning (89.3%) and that they preferred standards-based grading (85.7%). Most students who were uncertain indicated that the reason for their uncertainty was because standards-based grading was only implemented for half of the semester.

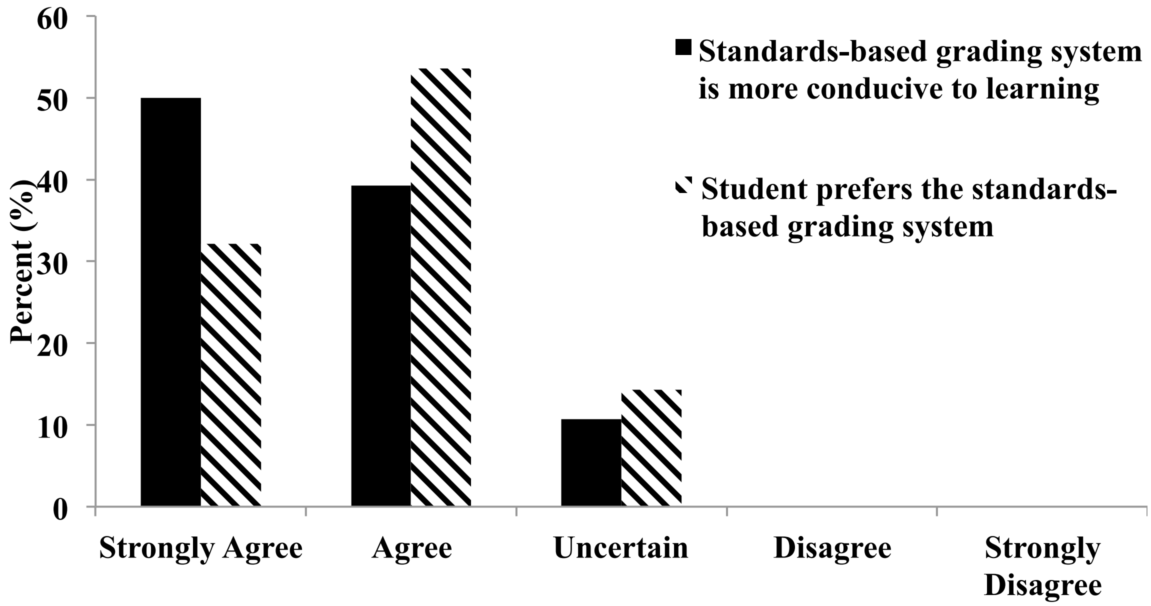

Figure 6: Student survey responses of standards-based grading for a course in Mechanics of Materials

The authors recognize a slight bias in the questions asked; however, the majority of written comments coupled to the quantitative results support the findings. The following are examples of typical responses from the mechanical engineering sophomore students:

> *"Standards-based grading allowed me to focus more on my skills in class rather than try to get through assignment after assignment."*

> *"The new standards-based grading gives more clean and concreate objectives to achive."*

> *"There is less pressure on worrying about my grade 24/7."*

> *"I feel that the standards-based grading system made us focus more on the work that we did rather than having an extremely long assignment and just trying to get it done."*

> "*The amount of feedback we receive and the ability to redo problems increases our ability to learn.*"

> *"The chance to redo work allows for better understanding."*

> *"I believe the standards-based scale is more effective because not all of us are good test takers, and the standards-based scale accounts for that."*

> *"It eliminates the stress of tests and allows the student to show their abilities."*

> *"Standards-based grading forced me to atually understand the material."*

"*Standards-based grading is much better because it allows teachers to focus more on helping students learn and understand the material rather than simply viewing students as a number in a grade book*."

"Standards-based grading emphasizes learning and applying concepts."

Lessons Learned: Modifications to the Standards-Based Grading System

Some significant implementation lessons were learned through this first pilot study. Additional feedback was obtained from the students through informal discussions throughout the semester. In particular, two major changes were made to the standards-based grading system for the Spring 2012 implementation of the Mechanics of Materials course.

First, the standards achievement report was modified to keep track of the students' development throughout the duration of the course. The standards achievement report shown in Figure 3 does not directly allow for tracking of changes in student development as it presents more of a snapshot view for a particular time. Although multiple versions of the standards achievement report were saved in order to view student progress over time, it was somewhat difficult to work with this setup from an educator's perspective. It was determined that the standards achievement report needs a third dimension for tracking development changes over time. Therefore, the standards achievement report was modified to represent the development of only one student, rather than all students, as shown in Figure 7. A spreadsheet file was created with one workbook for each student that will be utilized during the spring semester of 2012. This will allow the educator to view students' development towards achieving the course objectives throughout the duration of the course. This will also provide an added level of feedback to the students.

Secondly, numerical values were assigned to the levels of development towards achieving the course objectives. This was done mainly to increase the clarity in assigning final course grades. Although the grading policy shown in Figure 4 indicates that a student must receive marks at a level of at least appropriate development (✓) for all course objectives to receive a "B", it was determined that this grading policy was somewhat unfair. What grade would a student receive if they had ✓'s for all objectives, but had a ✓- for one objective? Would they receive a "B–", a "C+" or a "C"? What if they had ✓'s for all objectives, but had an *N* for one objective?

In order to provide increased clarity regarding the issuing of final course grades, a modified standards achievement report was created, which includes a row that is used to show the students' overall average development toward achieving the course objectives, as shown in Fig. 7. Numerical values of *4*, *3*, *2*, and *1* were used to replace the +, ✓, ✓-, and *N* development levels, respectively. A numerical value will now be assigned to a student for their development towards the appropriate course objectives involved with each particular assignment, i.e. weekly quizzes or a final examination. These numerical values will then be averaged for each column of student work to produce an instantaneous course grade using the grading scale shown in Figure 8. The modified assessment rubrics and guidelines are presented in Figure 9.

Utilizing an average numerical value to represent the students' overall development towards achieving the course objectives will provide an increased level of fairness, but will also allow some flexibility when issuing grades to students who are borderline between two grades.

Conclusions

A pilot study implementing standards-based grading was conducted in a sophomore-level course in Mechanics of Materials. The goals of this study are: 1) to obtain insight in how to best implement standards-based grading in an undergraduate STEM course, and 2) to obtain a sense of how students respond to standards-based grading. The results suggest that the vast majority of the students, at a minimum, agree that standards-based grading is more conducive to learning (89.3%) and that they prefer standards-based grading (85.7%). Student comments also support the quantitive results. Based on the results, the standards-based grading system was modified to be able to track students' development throughout the duration of a course and to utilize numerical values to represent their level of development towards achiveing the course objectives.

Standards Achievement Report

Name:
UID:
Date:

Student Work	
Q	*Weekly quiz*
FE	*Final examination*

Development Towards Achieving the Course Objectives	***Q1***	***Q2***	***Q3***	***Q4***	***Q5***	***Q6***	***Q7***	***Q8***	***Q9***	***Q10***	***Q11***	***Q12***	***Q13***	***Q14***	***FE***
1. Understanding the effects of forces and deformations within an elastic body															
1A. Analyzing normal stresses, strains and deformations of a body composed of elements															
1B. Understanding the elastic properties, stress limits and stress-strain responses of materials															
1C. Analyzing shear stresses and strains of a body composed of elements															
1D. Analyzing shear and bearing stresses in pin joints															
2. Analyzing the three fundamental patterns of deformation: axial, torsion, and bending															
2A. Analyzing stresses, strains and deformations of members subjected to axial forces															
2B. Analyzing stresses, strains and deformations of members subjected to torsion															
2C. Analyzing stresses, strains and deformations of members subjected to bending															
3. Determining deflection and the tendency for failure when multiple patterns of deformation occur in combination															
3A. Determining internal stresses, strains, and deflections for combinations of deformation patterns															
3B. Understanding stress transformations, maximum and minimum stress values, and Mohr's circle															
3C. Applying failure criteria to design members against material failure															
3D. Understanding the influence of geometric stress concentrations															
3E. Analyzing buckling of axially loaded members and designing for axial compression															

Overall Average Development Towards Achieving the Course Objectives															
Course Grade															

Notes

Progress Level	
4	*Strong development*
3	*Appropriate development*
2	*Approaching appropriate development*
1	*Needs practice and further development*

Figure 7: Modified standards achievement report for a course in Mechanics of Materials during the spring semester of 2012

Grading Policy

Your grade in this course will be determined using standards-based grading. This involves directly assessing your development towards achieving the course objectives and tabulating the results in the *Standards Achievement Report*. Assessments will be conducted using weekly quizzes and a final examination. Suggested homework problems will be provided and can be assessed by the TA if you want. Two confidential *Standards Achievement Reports* will be provided to you throughout the semester as a means to provide feedback regarding your development towards achieving the course objectives. One will be provided midway through the semester and the other will be provided towards the end of the semester. It is highly suggested that you maintain an updated *Standards Achievement Report* for your records. Your final grade in the course will be determined according to the table below. Note that course grades of *A*, *B,* and *C* may be modified by a plus (+) or minus (–) suffix if appropriate.

Final Course Grade	***Overall Average Development Towards Achieving the Course Objectives***
A	*3.7 – 4.0*
B	*3.0 – 3.6*
C	*2.0 – 2.9*
F	*1.0 – 1.9*

Figure 8: Modified grading policy for a course in Mechanics of Materials during the spring semester of 2012

Assessment Rubrics and Guidelines

Assessment of all student work will be based on the scale and rubrics presented in the table below. A list of guidelines regarding the assessment of student work is also provided.

Level	***Development Towards Achieving the Course Objectives***
4	*Strong development. In addition to exhibiting level 3 development, demonstration of in-depth inferences and proficiency with applications that go beyond what was taught in class.*
3	*Appropriate development. No major errors or omissions regarding any of the information and/or processes (simple or complex) that were explicitly taught. Work is presented in a clear, organized and professional manner.*
2	*Approaching appropriate development. No major errors or omissions regarding the simpler details and processes, but major errors or omissions regarding more complex ideas and processes.*
1	*Needs practice and further development. A partial knowledge of some of the simpler and complex details and processes.*

1. Weekly quizzes will be open book, but closed notes. Each quiz will typically involve a level *3* problem and a level *4* problem. Weekly quizzes will be partially cumulative and students will be continually assessed on the course objectives that have already been covered in class. Students are required to complete all weekly quizzes and must notify me ahead of time if you will miss a quiz. There will be a required quiz during the final examination.
2. The final examination will be open book, but closed notes. The final examination will be cumulative. Completion of the final examination is optional, but it gives you one last opportunity to demonstrate your development towards achieving the course objectives.
3. Assessment of your development towards achieving the course objectives can only go up a maximum level of *1* at any time according to your most recent work.

Figure 9: Modified assessment rubrics and guidelines for a course in Mechanics of Materials during the spring semester of 2012

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