

Using Standards-based Grading to Effectively Assess Project-based Design Courses

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Abstract

Standards-based grading (SBG) is an alternative to traditional score-based grading systems that allows an instructor to provide assessment linked to course objectives. SBG ties assessment throughout a course with these objectives, while also providing clear, meaningful feedback, fairness and transparency in the grading process, and useful program assessment. Project-based design courses align well with SBG because their nature demands repeat assessment of fundamental learning objectives. The following study investigated the use of SBG in two cornerstone design courses with similar learning objectives at different ABET accredited engineering programs. Overall, students reported that the standards based grading system has higher value (2.94 ± 0.87) than cost (2.03 ± 0.78) on a 4-point scale ($p < 0.001$). Students at the small, liberal arts college responded with generally higher ratings for both value and cost, with a larger average difference between combined value and cost (1.0 and 0.81, respectively), than students at a large, public university. Additionally, students reported higher self-efficacy in design-based objectives after the course, with an average self-efficacy increase of 15-20 points on a 100-point scale.

Introduction

Standards-based grading (SBG) is an alternative grading system that involves and depends on directly measuring the quality of students' proficiency on well-defined course learning outcomes, i.e., standards.¹⁻³ Student development toward achieving the course learning outcomes is tracked and monitored throughout the duration of a course using a Standards Achievement Report (SAR), shown in Appendix A. This report is used to provide a proficiency score and complementary feedback throughout the semester regarding the individual's learning and development. Rubrics are employed as a guideline for the instructor to assess student development toward achieving course learning outcomes relevant to particular student work. Student final course grades (i.e., A, B, C, etc.) are then determined based on their progress towards achieving the course learning outcomes according to an established grading policy (see Appendix A). This approach varies from the traditional approach of simply assigning scores to individual student assignments without providing connections to previous or future work, or directly to learning outcomes. Monitoring proficiency toward each standard allows for a richer assessment and reflection of student achievement.

Various educational benefits from SBG arise as a result of the personalized, clear, and meaningful feedback provided to students regarding their learning and development. Assessments are made about the quality of student work based on specific objectives that students are made aware of at the beginning of a course.¹ This provides fairness and transparency by grading each individual student based on the quality of their current work alone, regardless of how other students in the course perform or on the student's previous levels of development.¹ This in turn promotes the encouragement of student learning and continuous improvement by placing responsibility for learning on the students themselves.⁴ Standards-based grading also provides data for maintaining academic rigor and for assessing courses, curricula, and entire

institutional programs with great precision. Previous research has shown that transitioning to standards-based grading in engineering education provides the same benefits that have been documented in K-12 settings.^{5,6} However, previous use of SBG in engineering courses has proven to be taxing on the instructor except for instances when students practice what they learn. Application driven project-based design courses align well with SBG because their nature demands repeat assessment of fundamental learning objectives.

Methods

Sample

The SBG approach was implemented in project-based design courses at two institutions with ABET accredited engineering programs. These courses were taught at institutions with very different Carnegie classifications: a small, private, regional liberal arts college (Elizabethtown College) and a large, public, state research university (Arizona State University). While the courses differ in structure, they are comparable in that both were designed with the same purpose to provide students with opportunities to practice and apply the engineering design process.

Small, Private, Regional Liberal Arts College (Elizabethtown College): The first course was a 4-credit, 2-semester introduction to engineering for first-year students at a small, private liberal arts college. The institution has fewer than 2,000 students, with approximately 140 students in the engineering program. The institution offers ABET accredited degrees in computer engineering and in general engineering with concentrations in mechanical engineering, electrical engineering, and sustainable design, along with a non-accredited degree in industrial engineering management. All incoming students in all engineering degree programs are enrolled in the two-semester design sequence. There are no additional admissions criteria for engineering students, and historically 56% of incoming freshmen with an intended engineering major graduate with an engineering degree. The program is growing substantially, with approximately 35 incoming students in 2008, 45 incoming in 2012, and 68 incoming in 2013.

In the 2012-2013 offering of the courses comprised of two sections of a 2-hour weekly lecture, and three sections of a 2-hour weekly skills lab. Both semesters and all sections were taught by the same instructor to ensure consistent SBG implementation. Of the students that gave informed consent, 34 men and 10 women started the course in the fall, and 28 men and 7 women finished the sequence in the spring (N=35, 80% retention rate, 100% response rate of those remaining).

Large, Public, State Research University (Arizona State University): The second course was a 1 semester, engineering project-based design course for second-year students at a large, public university. The course is the third of a series of 8 design-based project courses, i.e. the “project spine”, required for completion of the engineering degree. The institution is the largest in the United States boasting over 69,000 students and two engineering programs on different campuses. The engineering program of interest for this study currently enrolls approximately 1100 students. The program offers an ABET accredited degree in general engineering with concentrations in mechanical systems, electrical systems, environmental/civil systems, robotics, and automotive as well as a non-accredited degree in manufacturing engineering. Program

growth has been substantial since its inception in 2005, starting with 28 students and now enrolling 497 students in Fall 2013 (21st Day Head Count of Engineering Majors).

The Fall 2011 course consisted of two sections of 39 and 40 students, respectively; 60 of the 79 students participated in the study (response rate of 76%). Only 6 of the total 60 students to complete the informed consent were women. Students in the course attended class twice a week for 90 minutes. Both sections of the course were co-taught by the same team of instructors.

Data Collection and Analysis

Students at both institutions were surveyed regarding perceived value and engineering design self-efficacy (see Appendix B). A post-analysis assessment of value was given to students completing the courses to analyze perceptions of the standards-based grading system. Questions were asked relating to value categories of intrinsic (interest, enjoyment), attainment (contribution to self), utility (advantages toward personal goals), and cost (sacrifices required). Self-efficacy and changes in self-efficacy in relevant design skills were also assessed using pre and post-analysis.⁷ Surveys were administered either using an online surveying tool or pencil and paper. Data were then entered into and analyzed using Excel.

Results and Discussion

Value

Overall, students reported that the standards based grading system has higher value (2.94 ± 0.87) than cost (2.03 ± 0.78) on a 4-point scale ($p < 0.001$) (Figure 1).

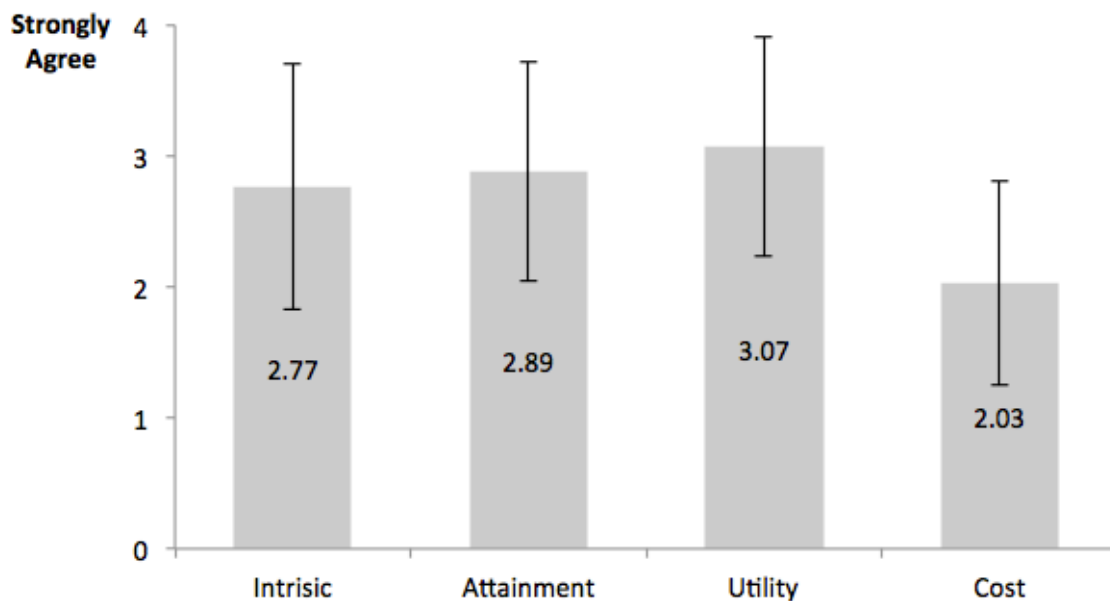


Figure 1. Average overall student scores (N = 95) for the four major areas of value for the standards-based grading implementation.

At both institutions, students were more focused on utility value than intrinsic or attainment value (Figures 2 and 3). Students at the small liberal arts college also gave generally higher ratings to both value and cost, with a larger average difference between combined value and cost (1.0 and 0.81, respectively). At both institutions, students rated combined value of the SBG system statistically higher than cost at a significance of $p < 0.001$.

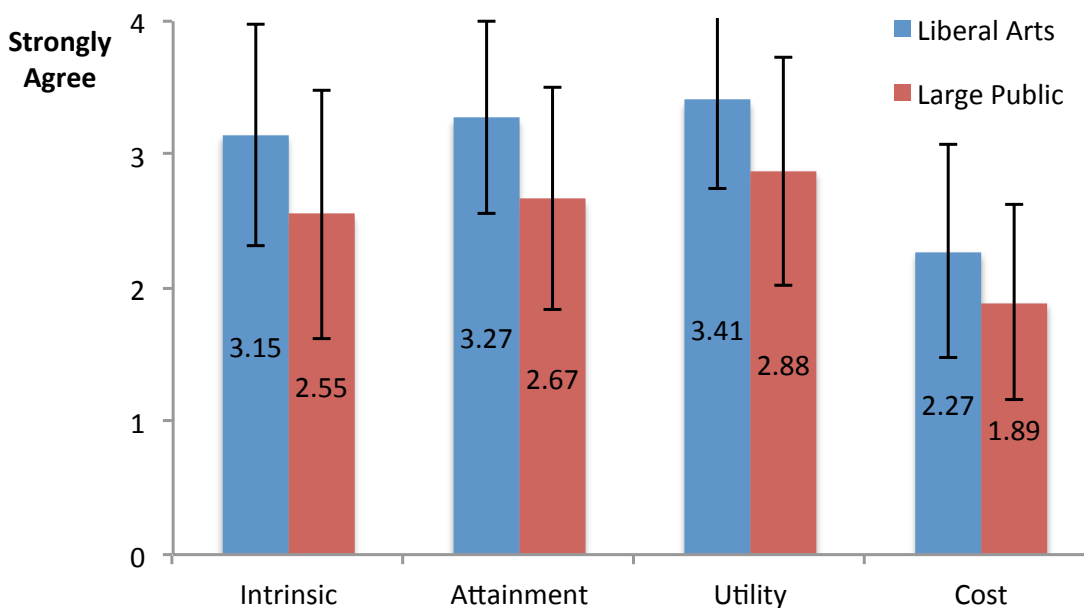


Figure 2. Average student scores for the four major areas of value from the liberal arts college students (N= 35) and the large public university students (N = 60). The liberal arts college students scored both value and cost higher, but for all students the value outweighed the cost ($p < 0.001$).

Written comments, included as part of the surveys, strongly supported standards based grading. Major themes that emerged from the comments were that the grading system was rigorous and helped students improve, and that the grading system fit project-based courses. For example, students said:

“The grading system worked very well in helping me achieve goals and helped me see what I was doing wrong and what I needed to work on.” (liberal arts)

“The grading system made me work harder as a student.” (liberal arts)

“Clear and to the point of what’s an A and what’s not. Made me want to be better each assignment.” (liberal arts)

“The grading system in this course, while very rigorous, is extremely effective in evaluating my understanding of the course material.” (liberal arts)

"I thought the grading system was fair and gave a good feeling for where I was at with concepts we were taught." (liberal arts)

"I feel that engineering abilities are hard to measure, but this course did a good job of doing so for the most part." (liberal arts)

"Since everything was hands on and team oriented, this grading system broke everything up so we could tell where we needed to improve."

"This system is as excellent as a grading system can be because it does more than just assign a letter help correct the misunderstanding." (liberal arts)

"The grading system fit the class perfectly." (liberal arts)

"The grading system used worked very well for this course." (liberal arts)

"Enjoy the grading system, provides in depth feedback." (large public)

"My primary benefit from standards-based grading was the clear statement and emphasis on learning outcomes. The direct correlation between grading and objectives forced me to pay attention to what I should be taking away from the course." (large public)

A few negative themes from students elucidated some of the student frustration with the grading system, namely knowing overall grade during the semester and dissatisfaction with the breadth of the 4-point scale. Example statements included:

"Personally, I do not like the 1-4 grading scale. It makes it difficult for students to know their grades or course average during the semester." (liberal arts)

"The grading system works fine for individual assignments but is difficult to figure out how I am doing overall." (liberal arts)

"The grading system was fair, but I found that it grouped the grades too closely together and did not give as much credit for great work." (liberal arts)

"The grading system is nice in the fact that it breaks each assignment into many parts. This way you can see where you lost credit. However, I feel as if the 4-point scale is too broad and not as specific as it should be. I would prefer the same grading method on a 100 point scale." (liberal arts)

"When the grade of a student is ultimately demonstrated by a number, then I see no benefit only confusion to assess grades based on other measures" (large public)

"Tying it back to a standard A-B-C system, broken into many parts and then averages would decrease stress caused by the enigma of the system" (large public)

Differences expressed by the student populations, especially regarding perceived cost, may be due to a lack of instructor familiarity with the grading system at the small liberal arts college. The semester in question was the first implementation of SBG at that institution and with that instructor. However, at the large public university, instructors had implemented SBG for several semesters and developed a mitigation technique. This issue was overcome by adding a class activity in the first week where the students create a personalized scoring spreadsheet on Excel that models the standards-based scoring rubric. Through this simple activity, students are familiarized with the grading system and can easily enter their scores to keep track of their grade throughout the semester. The inclusion of this activity at the large public university likely accounts for the lower cost score and the absence of this theme in the written responses.

Conversely, at the liberal arts institution the instructor often related the assigned score to an A, B, C, D, F scale, so students expressed less confusion about tying it back to a standard system. Students written comments clearly indicate value in the system, but this value is heavily influenced by how quickly students become comfortable with the different system and the instructors implementation of the system. Early use of this new system takes a short period of time to get used to, which may result in the frustrations seen from some students.

Engineering Design Self-Efficacy

Students at both institutions were queried to assess impact of the SBG courses on engineering design self-efficacy. Students reported higher self-efficacy in design-based objectives after the course, with an average self-efficacy increase of approximately 15-20 points on a 100-point scale (Table 1).

Table 1. Average self-efficacy scores in design objectives, at the beginning and end of the courses in which SBG was implemented.

	Liberal Arts College (N = 44 pre, N= 35 post)		State University (N = 60)	
	Pre	Post	Pre	Post
Design Overall	62.3	85.1	71.7	86.1
Conduct engineering design	58.4	84.9	67.6	86.2
Form a problem statement/ Identify a design need	56.4	84.9	70.3	86.5
Formulate product design specifications/ Research a design need	57.2	85.4	70.3	84.1
Develop design solutions	62.5	85.1	71.0	85.7
Select the best possible design	67.0	85.1	74.0	86.5
Evaluate and test a design	62.7	86.6	74.7	88.0
Redesign	63.9	88.0	74.2	87.8
Construct design as specified/ Construct a prototype	69.3	88.0	71.2	86.4
Communicate project outcomes in writing/ Communicate a design	63.4	78.0	71.5	84.0

The liberal arts college students started the design course with a lower overall average self-efficacy in design skills (Liberal Arts = 62.3; State University = 71.7), but also had a larger average increase (Liberal Arts = 22.8; State University = 14.4). It is important to note that the liberal arts college students were first-years, while the state university students were second-years who had prior experience in a design course. Both sets of students ended the semester at approximately 85 out of 100 for overall average design self-efficacy. Differences in wording reflect the different versions of the design process followed at the two institutions.

Conclusions and Implications

These results suggest that standards based grading is a valuable approach to assessment of engineering students in early cornerstone project-based design courses at a range of institution types. Standards-based grading is not difficult to implement in courses that can easily accommodate a set of clearly defined objectives for the entire course. Project-based courses, like the two courses assessed in this study, are clearly great fits for this system. Differences expressed by the student populations, especially regarding perceived cost, may be due to the instructor's lack of familiarity with the grading system. This limitation is decreased over time with practice and mitigation techniques.

The use of standards-based grading for project-based courses can greatly impact the way that such courses are taught and how students view their learning gains. Project-based courses are designed to offer students opportunities to apply what they have learned throughout their engineering education. Allowing students to practice and focus on a clear set of objectives throughout a project course simplifies what they need to focus on to do well in the course. The goal is to eventually encourage students to shift away from focusing on the grade and move toward a goal of learning and improving in each course objective.

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Appendix A. Sample Standards Based Grading Excerpt from Syllabus

GRADING:

Your grade in this course will be determined using standards-based grading. This involves directly evaluating your proficiency in achieving the course objectives and desired student behaviors. Your progress towards achieving these objectives will be tracked on a Standards Achievement Report (SAR); see Example. Evaluations will be conducted throughout the semester using performance and project deliverables. (See Course Schedule for tentative evaluation dates and descriptions of the work or performance to be evaluated). The course is divided into three sections/projects. You will receive a SAR at the end of each section that will show your performance towards achieving the course objectives. Each course section will provide new opportunities to demonstrate continual learning and proficiency toward the same set of course objectives. Your overall proficiency and final course grade will be determined by calculating your weighted average proficiency in each objective, across all sections/projects.

Standards Achievement Report (John Smith, 02/15/2014)					
Project 1: Product Dissection Activity	DB	M	TEC	C	PB
1: Design description	2	-	-	-	3
2: CAD model and 2D print	-	2	-	-	2
3: Mechanism model and calculations	-	3	2	-	3
4: Project report	-	-	3	3	2
Learning Outcome Scores	2.0	2.5	2.5	3	2.5
Project Score	2.4				
Project Grade	A				
Progress Level: 3 – Distinguished, demonstrates above average development 2 – Proficient, approaching appropriate development 1 – Novice, needs practice and further development 0 – Not assessed					
Learning Outcomes: DB – Design and build products using a use-inspired design process M – Utilize various forms of modeling C – Communicate and document learning TEC – Test, evaluate, and compare predicted and acquired measurements PB – demonstrate professional behaviors (teamwork, punctuality, and organization)					
Outcome Weighting: DB – 25%; M – 25%; TEC – 20%; C – 15%; PB – 15%					

Course Grade	Overall Progress
A+	2.80 – 3.00
A	2.40 – 2.79
A-	2.00 – 2.39
B+	1.70 – 1.99
B	1.40 – 1.69
B-	1.00 – 1.39
C+	0.70 – 0.99
C	0.40 – 0.69
D	0.20 – 0.39
F	< 0.19

Appendix B. Pre/post Survey

1. SELF-EFFICACY (DEGREE OF CONFIDENCE)

DIRECTIONS: Rate your current degree of confidence (i.e. belief in your current ability) to perform the following tasks by marking a number from 0 (cannot do at all) to 100 (highly certain can do).

	0	10	20	...	80	90	100
<i>1. conduct engineering design</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>2. form a problem statement</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>3. formulate product design specifications</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>4. develop design solutions</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>5. select the best possible design</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>6. communicate a design through sketching</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>7. communicate a design through CAD software</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>8. evaluate and test a design</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>9. redesign</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>10. construct design as specified</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>11. use project management techniques</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>12. work effectively in a team</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>13. communicate project outcomes in writing</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>14. communicate project outcomes orally</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>15. use time management to get school work done</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>16. study effectively to get the grades I want</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>17. describe working in the branch of engineering in which I'm interested</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. STUDENT VALUE OF THE GRADING SYSTEM

DIRECTIONS: Please read each of the following statements and indicate your level of agreement (A: completely agree, B: somewhat agree, C: somewhat disagree, D: completely disagree) based on your class experience.

THE GRADING SYSTEM USED IN THIS COURSE...	LEVEL OF AGREEMENT
<i>1. made the course objectives relevant.</i>	
<i>2. motivated me to do well in the course.</i>	
<i>3. will help me towards reaching my future career goals.</i>	
<i>4. was an effective way to assess my learning.</i>	
<i>5. required too much effort.</i>	
<i>6. was useful in my pursuit of other goals.</i>	
<i>7. made me frustrated and anxious.</i>	
<i>8. required too much time.</i>	
<i>9. helped me better understand my learning.</i>	
<i>10. increased my level of responsibility for my own learning.</i>	
<i>11. represented how the real world assesses success and failure.</i>	
<i>12. limited my ability to be successful in the course.</i>	
<i>13. accurately measured the understanding I gained on the course material.</i>	
<i>14. will help me towards reaching my future goals as a student.</i>	

Please take a minute to write down your general thoughts below about your overall experience with the grading system used in this course.