10-1-2012

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Recommended Citation

Carberry AR, Siniawski MT, Dionisio JDN. "Standards-based grading: Preliminary studies to quantify changes in student affective and cognitive behaviors." In *Proceedings of IEEE Frontiers in Education (FIE) 2012*; Seattle, Washington, October 3–6, 2012.

Standards-Based Grading:

Preliminary Studies to Quantify Changes in Affective and Cognitive Student Behaviors

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***Abstract*—Assessing student learning is a key component to education. Most institutions assess learning using a score-based grading system. Such systems use multiple individual assignment scores to produce a cumulative final course grade, which may or may not represent what a student has learned. Standards-based grading offers an alternative that addresses the need to directly assess how well students are developing toward meeting the course objectives. The course objectives are the focal point of the grading system, allowing the instructor to assess students on clearly defined objectives throughout the course. The system assesses how well students become proficient in the course objectives over the duration of the course. This study extends the use of standards-based grading at the K-12 level into the realm of undergraduate science, technology, engineering, and mathematics (STEM) education. Five STEM courses pilot tested the integration of a standards-based grading system to investigate how it impacts affective and cognitive student behaviors. The results suggest that a standards-based grading system increased student domain-specific self-efficacy, was perceived as valuable, and helped students develop more sophisticated beliefs about STEM knowledge.**

Keywords – standards-based grading, assessment, student behaviors

I. INTRODUCTION

The traditional system to assess student performance in science, technology, engineering and mathematics (STEM) at the higher education level is a summative score-based grading system. Summative grading provides students and teachers alike with a cumulative score on a series of independent measures (e.g., homework, quizzes, and exams). While this assessment does provide a score associated with student performance, the system does not directly assess student development towards achieving the overall course objectives. The summative assessment instead minimizes what was intended to be measured, true student learning.

Standards-based grading is an alternative approach to assessment of student performance and learning. The system involves the direct measurement of student development towards achieving specific, clearly defined course objectives. Student development is tracked throughout the duration of a course using a standards achievement report rather than one-time individually scored assignments. Final course grades are then determined based on students' overall development toward achieving the course objectives, rather than being based on how well the students' performed on independent (and often unconnected) assignments. The benefit to this approach is that it provides clear, meaningful and personalized feedback for both students and educators regarding student learning.

Although this approach has gained popularity at the K-12 level, there have been no empirical studies to date that analyze the effects of standards-based grading on undergraduate education. The following study discusses preliminary results gathered from an investigation of standards-based grading in undergraduate STEM courses. Our analysis focuses on how the grading system impacts affective and cognitive behaviors of students. Affective behavior was measured by assessing changes in students' self-efficacy and the value they place on standards-based grading. Cognitive behavior was measured by assessing students' epistemological beliefs of STEM knowledge. The intended goal of measuring affective and cognitive behavior is to identify how a grading system impacts the learning of both technical and personal/professional skills. The following paper will present: 1) the overall design and structure of the standards-based grading system and 2) a discussion of measured changes in student affective and cognitive behaviors resulting from the standards-based grading system.

II. STANDARDS-BASED GRADING

Grading systems have been used since the late 1700s to determine whether or not students are meeting relevant academic goals within their courses [1]. Most science, technology, engineering and mathematics (STEM) educators within higher education use the traditional, summative score-based grading system. 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. The system as it stands does not encourage instructors to stay true to the preset course objectives. As a result, course objectives become unconnected with the process and often are not mentioned beyond the course description and course syllabi [2]. This grading approach inherently fails to meet the conditions for sound assessment of student work and learning [2-4]. The final course grades that students eventually earn only display how

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well the students performed on completing a series of separate course assignments.

A new approach is to directly measure the quality of students' proficiency towards achieving well-defined course objectives through *standards-based grading (SBG)*. SBG 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]. SBG utilizes a student standards achievement report (SAR) to track and provide feedback regarding individual student learning and development (a snapshot example is shown in Table 1). More detailed information regarding the standard achievement report is provided in the following reference [7]. Student development towards achieving the course objectives is directly tracked throughout the duration of a course, rather than simply assigning one-time individual scores to student work. The system allows for changes in their development levels to be directly reflected over time. Final course grades are then determined based on students' development towards achieving the course objectives according to an established grading policy.

Educators gain numerous advantages when they use standards-based grading, including but not limited to:

- clear, meaningful and personalized feedback,
- connections between assessment and the predetermined course objectives,
- fairness and transparency in the grading process, and
- a highly effective tool for program assessment [2].

When students are given useful feedback, it provides them with an opportunity to gain insights into their personal learning and development. The content they will learn throughout the semester shifts from being unclear to extremely transparent, which makes students aware of what to expect from the beginning. This provides fair and transparent grading that emphasizes 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 [2]. This in turn promotes the encouragement of student learning and continuous improvement by placing responsibility for learning on the students themselves [5]. Standards-based grading can also provide detailed feedback for maintaining academic rigor and for assessing with great precision courses, curricula, and entire institutional programs.

Beyond the theoretical advantages, SBG provides tremendous ease of implementation and flexibility regardless of the institution, the course topics or objectives, the instructor, or even pedagogy. Instructors employing a traditional lecture-style approach and those using more progressive, even un-tested pedagogies can easily tailor the SBG system to meet their needs and expectations as necessary. The author's personal experience using SBG in our own classes suggests that the SBG system is even less time consuming to implement than traditional, score-based grading systems. Assessments of student work for each course objective can occur as often as an educator wishes to assess his or her students. Educators can use a one-time evaluation (e.g., homework, examinations, portfolios, a standardized test, etc.) or they can give students multiple opportunities to demonstrate development, i.e., the time allotted for student learning can be fixed or variable. There is also flexibility in how final course grades are determined. For example, a grade of 'A' could be earned if the students' overall average development ranges between 3.7 and 4.0, or if the students demonstrate strong development on a certain percentage of the course objectives. How the grading is best implemented into a course is completely up to the instructor.

Based on feedback obtained from our initial pilot studies [7] and this current study, we have developed a preliminary list of guidelines, or best practices, for implementing the standards-based grading system. In order to successfully implement SBG into your course, we suggest the following:

- establish well-defined course objectives and list them on the course syllabus,
- establish a clear course grading policy and a clear set of assessment rubrics and guidelines,
- develop a detailed standards achievement report and share it with your students at the beginning of the

TABLE I. SNAPSHOT EXAMPLE OF AN INDIVIDUAL STUDENT STANDARDS-ACHIEVEMENT REPORT (SAR)

Standards Achievement Report (John, 02/15/2012)					
Development Towards Achieving the Course Objectives	**Homework 1**	**Homework 2**	**Quiz 1**	**Exam 1**	**Quiz 2**
1A: Understanding the concept of stress in a body	2	2	2	3	3
2A: Analyzing members subjected to axial forces	2	2	3	3	4
3A: Analyzing members under combined loads	-	-	2	2	3
Overall Average Development	2	2	2.3	2.7	3.3
Current Course Grade	C-	C-	C	C	B
Progress Level: 4 Strong development 3 Demonstrates appropriate development 2 Approaching appropriate development 1 Needs practice and further development					

course, and

- center the course lectures, assignments, and schedule on the standards achievement report.

These theoretical and observed benefits of SBG in K-12 learning environments provide a foundation for our investigation of SBG in STEM undergraduate courses.

III. Research Design

A series of pilot studies have been conducted to assess the effectiveness of standards-based grading in STEM courses. Students at two diverse institutions – one small private institution and one large public institution – were taught a variety of STEM courses ranging from engineering design to mechanics of materials to computer interaction design. A total sample of 120 STEM students in five different classes taught by four different instructors was obtained for this study. The impact of standards-based grading was assessed through an analysis of student affective and cognitive behaviors.

A. Affective Behavior

1) Self-Efficacy: Self-efficacy, or an individual's confidence about their ability, is shaped by experiences, social persuasions, and physiological states [8]. The resulting self-efficacy an individual possesses plays a large role in what tasks are undertaken and the expectancy for success. An individual's performance or behavior is therefore mediated by how efficacious they are in their ability to successfully complete tasks. It is important to measure self-efficacy before and after our standards-based grading intervention to assure that the grading system is not negatively impacting STEM confidence and achievement. This is particularly important for women in STEM who tend to out perform their male counterparts even though they display lower self-efficacy toward their abilities [9-12]. The inclusion of a measure of self-efficacy will provide a gage of how self-efficacy impacts student development and learning in a standards-based grading system.

2) Value: Our second measure of affective behavior assesses the value students place on standards-based grading. According to Expectancy Value Theory, behavior is a function of the value one places on achieving a goal [13]. The interest, attainment, utility, and cost associated with perceived individual value impacts the effort and level of responsibility put forth [14-16]. It is our belief that standards-based grading increases the value students place on learning, which consequentially encourages them to put forth more effort. An increase in effort is likely to increase a students' level of responsibility toward learning. The overall measurement of value will provide insights into whether or not the standards-based grading system impacts students' desire to be more responsible toward their education.

B. Cognitive Behavior

Understanding comes from an ability to learn through an active process of constructing a knowledge base from personal experiences [17]. As we gain knowledge, we increase our ability to find and use it [18]. The understandings we have of a given context come from the adoption of schemata, which consist of the mental representations we use during perception and comprehension. How we learn and adopt new information is influenced by our preconceptions of the world and our metacognitively defined individual learning goals [19].

The SBG system is designed to more accurately measure what students actually understand after the courses. Instructor bias for the system precludes this research from using final course grades to assess student understanding. Instead, we will measure cognitive behavior through epistemological beliefs, or the beliefs we hold about the nature of knowing and learning. The analysis of epistemological beliefs provides a unique view of cognitive gains through the identification of how naïve or sophisticated the students' understanding is [20-21]. Course grades are too often representative of what a student was able to memorize during a course. By measuring epistemological beliefs, we can capture students' general understanding of what it means to actually know something in STEM.

IV. Results

Changes in self-efficacy and epistemological beliefs were evaluated through the use of a pre/post-analysis. Instruments were developed, modified, and validated to assess the specific course objectives and the general domain of STEM. Our assessment of value was given as an added post-analysis component to analyze student perceptions of the unfamiliar standards-based grading system.

A. Self-Efficacy

The base instrument used to measure self-efficacy for each individual STEM course was a modification of a previously validated instrument used to measure engineering design self-efficacy [22]. The task-specific nature of self-efficacy requires an individual assessment of each course based on the course objectives. The base engineering design self-efficacy instrument was modified by each of the course instructors to create a course/content-specific survey. The self-efficacy item development was paired with the development of course objectives to ensure that the survey items and course objectives are clear, concise, and appropriate for the course. Individual pre/post course evaluations revealed self-efficacy toward the course content to improve for all students on all items regardless of subject matter (Table II).

TABLE II. Self-Efficacy Average Scores.

		Average Self-Efficacy	
Course	**N**	**Pre**	**Post**
Engineering Design	60	71.4	86.1
Modern Web Applications	18	15.7	81.7
Interaction Design	5	18.9	82.3
Elements of Design	20	64.9	84.6
Statics	14	40.8	93.4

A paired-samples t-test revealed increases from pre to post in self-efficacy to be significant to at least the $p \leq 0.05$ level for each individual item. This suggests that the pilot courses improved students' confidence toward the specific course topic.

B. Value

The instrument to measure value was developed specifically for this study. Developed items were theoretically based on Expectancy-Value theory and were presented using a 4-point Agree/Disagree scale. Items were first tested to ensure validity and reliability of the instrument. Three factors emerged from a factor analysis: 1) Interest/Attainment Value, 2) Utility Value, and 3) Cost. An overall Cronbach's α of 0.888 was found for the instrument, which is acceptable by social science research standards [23].

Students overwhelmingly responded with high interest/attainment value and utility value regarding SBG; low cost was also observed (Fig. 1). Written comments supported the quantitative findings and provided great feedback:

> "*The feedback is great and very explicit – this is a good system for educational growth*."

> "*The primary benefit from standards-based grading was the clear statement and emphasis of learning outcomes. The direct correlation between my course grade and the course objectives forced me to pay attention to what I should be taking away from the course.*"

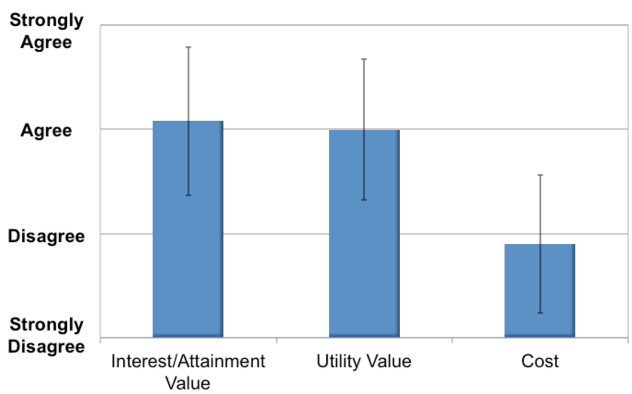

Figure 1. Average student scores for the three major areas of value of standards-based grading.

C. Epistemological Beliefs

The measure of epistemological beliefs was recorded before and after the standards-based intervention using a modified version of the Epistemological Beliefs Assessment for Engineering (EBAE) [24]. This measure identifies appreciated changes in epistemological beliefs.

The modified EBAE was presented using a 4-point Agree/Disagree scale. The items were first tested for validity using a factor analysis, which identified four factors: certainty, simplicity, source, and justification of knowledge and knowing. A Cronbach's α of 0.576 resulted. This value is below the acceptable level of 0.7, but was deemed viable for the pilot study. A pre/post analysis of epistemological beliefs was conducted for the pilot cohort of students, who on average began their course of study with a far greater propensity for naïve beliefs about STEM, but later exhibited more sophisticated beliefs at the conclusion of their courses (Fig. 2). A paired-samples t-test revealed these increases to be significant except for their belief about 'professional opinions' and 'reciting information being equivalent to understanding.' These generally positive changes were all significant to the $p \leq 0.001$ level.

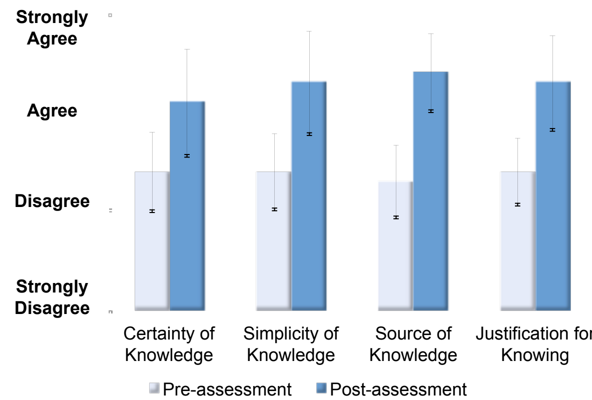

Figure 2. Average student scores for the four major areas of epistemological beliefs

V. DISCUSSION

Our preliminary analysis included an assessment of affective and cognitive behaviors for students participating in a standards-based grading system. We discovered that self-efficacy increased, epistemological beliefs became more sophisticated, and students found the intervention to be interesting without negatively impacting their learning.

The change from a traditional score-based system is intended to change student behaviors, while also helping students to improve their learning. The results suggest that the system does attend to these goals, but it is recognized that the foreign nature of the system causes some students undue stress and confusion. New systems that are unfamiliar to students may be beneficial, but until students open up to the new system and accept something different, the change may not have the intended impact. The observed benefits warrant that further analysis be conducted. The behaviors of the students participating in a standards-based grading system should also be compared to those of students participating in other grading systems to ensure the behaviors are not the same across classes.

VI. LIMITATIONS & FUTURE WORK

This preliminary study is a first step in providing reasoning to formally study and implement standards-based grading in undergraduate STEM courses. The study identified some deficiencies in the current instruments that will be addressed in our future analyses. First, the self-efficacy instrument will be tailored for each course and consist of two components:

1. *A general item pertaining to the course, and*

2. *A set of items that specifically address the course objectives.*

The general item will be used to compare courses that may have the same title, but vary in their execution. The implementation of such an approach will allow for more seamless comparison between courses.

The first time use of the value instrument was extremely successful for a newly fabricated instrument. The instrument was shown to be valid and reliable for the study sample. Further validation and reliability analysis will be conducted in future studies to ensure these trends persist.

The instrument to measure epistemological beliefs will continue to be modified to improve the overall reliability of the items. Our alpha value was below the acceptable level, but close enough for us to gain some preliminary insights into students understanding of knowing.

We will also add additional assessments beyond our current affective and cognitive behavioral instruments. Our future investigations of this system will keep a close eye on whether the system reduces student stress and concern over trying to get an 'A'. The current findings provide a solid foundation for more advanced assessments including a comparative analysis of standards-based grading versus traditional score-based grading and the impact of the grading system on the scholarship of teaching and learning.

VII. Conclusions & Implications

Standards-based grading represents an alternative to traditional score-based grading in STEM undergraduate courses. Our study suggests that implementing this alternative approach will positively impact students' affective and cognitive behaviors. Specifically, we discovered that self-efficacy increased and epistemological beliefs became more sophisticated after participating in a standards-based grading course. Students also displayed high interest, attainment, and utility value while not costing them valuable time and effort in order to learn.

The overall results of this study suggest standards-based grading to be a viable option for undergraduate STEM courses. The implications for switching from the traditional score-based grading system are not insurmountable and worthwhile if students continue to demonstrate improved confidence and knowledge. It is our desire that by switching to an SBG system we can help transform undergraduate STEM assessment by guiding learning with salient course objectives.

Acknowledgments

The authors would like to thank the instructors and the students who participated in these preliminary studies.

References

[1] Postman, N. 1992. *Technopoly: The Surrender of Culture to Technology*. New York, NY: Alfred A. Knopf.

[2] Sadler, D.R. 2005. "Interpretations of criteria-based assessment and grading in higher education." *Assessment & Evaluation in Higher Education*. Vol. 3, pp. 175-194.

[3] Broad, B. 2000. "Pulling you hair out: Crises of standardization in communal writing assessment," *Research in the Teaching of English*. Vol. 35, pp. 213-260.

[4] Shay, S.B. 2005. "The assessment of complex tasks: A double reading," *Studies in Higher Education*. Vol. 30, pp. 663-679.

[5] Reeves, D.B. 2003. *Making standards work: How to implement standards-based assessments in the classroom, school, and district*. Englewood, CO: Advanced Learning Press.

[6] Marzano, R.J. 2010. *Formative Assessment and Standards-Based Grading*. Bloomington, IN: Marzano Research Laboratory.

[7] Siniawski, M., Carberry, A. and J. Dionisio. 2012. "Standards-based grading: An Alternative to score-based assessment." 19-21 April 2012. *Proceedings of the American Society for Engineering Education Pacific-Southwest Regional Conference*.

[8] Bandura, A. 1986. *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

[9] Bandura, A. 1997. *Self-efficacy: The Exercise of Control*. New York, NY: W.H. Freeman and Company.

[10] Cech, E., Rubineau, B., Silbey, S. and C. Seron. 2011. "Professional role confidence and gendered persistence in engineering." *American Sociological Review*. Vol. 76, pp. 641-66.

[11] Hutchinson, M.A., Follman, D.K. and G.M. Bodner. 2006. "The factors affecting first-year engineering students' self-efficacy beliefs." *Journal of Engineering Education*. Vol. 95, pp. 39-47.

[12] Marra, R.M., Rodgers, K.A., Shen, D. and B. Bogue 2009. "Women engineering students and self-efficacy: A multi-year, multi-institution study of women engineering students self-efficacy." *Journal of Engineering Education*. Vol. 98, pp. 27-38.

[13] Eccles, J.S. 1983. "Expectancies, values, and academic behaviors." In Spence (ed.). *Achievement and achievement motivation*. San Francisco, CA: Freeman, pp. 75-146.

[14] Eccles, J.S. 2005. "Subjective task value and the Eccles et al. model of achievement-related Choices." In Elliot and Dweck (eds.). *The Handbook of Competence and Motivation*. New York, NY: Guilford Press, pp. 105-121.

[15] Eccles, J.S. 2009. "Who am I and what am I going to do with my life: Personal and collective identities as motivators of action." *Educational Psychologist*. Vol. 44, pp. 78-89.

[16] Wigfield A. and J.S. Eccles. 2000. "Expectancy-value theory of motivation." *Contemporary Educational Psychology*. Vol. 25, pp. 68-81.

[17] Jonassen D. and S.M. Land. 2000. *Theoretical foundations of learning environments*. Mahwah, NJ: Lawrence Erlbaum Associates.

[18] Simon, H.A. 1996. *Sciences of the artificial*. Cambridge, MA: MIT Press.

[19] Bransford, J.D., Brown, A.L. and R.R. Cocking. 2000. *How people learn: brain, mind, experience, and school*. Washington, D.C.: National Academy Press.

[20] Hofer B.K. and P.R. Pintrich. 1997. "The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning." *Review of Educational Research*. Vol. 67, pp. 88-140.

[21] Schommer, M. 1990. "The effects of beliefs about the nature of knowledge in comprehension." *Journal of Educational Psychology*. Vol. 82, pp. 498-504.

[22] Carberry, A.R., Lee, H-S. and M.W. Ohland. 2010. "Measuring engineering design self-efficacy." *Journal of Engineering Education*. Vol. 99, pp. 71-79.

[23] George, D. and P. Mallery. 2003. *SPSS for Windows step by step: A simple guide and reference*. Boston, MA: Allyn and Bacon.

[24] Carberry, A., Swan, C. and M. Ohland. 2010. "First-year engineering students' engineering epistemological beliefs." 20-23 June 2012. *Proceedings of the American Society for Engineering Education Annual Conference and Exposition*.