Mastery-based learning in college math courses and standards-based grading in high school settings: Goals, benefits, challenges, and unknowns

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Structure

- SBG in Math - Recommendations, Challenges, and Unknowns

  Results for a recent study

- SBG and Mastery Learning in College Math Courses

  Results from implementations

Questions to Ponder

- What Should Grades Represent?
- Why Do we Need Grades?

Grading Research History

- Researchers attempt to understand what grades, "symbols assigned to individual pieces of student work or composite measures of student performance on report cards" represent and how grades can inform educational decision-making.

- Grading research has evolved with the use of rigorous research methods and significant advancements in data analysis capabilities and techniques, yet several key findings remain relatively consistent.

Stable Grading Research Findings

- Grades assigned by teachers are moderately correlated with student achievement and account for approximately 25 % of the variation in students' scores on standardized tests (Bowers, 2011).

- Grades assigned by K-12 teachers report upon three main areas: academic knowledge, engagement, and persistence (Kelly, 2008; Willingham et al., 2002).

Stable Grading Research Findings

- Non-cognitive variables of engagement and persistence are mediated by a number of other factors such as teacher evaluations of behavior and work habits (Duckworth et al., 2012) and are related to student motivation and general interest in school (Klapp et al., 2009).

- A last stable finding relates to the low level of reliability of assigned grades both between teachers and within the same teacher (Brookhart et al., 2016).

Motivation for Change

- Mastery-orientation is not well served by traditional grading and assessment schemes.
    - Grades tend to consist of a mix of factors related to effort, attitude, and achievement and that grading practices did not conform to measurement standards.
    - Course grades are generally unreliable indicators of students' academic learning due in part to teachers' lack of knowledge of grading and assessment practices, differing beliefs about the role of grades, and misunderstanding of how to address confounding factors when determining final grades.

Teachers' Grading Practices

- Teachers tend to incorporate non-cognitive factors in final grade allocations such as effort, improvement, ability, participation and attention.

- Inclusion of non-cognitive factors, often considered to be "life skills," is thought to confound the measurement of academic performance and enable bias in determining grades. Therefore, many experts advocate for the removal of non-cognitive factors from content grades.

Rise of Standards-Based Grading

- Standards-based grading is a method of grading students based upon a set of defined learning objectives with separate grades provided for work habits *(process*), improvement (*progress*), and learning (*product*).
- Students are individually assessed on distinct content standards that define learning goals and given opportunities to reassess areas of deficiency.
- Standards-based grading ideally facilitates greater emphasis on student learning, requires that all students participate and achieve, and informs decisions regarding needed changes in instruction.

What is SBG Today?

- Provide students with a content score or grade that reflects only their performance or proficiency in relation to set learning objectives or standards *(product)*.
- The underlying intention is to convey a clear and understandable picture of what needs to be learned and what constitutes proficiency in a content area.
- Experts advocate that teachers diligently record and report scores associated with the learning *process* or life skills, which may include non-cognitive factors such as effort, participation, work habits, and punctuality.
- More recently, a third area for grading has been added in order to report upon students' improvement or *progress*.

Discussion

- How do you or your school/college assess students’ knowledge in math classes?
- What portion of a students’ grade is ultimately based on mastery of content, productive habits or non-cognitive factors, and progress towards mastering content?
- What works about your current grading and assessment system?
- What do you think should change? Why?

Share Small Group Discussion

- Themes

Specifications 'Specs' Grading

- First described by Dr. Linda Nilson in 2014.
- *Specifications* are provided for each assessment.
- Student submissions for assessments are graded as 'satisfactory' (+) or 'not yet satisfactory' (-) depending on if they meet the stated specifications.
- There is a notion of 'revise and resubmit' for (-) submissions.
- Course grades are determined by the student's ability to assemble *bundles* of (+) assessments. These bundles are constructed to align with the learning outcomes and are communicated on the first day of class.

Specs grading in a college course

- Math 156 - Abstract Algebra II, spring 2025
- 3 credit, second semester course in Abstract Algebra focusing on ring and field theory. Emphasis is on continued development of proof writing/communication skills and the navigation of abstract mathematics.
- Our major requires students to complete a year long sequence in either Algebra or Analysis.

Learning Outcomes

- Develop a working understanding of relevant abstract algebraic structures.
- Develop as abstract problem solvers and critical thinkers.
- Refine written communication skills with regards to logical arguments and proofs.
- Develop independent learning skills through readings in the field of abstract algebra.
- Develop oral communication skills of mathematics both as an ‘expert’ and ‘collaborator’.

Manners of Assessment:

- Students were assessed in three manners:
- **24 HW sets** were assigned throughout the semester, with each set individually assessed as (+) or (-). Students could submit up to four HW sets per week, with no additional limit on number of attempts other than end of term.
- A **group presentation** was assigned on day one and contained four subcomponents each assessed as (+/-).
- An **oral final exam**, with three subcomponents was given.
- This results in a total of 31 opportunities for satisfactory assessment.

HW sets

- Specifications: A satisfactory submission will:
  - Present proofs which are logically and mathematically sound for all problems.
  - Present proofs which are consistent with the course and material covered at the time of assignment.
  - Present proofs which contain ample detail and communicate clearly all steps.
  - Present proofs which do not leave open the opportunity for the reader to reasonably ask ‘Why?’.
  - Present proofs which leave no doubt the student understands their own argument and the content at hand.

Four examples of HW sets

- Prove that a number is divisible by 9 if and only if the sum of its digits is divisible by 9. Prove likewise for 3. What property do 9 and 3 have which is vital to your proof but not possessed by any other integer? (10 mod n = 1).
- Prove that it is impossible to construct a regular nonagon (9-gon) with a compass and straightedge.
- Prove that the characteristic of an integral domain is 0 or prime.
- Prove a collection of properties about Ring Homomorphisms.

Other Assessments

- Project - four subcomponents
  - First two were progress check-ins
  - Later two were for the presentation, one for quality of talk and one for quality of mathematics
- Oral Final - three subcomponents
  - Students were given 3 problems two weeks in advance, knowing one would be randomly selected for their final*
  - The first subcomponent assessed the students ability to answer preliminary questions about the selected problem
  - The second assessed their ability to give a solution to the selected problem and answer relevant questions
  - The third assessed their ability to expand on the problem in a manner which the student could not prepare for

Final Exam Problem Example

- Prove that no integral domain can have exactly 3 ideals.
- Preliminary Questions:
  - What is an ID and what makes them special? What properties do they have that often show up in proofs? What is an ideal and how do I prove something is an ideal? What is special about an ideal?
- Follow up Questions:
  - Where did 3 show up, is it important? Can you state and prove a more general statement? (Every Integral Domain has either exactly 2 or an infinite number of ideals)

Course Grades

Course grades are assigned consistent with the following table.

Grade	Total (31)	HW (24)	Project (4)	Final Exam (3)
A	Earn at least 29 +’s total	Earn at least 22 +’s on HW	Earn at least 3 +’s on the project	Earn 2 +’s on a random problem.
B	25	18	3	Earn 2 +’s on a random problem, one veto.
C	20	14	2	Earn 2 +’s on a problem of student’s choice
D	15	10	2	Earn 1 + on a problem of student’s choice

My experiences, the positives

- ‘Holisticness’ to grading, no ‘dead frog problem’
- Grades better reflect learning and eventual understanding
- Grades better reflect learning outcomes
- Grades trend towards bimodal, with net increase in GPA
- Highly equitable, students can productively invest more energy
- Initial concern from students becomes high buy in. In general students simultaneously report
  - Working harder
  - Learning more
  - Wanting to take more courses under this model
- Sizeable decrease in time grading*
- I can give fewer but more challenging problems without creating other problems

My experiences, the negatives

- First time implementing in a particular course can be a major time commitment
- Spec only models can struggle in highly technical courses
- Difficult to judge reasonable expectations
- It can exacerbate pre-existing issues with student self discipline

Advice

- Keep it simple
- Hybrid models work
- Recycle learning outcomes and specs if possible (align with program goals/outcomes)
- For more technical courses, ensure repeat opportunities to teach before attempting
- Communicate with students on your goals and objectives when using a mastery model

Discussion

- What has been your experience with mastery-based learning?
- If you are experienced in this world, what have been your personal positives and negatives regarding such systems? What modifications could you make (be creative!) to remove or offset some of the negatives?
- If you are newer to this world, do you see potential for mastery-based instruction to resolve any issues you may have with your current grading and assessment system?

An Implementation Study in HS Geometry

- Operationalizing such a model has proven to be difficult in part because some researchers and educators value *progress* and *process* differently.

- In this study, we report upon changes within a grading system that reports only *product* grades at the course-level, and *process* grade across courses.

Math Learning & Motivation

- Attempts to shift students' orientations from performance-based to mastery.
- Students will take ownership of their own learning and develop the intrinsic motivation needed to learn content in a deep, connected, and purposeful manner.
- Specific to mathematics, researchers have shown that a strong relationship exists between intrinsic motivation and mathematics achievement.
- In a large-scale study of 6829 students who participated in an international mathematics assessment, Acar Güvendir (2016) found that while other factors relate to mathematics achievement, intrinsic motivation in particular has the strongest relationship.

Motivation or Achievement First?

- Researchers found that intrinsic motivation for mathematics learning develops during grades 1 through 4, and that mathematics achievement predicts intrinsic motivation.
- By the end of primary school, motivation is well-established and demonstrates stability after grade eight.
- Student motivation (performance-based) can play a role in completing practice work, as many students are more inclined to exert effort and complete classwork when they are provided with multiple opportunities for meaningful formative and summative assessments that "count" toward their final grade.
- It is unclear and unproven the direction of the relation between intrinsic motivation and achievement in mathematics.

Recent Research Results for SBG

- Peters et al. (2017) found declines in secondary students’ motivation, work completion, and timeliness after transitioning to standards-based grading.
- However, Knight and Cooper (2019) reported an initial decline in student motivation when transitioning to a standards-based grade system followed by students assuming more accountability over time. However, teachers remained concerned about students’ poor work habits despite shifts in accountability.
- The grade mindset versus growth mindset has proven difficult to shift with secondary students in particular. For example, in a study of students enrolled in algebra 2, participants continued to focus upon their final grade computations versus mastery of learning objectives during the initial year of standards-based grading implementation (Rosales, 2013).

Recent Research Results for SBG

- Overall, students made the decision to reassess based upon implications to course grades, versus opportunities for mastering content and viewed extra learning activities as punitive.
- The few studies involving secondary mathematics classrooms indicate that most students feel more in control of their mathematics learning in standards-based grading environments and appreciate knowing what they are doing well and how they can improve through detailed feedback provided by the teachers.
- Other studies reported that African American students enrolled in science classes improved both grades and end-of-course exam scores.
- Research specific to math and secondary students is limited in nature, but increasing.

Participants

- The subjects of the study were in grades 8 and 9 and typically either 13, 14 or 15 years old.
- Cohorts 1 and 2 consisted of 122 and 123 students, respectively enrolled in geometry during the 2018–2019 and 2019–2020 academic years.
- The cohorts were determined to be high-achieving with only 1 student from cohort non-proficient in annual assessments.

Study

- The *process* grades did not contribute to the student's academic standing in any way, but a grade was provided on each student's report card.
- During data collection for Cohort 1, practice work for mathematics classes contributed to a portion of the final *product* grade related to academic performance.
- During data collection for Cohort 2, practice work contributed instead to the *process* grade and was removed from the *product* grade in alignment with recommendations from standards-based grading experts.

Research Questions

1) How does student performance change during the first year of a grading policy change?

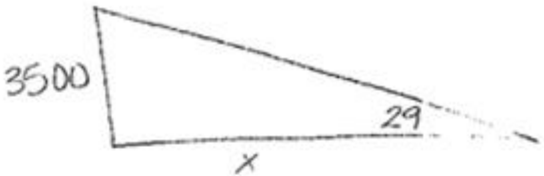
1) How do high-achieving students self-report changes to their behaviors and work habits specific to completion of practice work?

   What reasons do students offer in relation to these choices?

Instruments – Data Collection

- Two types of instruments: assessment items aligned by standard and a questionnaire.
- The assessment items originated from exam items provided by the textbook publisher HoltMcDougal with the textbook titled "Geometry: Common Core Edition", but were adapted by teachers.
- Each item on exams aligned with one and only one standard or criterion, which has shown be to best practices.

9. Suppose a plane is at an altitude of 3500 ft. and the angle of elevation from the airport to the plane is 29°. What is the horizontal distance between the plane and the airport?



$\tan 29° = \frac{3500}{x}$ ✓

$3500 \cdot \tan 29° = x$

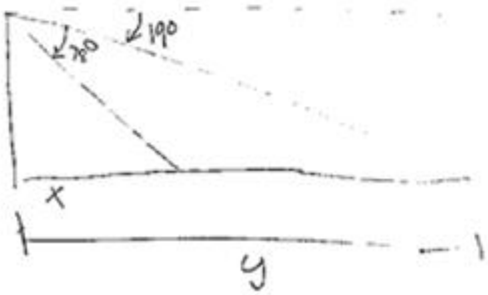
$x = 1940$ ft

10. A pilot flying at an altitude of 12,000 ft sights two airports directly in front of him. The angle of depression to the closest airport is 78°, and the angle of depression to the other airport is 19°. What is the distance between the two airports?

✓ $\tan(71°) = \frac{12000}{y} \rightarrow 12000(\tan 71) = 34851$

✓ $\tan(12) = \frac{12000}{x} \rightarrow 12000(\tan 12) = 2551$

$34851 + 2551 = 37402$ ft



The above test questions align with Common Core Standard G-SRT.C.8: "Use trigonometric ratios…to solve right triangles in applied problems" (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). A student would score "below

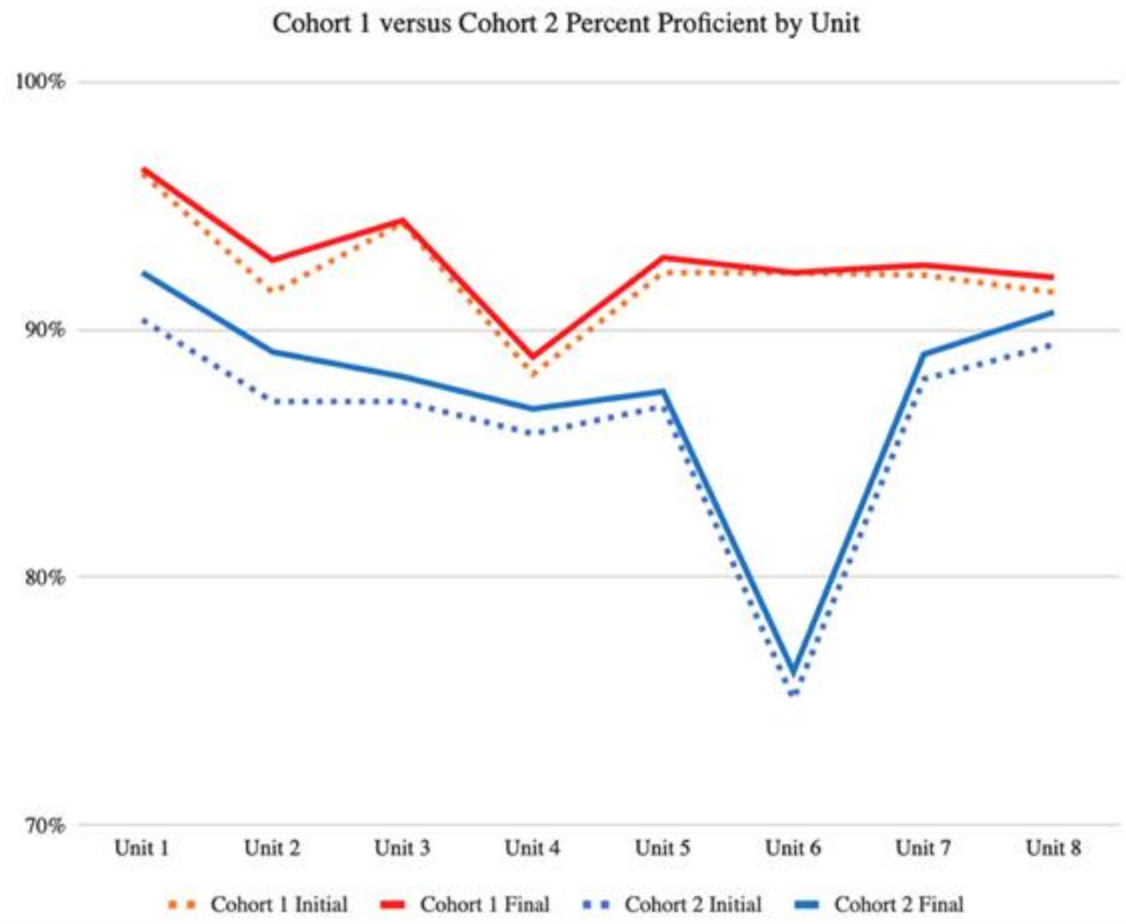


Fig. 1. Percent Proficient by Unit for Cohorts 1 and 2.

Results of Summed Composite Scores from each Unit from Cohort 1 and 2.

	Before Reassessment					
	Cohort 1		Cohort 2		t (243)	p-value
Unit	Mean	SD	Mean	SD		
1	59.43	4.00	57.46	5.55	3.202	0.002 *
2	35.91	3.35	34.62	3.72	2.855	0.005 *
3	36.13	2.96	34.89	4.01	2.766	0.006 *
4	56.35	5.45	56.09	5.51	0.375	0.708
5	51.01	4.40	49.55	5.56	2.271	0.024 *
6	35.32	4.12	33.10	5.38	3.633	0.000 *
7	50.41	4.10	48.21	4.78	3.853	0.000 *
8	42.15	3.42	42.48	3.80	-0.722	0.471

* p-value < 0.05

Results of Summed Composite Scores from each Unit from Cohort 1 and 2.

	After Reassessment					
	Cohort 1		Cohort 2		t (243)	p-value
Unit	Mean	SD	Mean	SD		
1	59.63	3.84	57.98	5.23	2.812	0.005*
2	36.20	3.15	35.13	3.59	2.474	0.014*
3	36.20	2.94	35.08	3.87	2.559	0.011*
4	56.63	5.39	56.36	5.44	0.395	0.693
5	51.20	4.42	49.67	5.48	2.404	0.017*
6	35.32	4.12	33.27	5.29	3.388	0.001*
7	50.57	4.01	48.69	4.86	3.295	0.001*
8	42.24	3.39	42.69	3.74	-0.979	0.328

* $p\text{-value} < 0.05$

Questionnaire Results

- When prompted to reflect upon their completion of practice work in math compared to the previous school year,
  - **23 % (26) of students reported completing less practice work,**
  - **27 % (31) of students reported doing more practice work, and**
  - **50 % (58) reported completing about the same amount as the previous year.**
- When asked how much practice work students typically completed before an assessment,
  - **75 % (86) reported more than half or almost all,**
  - **16 % (18) reported about half,**
  - **and only 7 % (11) reported less than half.**

Questionnaire

- However, when asked if students would complete more practice work if it were factored into their grade calculation, students overwhelmingly reported that they would.
  - **Seventy-seven percent answered that they would complete more practice work if it directly impacted their course grade,**
  - **and only 4% of students stated that grades for practice work would not affect their decision to complete it.**

- When asked to explain why their practice work completion might have changed from the previous year,
  - **34% of students wrote that they complete any schoolwork that is expected of them as a matter of course.**

Questionnaire

- ***"I would [complete more practice work] because it would actually benefit my grade…doing all that work with no benefit gradewise kind of discourages kids to actually do the work."***
- Another student thought that completion grades should be provided stating "***you have to learn something before you apply it…that's why homework should be a completion grade that does affect grades rather than an actual score while you're still learning and progressing."***
- Another student provided a rationale for why he completed less practice work compared to prior years ***"because, bottom line, I want to do good on whatever counts toward my grade, and right now since it doesn't…I do half the homework."***

Questionnaire

- Other peers interpreted practice work as being less important due to grading changes. One student said, ***"they don't have any worth this year, but they did last year"*****,** and another stated ***"homework is an option now and not a priority."***

- Still others saw practice work as something that they should get credit for completing similar to prior years and reported a lack of motivation to do work without receiving a reward.

- One student simply said that grading should be about ***"completing something and getting credit for the work you've done."***

Questionnaire

- ***"I don't think homework should be graded, considering it's just to improve your understanding and help you remember how to do it…if someone knows how to do it really well then homework shouldn't matter."***
- While another hinted at less stress around practice work with the policy changes and said ***"with the homework not being graded, it's easier for me to learn it."***
  - **Of the 18 % (21) of students who responded that they were unsure if the inclusion of practice work in grades would change their work habits,**
  - **15 stated that they complete all practice work and, therefore, would be unable to complete any more.**
  - **A subset of students seemed to understand.**

Questionnaire

- One student said, ***"for the few assignments I have completed, I have aced the tests on those assignments,"*** and another stated that ***"the assignment itself is like a practice test, leading to higher grades."***
- One student made observations about receiving needed feedback from practice work, as it ***"shows me what areas I need to focus on more than others."***
  - **When directly asked if practice assignment helped prepare students for the assessment, 98 % responded affirmatively.**
- When asked to explain why, one student said, ***"because practice is a way of studying, and completing the assignments is practice"*** and another said, ***"because I do better when I complete them."***

Conclusions

Wormeli (2018) has stated repeatedly that ***"some teachers claim that students will not do homework assignments if they are not graded…this notion is false" (p. 193).***

This study contradicts Wormeli's claim to an extent, as practice work completion rates were lower than the prior year coupled with lower scores on assessments levels overall.

Students in this study did engage with practice work, but perhaps in different ways than before. A portion of students seemed to understand the intentions behind changes in the grading system, while others felt that completing practice work was optional in nature or was disincentivized compared to prior years.

Conclusions

These findings align with a study conducted by Peters et al. (2017), who suggest that students have several misconceptions about teaching and learning that need to be addressed for successful implementation of standards-based grading.

- **If something is not required by a teacher, it is not important.**
- **Students expressed frustration regarding the relationship between less completion of practice work leading to lower exam scores.**

It is unclear that all students can or will make the shift from performance-based motivation to intrinsic for all subject areas, and perhaps especially mathematics.

Conclusions

- The number of statistically significant differences in results related to performance levels in favor of Cohort 1 seem to imply that adjustments in grading policies have immediate impacts to student behaviors and learning.

- Reassessment opportunities produced negligible effect overall of with only small changes in proficiency levels and only four changes in statistically significant differences at the test item level, which seems to imply that students were not aware of or did not value changing their performance.

Conclusions

- Math teachers value effort as a key contributor to generating grades, the element of standards-based grading that has received the most attention and development relates to academic achievement.

- As Resnick (1987) noted, tested achievement represents only part of what is learned at school and privileges "individual cognition, pure mentation, symbol manipulation and generalized learning" (pp. 13–15).

- Mathematics teachers in particular strongly believe that students need to participate fully in the process of learning and persevere through challenging times in order to learn in a deep and meaningful manner, and research supports this claim (Shepard et al., 2018).

Conclusions

- Math teachers tend to incorporate effort (*process)* in final grade computations both in traditional grading and standards-based grading systems regardless of guidance provided by administration (Tierney et al., 2011).

- Administrators who require grading system entirely focused on *product* performance measures are implementing policy in direct conflict with math teachers' belief systems.

- Experts in SBG agree with math teachers that *process* is as important as *product* for grades.

Recommendations

- Mathematics and other content-specific teachers need to be included more fully during the implementation and decision-making process as valued partners.

- The data collected in this study are readily available in most schools' grading systems and should be analyzed in partnership between teachers, instructional coaches, curriculum specialists, and others involved to study the nuanced effects of grading policy changes and further inform instruction.

- Longitudinal studies are need to assess not only impacts to achievement over time, but *process* outcomes.

Discussion

- Mastery mean different things to various teachers.
- How can we better align expectations across grades, courses, and institutions?
- What messages are we inadvertently or purposefully sending to students?
- How may this be influencing their confidence levels and associated motivation, as well as, achievement?

Q&A and Thank You!

- For the full article see: Studies in Educational Evaluation 75 (2022) 101211