Fostering Growth Mindsets: Implementing Standards-Based Grading in College Algebra

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Abstract

In mathematics courses, grading practices often focus on performance through a cumulative point system, which can mask students' true understanding of the material. For students at EPSCoR institutions, many of whom are first-generation college students from rural communities, this traditional grading approach does not always foster the depth of learning or resilience required for long-term success. With the goal of encouraging a growth mindset, faculty members at these institutions sought a grading system that would better reflect students' comprehension and support their academic growth. Standards-based grading (SBG) was implemented to meet these needs by shifting the focus away from partial credit accumulation and toward a more meaningful assessment of learning.

SBG was adopted in College Algebra courses to encourage students to master specific learning objectives through an iterative process of reassessment. Unlike traditional weighted average grading (WAG), SBG emphasizes mastery of content, giving students multiple opportunities to demonstrate their understanding. This paper will present a statistical analysis between student outcomes in SBG and WAG college algebra courses.

Supported by recent literature, SBG has been shown to foster student engagement, reduce math anxiety, and cultivate a growth mindset. This paper additionally explores the logistical aspects of implementing SBG, the process of gaining administrative and student buy-in, and provides resources for instructors interested in adopting SBG in STEM fields to improve student outcomes.

Introduction

A common refrain in education is the adage that in order to grow, one must learn from one's mistakes. However, as faculty in higher education, we seem to frequently forget this maxim in the design of our own courses. Anecdotal evidence suggests that the most common grading scheme in STEM courses is **weighted average grading** (WAG), in which the total number of available points are divided amongst categories (e.g. homework, quizzes, and exams), points in each category are allocated using the average of assignment grades, and letter grades are assigned based on the percentage of available points the student has accumulated throughout the course. Counter-intuitively, WAG offers a punishment for mistakes made – loss of points – and no reward for remedying those mistakes. Indeed, while we may attempt to incentivize students to fix gaps in their knowledge under threat of losing even more points on, say, a cumulative final exam, the points lost on previous assignments may never be regained.

Structuring our courses this way creates a perverse incentive structure wherein students erroneously conflate accumulation of points and understanding. This often gives rise to undesirable behaviors in our students, such as superficial learning and disengagement [1], as well as undesirable outcomes.

> "The chair of the department of a Big Ten university once observed, probably after a bad day, that it was possible for a student to graduate with a mathematics major without ever having solved a single problem correctly. Partial credit can go a long way."
>
> —Dudley Underwood [2]

Recently, in an effort to combat these problems, segments of the mathematics community have begun to employ grading techniques[3] other than WAG in their courses, known collectively as **alternative grading**. While these approaches to grading may look dramatically different in practice, they all share a common goal of prioritizing accurately measuring student learning over accumulation of points.

As a framework, **Standards-Based Grading** (SBG) aims to provide a more accurate measure of knowledge through a grading process that is both **iterative** and **forgetful**. The course material is discretized into bite-sized chunks called **standards** – such as a concept or a mechanical task – each student is expected to master by the end of the course. These standards are assessed at regular intervals, similar to WAG, and are graded based on whether the student has or has not demonstrated *mastery* of the standard – meaning there is no partial credit and no points to accumulate. Throughout the course, students have opportunities to reassess standards not already mastered and, by demonstrating mastery on the reassessment, previous mistakes are forgotten. This provides a mechanism by which students are incentivized to learn from their mistakes without penalty.

While this approach has been shown to reduce students' anxiety around mathematics [4] [5] and reduce avoidance goals in students [6], claims that SBG increases engagement [7] and perseverance [8] [5], generates grades that better reflect student knowledge [9] [4], and promote deeper understanding of the material [5] [10] [11] [12] remain largely anecdotal. This lack of rigorous evidence is particularly notable for the latter two claims, which are frequently cited as compelling arguments for implementing SBG. We address this critical gap in the literature by examining student outcomes in College Algebra courses and subsequent courses at a National Science Foundation (NSF) Established Program to Stimulate Competitive Research (EPSCoR) eligible institution.

By definition, "a jurisdiction is eligible to participate in EPSCoR programs if its level of NSF funding is equal to or less than 0.75 percent of the total NSF budget over the most recent five-year period, excluding NSF funding to other federal agencies and EPSCoR RII and workshop/conference funding." [13] These jurisdictions tend to be more rural with lower median household incomes and limited access to advanced educational resources. As a result, many students at institutions of higher education (IHE) in these jurisdictions are first-generation college students and exhibit wide variation in academic preparation.

By rigorously analyzing the impact of SBG on student performance and learning, we aim to contribute to the body of evidence supporting SBG as a more effective alternative to WAG for promoting deeper conceptual understanding in university-level mathematics courses.

Methods

Data were collected at a rural, public, research university with an approximate enrollment of 11,000 students in an EPSCoR eligible jurisdiction under the approval of the Institutional Review Board. Six face-to-face sections of freshman-level College Algebra utilizing SBG for assessments were offered by one of the authors across academic years (AY) 2020 – 2021 and 2021 – 2022 with an average enrollment of 35 students. Five face-to-face sections utilizing WAG were offered by five other instructors. Majors from various colleges within the university are represented in the student population as College Algebra is a general education requirement (GER) for most majors and programs at the institution.

Implementation

Students in the SBG College Algebra courses were evaluated on demonstrated mastery of 25 standards listed in Appendix A. Grading for the course comprised in-class, written assessments, and homework assignments completed using the MyMathLab online homework system. Letter grades were assigned at the end of the term using the scale in Table 1.

Table 1: Grading Scale

	MyMathLab Average				
# Standards Mastered	90% - 100%	80% - 89%	70% - 79%	60% - 69%	< 60%
22 – 25	A	B	B	B	C
19 – 21	B	B	C	C	D
16 – 18	C	C	C	D	D
13 – 15	D	D	D	D	F
< 13	F	F	F	F	F

Students were given in-class assessments five times throughout the course. The assessments contained a section with at least one problem for each standard that had been covered up to that point in the term. Each student could attempt any standard that he or she had not already mastered on a previous assessment. The standards were scored independently, with an overall grade of M, P, or N assigned to a standard based on the rubric in Table 2. If a standard contained multiple problems, the score reflected the student's performance on all problems.

Generating Faculty Buy-In

Initially, department administrators opposed the implementation of SBG in College Algebra for fear that the iterative nature of the grading scheme would trivialize the course content. Over the

Table 2: Problem Scoring

Score	Description
Mastery	Core understanding is solid with no errors or with trivial, easily correctable errors.
Progress	Core understanding is evident, but with gaps or non-trivial mistakes.
Needs Improvement	Significant gaps or errors in core understanding.

course of several meetings, we were able to allay these concerns by emphasizing that the iterative nature of SBG empowers the instructor to shift the emphasis on assessments toward testing deeper conceptual questions over rote computation[14], and by citing existing literature to support positive student outcomes in similar courses[10].

With administrative permission to proceed, we set about generating additional support amongst the wider mathematics faculty. We found the most success in building this support by emphasizing the efficiency of grading[11] and the shift in instructor-student interactions [6] [10]. Eliminating the need to agonize over how much partial credit to assign, instructors are able to spend less time grading and are able to return assessments in a more timely manner. Moreover, when assessments are returned, the interactions with students tend to shift away from haggling over points and towards understanding. Hence in one-on-one interactions, the instructor can spend more time discussing content by reviewing, identifying, and rectifying misconceptions.

Based on our experience, we recommend the following approach for faculty interested in implementing SBG:

1. **Ground Your Case in Evidence:** Begin by reviewing the literature on SBG, focusing on studies that highlight its effectiveness and address common concerns, such as academic rigor and student engagement. Being well-informed will prepare you to confidently address questions from administrators and colleagues.

2. **Engage Administration First:** Schedule a meeting with your supervisors to discuss the potential implementation of SBG in your courses. Approach the discussion as an opportunity to collaborate and address institutional priorities. Be prepared for ongoing conversations, as gaining approval may require multiple discussions.

3. **Frame the Conversation for Faculty:** When speaking with colleagues, emphasize the benefits of SBG for both instructors and students. Highlight how SBG can reduce grading time by eliminating partial-credit calculations and provide more meaningful feedback to students. Share how SBG fosters deeper learning discussions, shifting the focus from point disputes to conceptual understanding.

4. **Acknowledge Resistance:** Understand that not everyone will embrace the approach immediately. Focus your energy on faculty who are curious or open to trying something new. Use their experiences as examples to build momentum.

5. **Build Momentum Gradually:** Pilot SBG in one course or with a small group of students. Share the results —both successes and challenges — with your department. This incremental approach can demonstrate feasibility while building trust and interest among colleagues.

6. **Find or Create a Community of Practice:** Seek out professional communities or conferences focused on alternative grading practices, such as the Grading Conference. Engaging with like-minded educators provides a space to share challenges, exchange ideas, and gain support. If such a community does not exist locally, consider starting one within your institution or professional network to reduce feelings of isolation and foster collaboration.
7. **Be Persistent and Flexible:** Recognize that systemic change takes time. Be willing to adapt your approach based on feedback and institutional needs. Continued communication and sharing of positive outcomes will help sustain interest and progress.

These steps can help faculty navigate institutional challenges and encourage meaningful dialogue around SBG. The key is persistence, transparency, and a collaborative mindset.

Generating Student Buy-In

While securing faculty buy-in is critical to beginning an implementation of SBG, securing buy-in from the students is critical to a successful implementation. Following the literature [15], much of the first meeting is spent not only explaining the system, but telling the students *why* we have chosen to implement SBG. It is important that the students understand that we make our decisions around course design for their *benefit*. We are transparent in our explanations to prevent an adversarial relationship that can sometimes form in courses that are perceived by students to be difficult. We are careful to emphasize that because SBG demands that students meet a high standard, the course will not be easy and so the relationship *must* be "us, together, against the course material."

Building this classroom environment begins by setting clear goals for the students and a pathway to achieving those goals. It is crucial to effectively explain to students that demonstrating a particular level of mastery of the material in a SBG course is inherently different from accruing points for a letter grade in a WAG course. Carefully explaining to students that mastery of a standard requires complete and correct solutions to all of the problems on an assessment sets a clear goal of fully understanding the material in the order it is presented. Supporting this expectation of mastery with the idea that students will be provided multiple opportunities to demonstrate their understanding presents students with a pathway to success that is cyclic in nature: learn, assess, revise, and repeat.

The process of securing buy-in from students is typically incremental, especially in general education courses targeted to first-year students. We are mindful to routinely repeat goals, expectations, and details of SBG to ease the adjustment to an unfamiliar grading system. Leading up to assessments, we reiterate mastery goals and frequently provide anonymized graded work to help students effectively prepare and understand how their work will be graded. We emphasize the reassessment mechanism and available resources when returning graded work to encourage students to effectively identify and fill gaps in their understanding. In addition to setting norms for learning behavior, this process helps to foster a growth mindset in students by emphasizing that this cycle provides a learning environment in which failure is an opportunity to learn and grow.

Based on our experience, we offer the following suggestions for successfully gaining student buy-in for SBG:

1. **Be Transparent from the Start:** Begin by explaining the purpose of SBG on the first day of class. Clearly communicate how it prioritizes mastery and long-term understanding over point accumulation. Frame the system as a tool for helping students succeed and grow.
2. **Define Mastery Clearly:** Ensure students understand what constitutes mastery of a standard. Walk them through specific examples and emphasize the importance of complete and correct solutions to demonstrate their knowledge.
3. **Reinforce the Process Regularly:** Reiterate the reassessment process throughout the term. Remind students that mistakes are not final but opportunities for growth, and highlight resources available to help them improve.
4. **Foster a Collaborative Mindset:** Emphasize that SBG requires effort from both students and instructors. Use language that frames the course as a joint effort—"us against the material"—to create a team-oriented environment.
5. **Use Empathy to Address Concerns While Setting Clear Expectations:** Reassure students that one bad test day won't ruin their grade and emphasize that the grading system is designed to measure what they know by the end of the course. You might say something like, *"My goal is to ensure you understand the material by the time the course ends. We all learn at different paces, and this system allows you opportunities to demonstrate mastery along the way."* This framing balances support with accountability, helping students see that their progress matters throughout the course.
6. **Use Examples and Success Stories:** Share anonymized examples of mastered work and provide specific feedback to students to guide their improvement. When possible, highlight stories of past students who succeeded under the SBG system, reinforcing that it is achievable.
7. **Be Patient and Persistent:** Recognize that adapting to SBG is a learning curve, especially for first-year students. Expect some resistance or confusion early on, and use it as an opportunity to model the growth mindset you're encouraging in your students.

Following these steps will allow instructors to help students embrace SBG as a learning-centered approach to assessment. While the adjustment may take time, creating a supportive and transparent environment can pave the way for a smoother transition and more meaningful engagement with the material.

Results

This study focuses on three different academic terms consisting of 346 students across 11 different sections with five different instructors. The students studied were considered regardless of whether they had previously attempted College Algebra. The author is the only instructor who utilized the SBG method in the college algebra course. The studied population is presented in two groups: the students who were assessed using a traditional WAG method (136 total students) and those who were assessed using the SBG method (210 total students). The grade distributions of these two groups are shown in Table 3.

Table 3: Grade distribution in all College Algebra sections

	WAG	WAG%	SBG	SBG%
A	12	8.82	48	22.86
B	22	16.18	31	14.76
C	29	21.32	28	13.33
D	11	8.09	23	10.95
F	16	11.76	48	22.86
W	46	33.82	32	15.24
ABC	63	46.32	107	50.95
DFW	73	53.68	103	49.05

The p-value for the difference between the pass rates of the two groups was found to be 0.40. The 95% confidence interval around the pass rate difference of 4.63% is $\pm 10.7\%$.

Shown in Figure 1 are the percentage values presented in Table 3 and the comparison between the two different assessment methods. The green arrows represent an increased percentage of a specific letter grade from the WAG method. The orange arrows represent a decreased percentage of a specific letter grade from the WAG method.

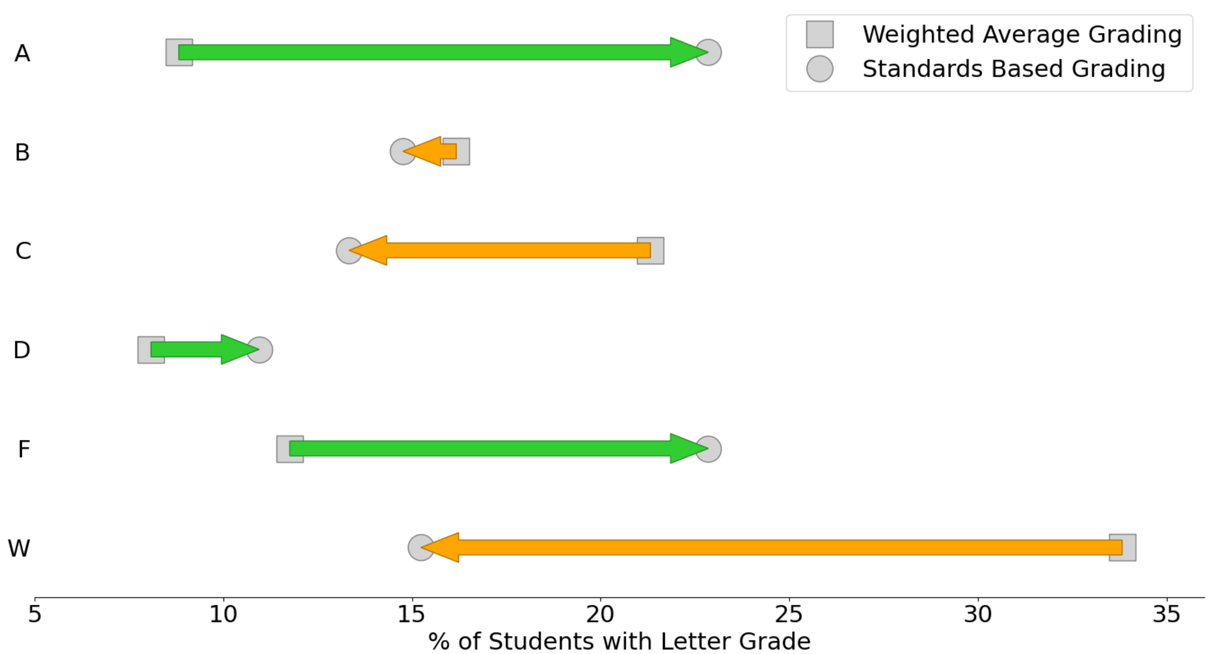

Figure 1: College Algebra outcome comparison

This study also investigated the outcomes of future math courses of the two groups of students. Of the 346 students who took College Algebra in the studied terms, 266 students had taken a follow-up math course at the time of the study's analysis. These follow-up math courses consisted of various courses, including College Algebra, College Trigonometry, and Pre-Calculus. The grade distributions of the two groups of students in their follow-up math course are shown below in Table 4.

Table 4: Grade distribution in all follow-up math courses of students previously in College Algebra

	WAG	**WAG%**	**SBG**	**SBG%**
A	13	10.66	24	16.67
B	18	14.75	27	18.75
C	26	21.31	22	15.28
D	12	9.84	12	8.33
F	21	17.21	23	15.97
W	32	26.23	36	25.0
ABC	57	46.72	73	50.69
DFW	65	53.28	71	49.31

The p-value for the difference between the pass rates of the two groups was found to be 0.52. The 95% confidence interval around the pass rate difference of 3.97% is $\pm 12.0\%$.

Shown in Figure 2 are the percentage values presented in Table 4 and the comparison between the two different assessment methods. The green arrows represent an increased percentage of a specific letter grade from the WAG method. The orange arrows represent a decreased percentage of a specific letter grade from the WAG method.

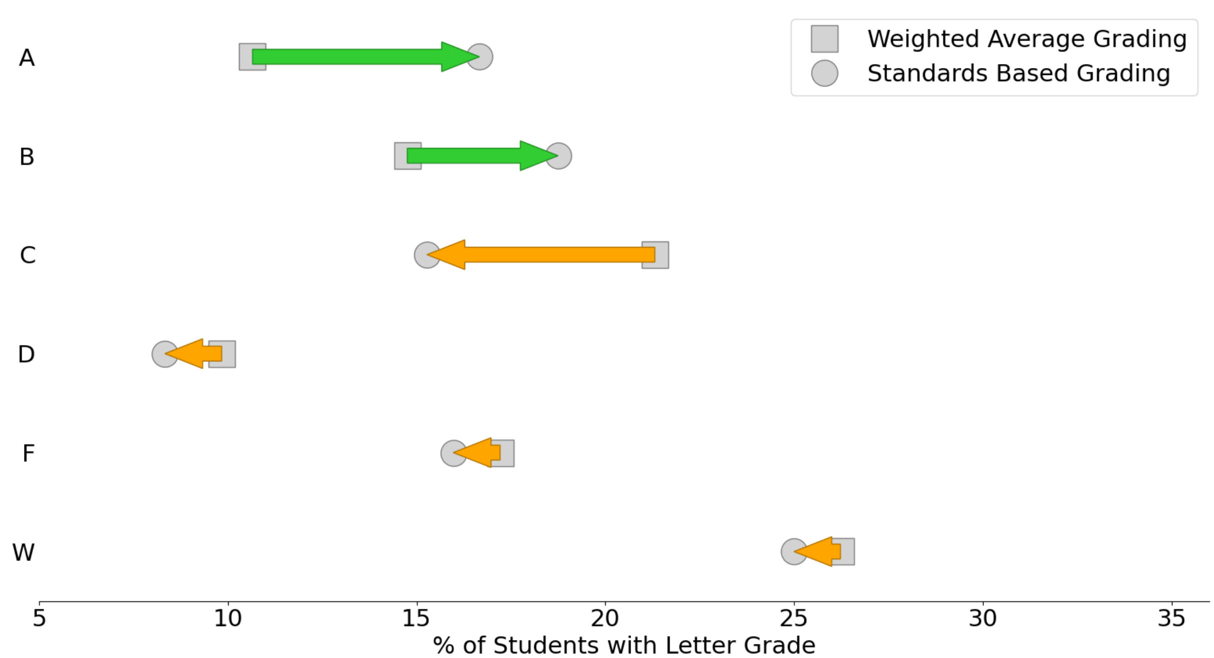

Figure 2: Follow-on math courses outcome comparison

Discussion

In analyzing final grades for College Algebra courses, we did not observe a statistically significant difference between the pass rate of students enrolled in SBG and WAG sections. However, compared to WAG, we observe two interesting trends in the SBG data that warrant further investigation. First is the grade distribution, where we observe that grades tend away from the customary average (C) towards the extreme ends of the scale.

Anecdotal evidence gathered from classroom experience suggests that our observation is best explained by our students' behavior, and thereby eludes quantification in our analysis. For context, we note that WAG courses follow a standard departmental syllabus that utilizes a high-stakes testing regime to determine the final grade (see Table 5). As noted in the introduction, we frequently observe two types of perverse outcomes in WAG: students with a final grade that under-represents their knowledge and students with a final grade that over-represents their knowledge. The former category is frequently inhabited by capable students who have no course to remediate mistakes made early in the course, while the latter is inhabited by students who earn just enough partial credit to pass the class.

Table 5: Weights for coordinated WAG College Algebra course.

Instrument	**Weight**
In Class Exam (4)	$33.\bar{3}\%$
Cumulative Final Exam	50%
Homework	$16.\bar{6}\%$

The commonality between these two groups in a WAG course is often a grade of C. In the SBG courses, we expect the students in the former category move up, while the latter category moves down, accounting for much of the movement away from a final grade of C. The capable students who struggle at the beginning of the course are often determined to improve, regardless of the grading scheme, and are rewarded in the SBG course with a grade that reflects this effort. However, the student who would normally pass on the basis of partial credit alone will typically fail the course if he or she approaches it the same as a WAG course. From our perspective, the behavioral aspect of failure lies partially with student motivation and partially with buy-in [15].

In particular, we have observed a subset of students — especially in general education courses — who seemingly refuse to use the reassessment mechanism to improve content knowledge. Indeed, these students make a mistake on the first attempt at a standard and, rather than use the mistake to grow, continue to make the same mistake on future reassessments. While we have attempted to rectify this phenomenon using frequent reminders about the need to remediate past mistakes and available resources for doing so (e.g. office hours, tutoring centers, etc.), some students appear unmoved by our efforts to persuade them.

Additionally, we believe some of the growth in failing grades (D and F) can be attributed to a phenomenon we have dubbed "False Hope" that occurs at the deadline to withdraw from a course. In the traditional WAG course, under-performing students can use Table 5 to come to the realization that it has become mathematically impossible to pass the course and subsequently withdraw. However, the structure of SBG provides a student in a similarly grim situation a glimmer of hope that he or she can radically change his or her behavior and finish the course with a passing grade. This comeback rarely comes to fruition due to the substantial number of standards the student must master on the remaining assessments. While we tell our students plainly that this type of comeback is highly improbable, some portion remain undeterred.

The second noteworthy trend that we observe is a pronounced improvement of SBG students in the follow-up math course compared to their peers in WAG courses. Particularly, the percentage of students earning a grade of A or B is significantly higher for students having taken the SBG College Algebra course than for those having taken the WAG College Algebra course, while the percentage of students earning a grade of C is significantly lower for students having taken the SBG College Algebra course than for those having taken the WAG College Algebra course. This appears to provide preliminary evidence to support anecdotal claims in the literature that students in SBG courses earn grades that more accurately reflect student knowledge [9] [4] and learn concepts at a deeper level than their peers in WAG courses [10] [11] [12]. This suggests the need for a carefully designed longitudinal study of outcomes for students in SBG courses to confirm these hypotheses.

Conclusion

This study examined the implementation of SBG in College Algebra courses and its impact on student outcomes compared to traditional WAG. While no statistically significant differences in pass rates were observed, the grade distributions and trends in follow-up course performance suggest that SBG may better reflect students' mastery of course material. These findings provide preliminary evidence that SBG fosters deeper engagement and learning, though further research is needed to confirm these trends.

We recognize the limitations of this study, including the small sample size and reliance on a single instructor for SBG sections. Additionally, the variability in student demographics and external factors may have influenced the results. Future work should address these limitations by expanding the sample size, involving multiple instructors, and exploring the long-term effects of SBG across diverse contexts.

From this experience, we gained valuable insights into the challenges and benefits of SBG. The iterative nature of SBG empowers students to learn from their mistakes, fostering a growth mindset and encouraging persistence. However, securing student buy-in requires consistent communication and support, and some students may struggle to adapt to the demands of this grading system.

We encourage other educators to explore SBG in their own classrooms and to contribute to the growing body of research on its efficacy. By working collectively to provide quantitative and qualitative evidence, we can better understand how SBG impacts student learning and engagement. With continued investigation and collaboration, SBG has the potential to transform grading practices in STEM education, promoting mastery and meaningful learning for all students.

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A Standards

Chapter P

P.3.1 I can simplify expressions involving rational exponents and convert between them and radical notation.
P.6.1 I can determine where a rational expression is undefined.
P.6.2 I can combine rational expressions using addition, subtraction, multiplication, and division. I can simplify the resulting rational expression.

Chapter 1

1.1.1 I can solve linear and absolute value equations in one variable.
1.1.2 I can solve an equation involving rational expressions.
1.3.1 I can find the distance and midpoint between points in the plane.
1.3.2 I can complete the square to put the equation of a circle into standard form. I can translate between the standard form and the graph of the circle.
1.4.1 I can graph a line by plotting any two points on the line. I can determine the slope of the line passing through two points in the plane. I can write the equation of that line using Point-Slope and Slope-Intercept Form.
1.4.2 I can determine whether two lines are parallel or perpendicular, and I can find the equation of lines that are parallel or perpendicular to a given line.
1.5.1 I can solve quadratic equations using each of the following methods: Complete the square, Factor, The Quadratic Formula, and The Square Root Method.
1.6.1 I can solve general polynomial, polynomial-like, and quadratic-like equations and verify that a value is a solution to a given polynomial equation. I can solve equations involving rational exponents, including radical equations.
1.7.1 I can solve linear and absolute value inequalities in one variable. I can express the solutions to these inequalities graphically and using interval notation.

Chapter 2

2.1.1 I can find the domain and range of a given relation. I can determine whether a relation is a function.
2.2.1 I can identify, evaluate, and graph piecewise defined functions.
2.3.1 I can use transformations to graph a function.
2.4.1 I can compose functions, decompose functions, and correctly identify the domain of a composition.
2.5.1 I can determine whether a given pair of functions are inverses of one another. I can determine whether a function is one-to-one and, if so, find its inverse.

Chapter 3

3.1.1 I can determine the following attributes of a quadratic function: opens up or down, the vertex, the x-intercepts, the y-intercept, and the line of symmetry. I can use this information to graph a quadratic function.
3.1.2 I can use quadratic functions to solve minimization and maximization problems.

Chapter 4

4.1.1 I can identify an exponential function, its domain, its range, and whether it represents growth or decay. I can use this information to graph an exponential function.
4.1.2 I can solve application problems involving exponential functions.
4.2.1 I can identify a logarithmic function, its domain, and its range. I can use this information to graph a logarithmic function.
4.3.1 I can evaluate logarithms, using the change-of-base formula as necessary. I can use properties of logarithms to combine and expand logarithmic expressions.
4.4.1 I can use the properties of exponentials and logarithms to solve equations.

Chapter 5

5.1.1 I can solve a system of linear equations in two variables using the methods of elimination and substitution. I can determine whether a system of linear equations is consistent and, if so, whether the system has a unique solution. If the system is dependent, then I can express the solution space as a set.

I can solve a system of linear equations in three variables by building on the techniques learned in 5.1.1