Mastery Grading System for Chemistry

Rules & Metrics

"Without continual growth and progress, such words as improvement, achievement, and success have no meaning."
-- Benjamin Franklin

Introduction

The mastery grading system for chemistry is based heavily on a technique known as *standards-referenced* grading. The standards-referenced grading system scores students based on their ongoing improvement in various general and content skills, not as an average of their performance throughout the grading term. Essentially, it rewards students for diligence in working to master each skill in the course, and does not penalize them for lacking skills in any particular indicator when they first begin to learn new material. Instead, as they practice and participate in the course's inquiry activities, their skills improve and, commensurately, so do their scores improve. In effect, early, less successful attempts to demonstrate mastery have no impact on a student's final grade.

In this system, students do not receive a composite score or grade for each individual assignment that they complete as they might in a traditional course. Instead, students are scored on a 1 to 10 scale[1] for area of content and skills known as "mastery indicators." Each mastery indicator encompasses a specific chemistry topic or non-content "general skill," which in turn contains a number of concepts, ideas, and skills that students will be able to do flawlessly (or nearly so) by the end of the course. Each indicator is scored based on a simple rubric which essentially describes a student's relative mastery for that area.

> *Example: if a student has only mastered the naming of binary ionic, polyatomic ionic, and binary molecular compounds, but still has difficulty with acids, multiple-charge metals, and alkanes, that student will have acquired a score of at least 5 (for mastering half of the items, which in this case are weighted equally), but could have a higher score depending on the degree of difficulty experienced with the other three.*

"Research indicates that the score a student receives on a test is more dependent on who scores the test and how they score it than it is on what the student knows and understands" (Marzano, 2006, p. 30). A substantial benefit of the mastery grading system is that it offers the instructor only a small amount of discretion in the assigning of a mastery score (since the mastery of a concept is cut and dry, especially in qualitative analyses, since the student's projected skills are based on the New Jersey Core Curriculum Content Standards for science). As in any inquiry-based classroom, students will also participate in metacognition and self-reflection with some frequency, and their explanation of their thinking will aid them in boosting any given score to a higher level of mastery.

[1] This scale is arbitrary, selected primarily because it lends itself to simple mental math. An instructor could easily adjust this scale to fit his or her own specific needs.

Example: a student shows difficulty with the mathematics involved in solving problems with Hess's law, but her reflective writing indicates that she has a strong conceptual grasp of the material. This may lead the instructor to assign her a slightly higher mastery score (typically only one point) for Thermochemistry (enthalpy and Hess's law), and then work with her to get the mechanics correct.

This example leads in to the most important benefit of mastery grading: because each and every assessment explicitly defines the mastery indicators necessary for that assessment, along with an "expected mastery" to solve the problem thoroughly, students get instant and specific feedback on their strengths and weaknesses, and can focus their efforts on specific skills and concepts. Traditional assessments, which are typically scored out of an arbitrary number of points, do not by their nature provide students with specific feedback on their strengths and weaknesses, and therefore the instructor is as unaware of each of the students' needs as are the students themselves. Mastery grading offers just this type of feedback, and makes it easy and systematic for students to determine their exact current performance and future improvement needs.

The complete alphabetical list of mastery indicators follows. They are divided into two categories, which are relevant for the rubrics (below), but they carry equal weight regardless of their classification:

General Skills

1. Arithmetic
2. Literacy (reading comprehension)
3. Literacy (writing)
4. Oral Communication
5. Preparedness
6. Safety
7. Teamwork
8. Timeliness

Chemistry Content*

9. Atomic Structure
10. Bonding Theory
11. Chemical Reactions
12. Dimensional Analysis
13. Electrons
14. Elements
15. Gas Laws (BCGC, ideal gases)
16. Gas Laws (DLPP, GLE)
17. Intermolecular Forces
18. Laboratory Technique
19. Lewis Structures
20. Measurement
21. Mole Concept
22. Nomenclature
23. Periodic Law
24. States of Matter
25. Stoichiometry (excess/limiting)
26. Stoichiometry (MMVP)
27. Thermochemistry (calorimetry)
28. Thermochemistry (enthalpy)
29. Thermochemistry (flow of energy)
30. VSEPR Theory
31. Water, Aqueous Systems, & Solutions

**The appendix at the end of this document lists the specific content items and NJCCCS standards covered by each of the content indicators.*

A Note About Curriculum

It is important to point out that the mastery grading scheme *does not* require a change in existing curriculum. Students learning chemistry in a class using the mastery grading system will be exposed to an identical curriculum as students in a course using a traditional points-based grading system. Student in each class are also assessed in the same way, using the same types of assessments. Ultimately, the difference lies *in the way grades are reported*. The nature of the tracking method, which involves a more strategic means of providing feedback to students, is what leads ultimately to greater performance.

How Student Skills are Assessed

The mastery grading system serves to reinforce individual skills as a part of the whole, even when they are presented as component parts of a problem or system to be solved. Mastery grading allows students to determine their precise areas of strength and weakness and focus on honing and refining those skills.

Whenever a problem is presented for grading, a grid of "Mastery Indicators" required for completion of a problem will be provided with the assessment. Each of these areas can be scored referred to as a "Mastery Score") on a scale of 1 through 10, with a 1 indicating Below Basic mastery, and a 10 indicating Superior mastery. These individual scores are not combined to give an overall "grade;" rather, the individual skill mastery areas have an impact on the student's overall grade for the term.

Competence in all of the mastery indicators for the term is reflected in a running tally of the student's grade for the term. Of course, the end of each marking period requires computation of final grade. The student's overall mastery of chemistry content is reflected in the form of a traditional percentile grade on the report card – a simple average of all of the mastery indicators being assessed for that term.

When a student achieves a degree of mastery in a particular area (on the 1 to 10 scale), the instructor uses the mastery value to compute the grade for the term. Since chemistry is a cumulative subject, any mastery indicators that are necessary for the following term are transferred to that term *beginning at the level of mastery achieved in the previous term.* For example, if a student achieves mastery score of 8 in Dimensional Analysis in Marking Period 1, that student would begin Marking Period 2 with a mastery score of 8 in Dimensional Analysis. From this point, the student can continue to improve that score (or, strictly speaking, it could dip back below 8).

Adaptation to ProgressBook and East Culture

In an effort to integrate Mastery Grading into the Chemistry 1A course at Cherry Hill East, certain considerations must be made of the method used to rank students and the limitations of the grade-tracking software, ProgressBook.

In this Chemistry course, students will be assessed and scored using the Mastery Indicators, but several instances of the same indicator may appear throughout the course of the term. These may be adjusted in their scale (out of 5, or 6, or 8, for example, rather than 10) to reflect the relative difficulty and, ultimately, mastery of each specific assessment. As with the normal Mastery Grading System, students will be have multiple opportunities to improve their previous scores, with lower scores having little or no impact on later, improved scores.

I also reserve the right to offer "interim assessments;" that is, composite assessments scored outside of the Mastery Indicators. These assessments will typically be formative, and will supplement the mastery indicators, especially for units with many complex and challenging concepts.

Assessment Example

Below is an example of a typical mastery assessment for the unit on stoichiometry. Note that the grid of Mastery Indicators includes, in the second row, an "Expected Competency" for each of the indicators. These are approximate baseline degrees of mastery required to complete this particular problem. The "Comments" section offers a dedicated space for the instructor to make notes about the student's work.

Stoichiometry (Limiting Reactants) – Mastery Assessment

Ammonia Production by Dry Distillation

Mastery Indicators for this Problem

Nomenclature	Dimensional Analysis	Mole Concept	Chemical Reactions	Stoichiometry (limiting)	Literacy (reading comprehension)	Literacy (writing)
6	**10**	**8**	**6**	**10**	**6**	**5**
Comments:						

Prior to World War II, ammonia was produced by a process called dry distillation, by which solid ammonium chloride and solid quicklime (calcium oxide) react to form calcium chloride, calcium hydroxide, and ammonia gas.

If 80.0 g of ammonium chloride is allowed to react with 50.0 g of quicklime:

a. How many grams of the excess reactant are left over?
b. How many grams of ammonia are formed?
c. Summarize what is occurring during this reaction in plain English and in no more than one concise, grammatically correct sentence.

In this particular example, there are seven mastery indicators for the student to consider when working through the problem. A description of the expected degree of mastery for each area follows:

- **Nomenclature –** This problem requires the writing of chemical formulas for binary ionic, polyatomic ionic, and molecular compounds. The molecular compound in this case is indicated by its common name, one of several which students are required to be familiar with. The expected degree of mastery for this problem reflects the fact that no multivalent cations or organic molecules are included in this problem.
- **Dimensional Analysis –** Flawless dimensional analysis is required for successfully solving a Stoichiometry problem.
- **Mole Concept –** The student must understand the mole concept, calculate molar masses, and interconvert between moles and mass within the dimensional analysis setup. Since the conversion between mass tends to be less challenging for students that conversions involving particles and volume, absolute flawless mastery of the mole concept is not required.

- **Chemical Reactions –** This problem lists the products and reactants of this reaction, so prediction is not required. The student must arrange these compounds into a reaction and balance it properly. The expected degree of mastery reflects the lack of product prediction in this problem.
- **Stoichiometry (limiting & excess reactants) –** Students must have a comprehensive understanding of the process of stoichiometry, must be able to determine the proper method for finding the limiting and excess reactants, and properly interpret and manipulate the results of their calculations.
- **Literacy (reading comprehension) –** Students must properly interpret all aspects of this problem, discount unnecessary information, and use the given information properly in the problem. The expected score represents the relative difficulty of decoding and understanding this problem.
- **Literacy (writing) –** Students must concisely describe the process occurring in this problem in plain English.

Why Mastery Grading Works

A standards-referenced approach to grading is a more effective method of assessing student achievement because it simultaneously addresses a number of important points about academic achievement. It allows students to move on to the next area of content even if they have not obtained complete mastery of the current material. The opportunity to examine new material and apply existing knowledge to it offers the potential to improve understanding in previous content areas.

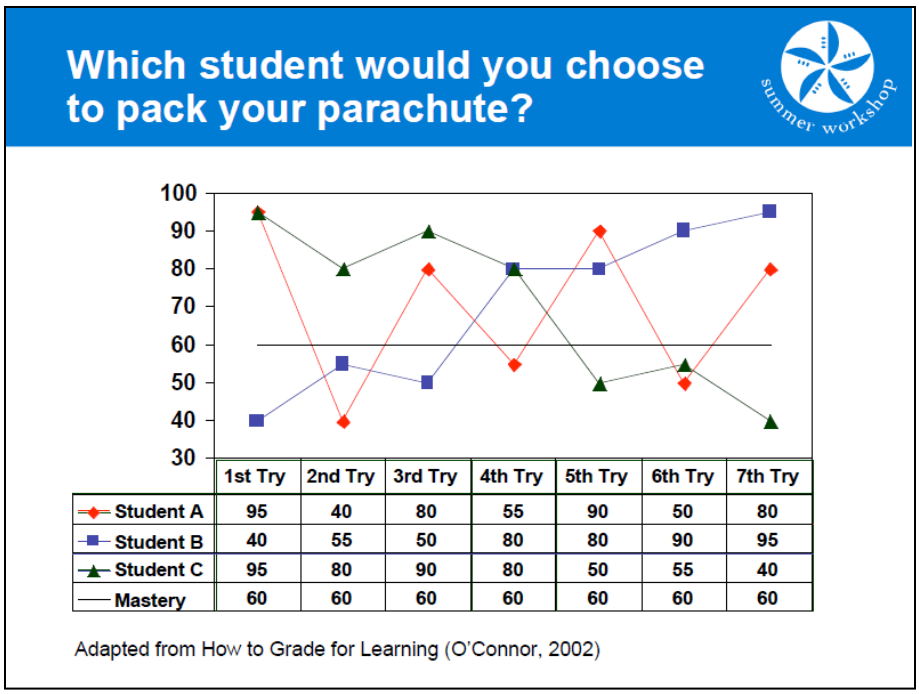
The design of the rubrics and the associated lessons allow the mastery scores assigned to indicate exactly what students know and are able to do in each content area. This allows the teacher to measure a student's progress towards mastering each content strand of each standard. The rubrics, combined with the skills and concepts lists in the appendix, also clearly communicate the learning expectations well in advance of beginning to work on a topic, and so students have some sense of how their performance in the present will impact their performance on future indicators.

Learning under this system in very organic – students will continue to improve as they practice, discuss, and apply complex knowledge, and they are evaluated ultimately on how much they have improved (a cumulative measure of their progress over time), and they are not penalized by their early, unskilled mistakes. Assessing students can occur whenever it is appropriate to do so, not just as a matter of routine. And when they are assessed, each of the various indicators relevant to the assessment is evaluated independently, revealing specific misunderstandings, strengths, and areas in need of improvement.

The slide shown on the next page is from a United States Department of Education presentation developed to demonstrate how a grading system like this one works. In this example, the graph shows the progress of four students over time as they learn to pack a parachute.

Careful analysis of the graph shows that student A demonstrates inconsistent skill – there is no guarantee that his next attempt to pack a parachute will be successful. Student C starts off well, but for some reason his performance drops off and his mastery in incomplete.

Student B's first few attempts are unsuccessful; however, after more practice and instruction, that student shows consistent mastery performance. This is the type of performance that the mastery grading system seeks to foster in chemistry. Naturally, it is expected that students will demonstrate imperfect performance in content they have never encountered before, but should ultimately show a consistent ability to do chemistry successfully.



	1st Try	2nd Try	3rd Try	4th Try	5th Try	6th Try	7th Try
Student A	95	40	80	55	90	50	80
Student B	40	55	50	80	80	90	95
Student C	95	80	90	80	50	55	40
Mastery	60	60	60	60	60	60	60

Adapted from How to Grade for Learning (O'Connor, 2002)

Standards-referenced grading in chemistry would be unsuccessful without chemistry's inquiry learning model. With an inquiry approach to learning, students use authentic experiences to construct their knowledge with high-level thinking, and they are much more likely to demonstrate meaningful understanding rather than just the rote repetition of facts. This translates to higher mastery scores as the students will be able to demonstrate their ability to understand complex or abstract concepts, synthesize ideas that were not directly taught, and approach problems with the highest levels of thinking.

What Happens When a Student Masters an Indicator?

Ultimately, students will begin reaching high levels of mastery in some (or many) indicators. Some students will, naturally, do this more quickly than others. Despite the engaging nature of inquiry, it is inevitable that some students may feel compelled to reduce their effort once their scores begin to reach the top of the rubric. So what happens when a student feels that now that he or she has reached mastery, and uses it as an excuse to stop working to improve that indicator?

Simply, students must continue to demonstrate mastery or their mastery score in an indicator can slip and be reduced. Just because a student has demonstrated mastery in the past does not guarantee that the student will maintain that level of skill. Each student must continue to demonstrate mastery to hold a high score in any given indicator.

Mastery Grading and Homework

Standards-referenced grading does not directly penalize students' work towards a standard for their attendance, effort, degree of participation or even their timeliness in completing assessments. In fact,

most assessments under this system are *untimed* – students' mastery of a standard is a function of his ability to solve a problem, not to beat the clock.

Lack of positive behaviors in areas like attendance, effort, and so forth can of course lead indirectly to a dip in performance. They are all required to achieve each standard, so weaknesses in these "non-assessed" areas will lead to poorer performance, while strengths in these areas will lead to superior performance. Essentially, factors that do not directly influence achievement of mastery of the standards are not reported as a part of a students' performance. They may, however, be reported by other means (such as disciplinary reports or parental conferences). Timeliness, as shown on the list of indicators, *is* an assessed indicator, and will be scored appropriately.

Attendance, promptness, effort, and degree of participation are most frequently associated with the degree of performance on homework. However, in the mastery system, there is very little compulsory homework assigned. The few assignments that are given with a deadline will still be scored for mastery according to the normal rubrics, but *may* be penalized for behaviors like timeliness under that separate indicator.

Most critically, homework assignments may vary from student to student, as they will focus on different levels of the mastery indicators, depending on the student's degree of mastery. This customization is intended to make completion of compulsory homework more likely and more effective as a teaching tool, since it aligns more closely with each student's needs.

Rubrics

Content Indicators

The rubrics for the mastery indicators are divided into two types. The content rubric, below, applies to all of the chemistry content areas only:

1. Atomic Structure
2. Bonding Theory
3. Chemical Reactions
4. Dimensional Analysis
5. Electrons
6. Elements
7. Gas Laws (BCGC, ideal gases)
8. Gas Laws (DLPP, GLE)
9. Intermolecular Forces
10. Laboratory Technique
11. Lewis Structures
12. Measurement
13. Mole Concept
14. Nomenclature
15. Periodic Law
16. States of Matter
17. Stoichiometry (excess/limiting)
18. Stoichiometry (MMVP)
19. Thermochemistry (calorimetry)
20. Thermochemistry (enthalpy)
21. Thermochemistry (flow of energy)
22. VSEPR Theory
23. Water, Aqueous Systems, & Solutions

	Descriptor	Student is able to:
10	**Superior**	• independently **synthesize** ideas, concepts, and patterns and **construct** meaning from them. • **skillfully analyze** complex problems and **apply** [multiple] comprehensive solutions. • **make no errors with the simple and complex** ideas and processes.
8-9	**Advanced**	• **synthesize** ideas, concepts, and patterns. • **skillfully analyze** complex problems and **apply** comprehensive solutions. • **make few or no errors with the simple and complex** ideas and processes; errors are **self-corrected**.
6-7	**Proficient**	• e**ffectively analyze** complex problems but shows only **some ability** to **apply** solutions. • **make no errors or omissions with the simple** ideas and processes. • **make few or no major errors or omissions** with **complex** ideas and processes.
4-5	**Basic**	• a**dequately analyze** complex problems but shows only **limited ability** to **apply** solutions. • **make few or no major errors or omissions with the simple** ideas and processes **but makes major errors** with **complex** ideas and processes.
1-3	**Below Basic**	• **demonstrates no or significantly limited ability** to **analyze** complex problems or apply solutions. • **makes major errors or omissions with the simple and complex** ideas and processes.
0	**No Score**	• demonstrates no success in this area even with extensive guidance from peers and the instructors.

The rubrics for each of the general skills indicators are presented in the following pages. They each require unique strands for evaluating students, and as a result do not fit well into the above template. These rubrics still use the six descriptors presented below for consistency:

Superior indicates a clear and strong understanding of the material. These students are capable of analyzing the problems presented in this topic at the highest levels of thinking, and can make connections that were not presented in class. These students typically have no trouble solving multi-step problems involving this topic, and can frequently be relied upon to serve as "deputy teachers" to help other students with the material. Students at this level of mastery can make connections about the material that are not explicitly "taught" in the class.

Advanced indicates a very sound understanding of the material, but with a small amount of room for improvement. These students can also think at the highest levels, and can also generally serve as deputy teachers to instruct other students, but their mastery is imperfect but typically need very little (if any) guidance to correct their own mistakes.

Proficient understanding indicates that the student has a substantial understanding of the material. These students may occasionally demonstrate thinking at the highest levels, but typically their performance is closer to the middle of the taxonomy. These students generally require occasional to regular guidance from their peers or instructor, and will not typically have a strong enough knowledge of the material to help other students. This student may encounter some difficulty when combining this topic with others in a multi-part problem.

Basic understanding indicates that the student has some grasp of the material, but it is mostly at the lower levels of thinking. The student can recall facts and perhaps solve some basic problems by replicating solutions seen in their notes, but their ability to analyze problems and evaluate evidence is limited. This student typically requires extensive guidance and may even have difficulty retaining material from day to day. A student who persists at this level for multiple assessments and over several indicators may need to reconsider his or her level placement in the course.

Below Basic understanding indicates essentially no grasp of the material. The student may remember random, disconnected facts, but makes no connections from day to day and shows no ability to even replicate examples when assessed. Students at this level are in need of substantial intervention, beyond that of peer or instructor guidance. A student who persists at this level for multiple assessments and over several indicators may need to reconsider his or her level placement in the course.

Rubrics

General Skills Indicators

1. Arithmetic
2. Literacy (reading comprehension)
3. Literacy (writing)
4. Oral Communication
5. Preparedness
6. Safety
7. Teamwork
8. Timeliness

	Arithmetic	Laboratory Technique
10	• Demonstrates a **clear and strong** understanding of arithmetic and algebra as it applies to chemistry content. • Demonstrates a **clear and strong** understanding of the use of a calculator when used for course-relevant arithmetic.	• Student demonstrates a **clear and strong** understanding of the laboratory techniques described in course materials, lab activities, and as modeled by the instructor.
8-9	• Demonstrates a s**ound** understanding of arithmetic and algebra as it applies to chemistry content. • Demonstrates a **sound** understanding of the use of a calculator when used for course-relevant arithmetic.	• Student demonstrates a **sound** understanding of the laboratory techniques described in course materials, lab activities, and as modeled by the instructor.
6-7	• Demonstrates an **adequate** understanding of arithmetic and algebra as it applies to chemistry content. • Demonstrates an **adequate** understanding of the use of a calculator when used for course-relevant arithmetic.	• Student demonstrates an **adequate** understanding of the laboratory techniques described in course materials, lab activities, and as modeled by the instructor.
4-5	• Demonstrates an **insufficient** understanding of arithmetic and algebra as it applies to chemistry content. • Demonstrates an **insufficient** understanding of the use of a calculator when used for course-relevant arithmetic.	• Student demonstrates an **insufficient** understanding of the laboratory techniques described in course materials, lab activities, and as modeled by the instructor.
1-3	• Demonstrates a **very limited** understanding of arithmetic and algebra as it applies to chemistry content. • Demonstrates a **very limited** understanding of the use of a calculator when used for course-relevant arithmetic.	• Student demonstrates a **very limited** understanding of the laboratory techniques described in course materials, lab activities, and as modeled by the instructor.
0		
NJCCCS		

	Literacy (reading comprehension)	Literacy (writing)
10	• **Independently identifies** the purpose of the text. • Demonstrates an **insightful understanding** of the relevant aspects of the topic. • **Consistently and independently** makes connections to other topics and texts. • **Explores** multiple possibilities of meaning, offering original ideas.	• Content, organization, and style are consistent with the Cherry Hill Writing Rubric (9-12) for this mastery level (see Appendix A).
8-9	• **Independently identifies** the purpose of the text. • Demonstrates **a literal understanding** of the relevant aspects of the topic. • **Frequently and independently** makes connections to other topics and texts. • **Explores** multiple possibilities of meaning.	• Content, organization, and style are consistent with the Cherry Hill Writing Rubric (9-12) for this mastery level (see Appendix A).
6-7	• **Identifies** the purpose of the text with some peer guidance. • Demonstrates a **literal understanding** of the relevant aspects of the topic. • **Frequently** makes connections to other topics and texts with some guidance from the instructor or peers. • **Identifies** different meanings in the text.	• Content, organization, and style are consistent with the Cherry Hill Writing Rubric (9-12) for this mastery level (see Appendix A).
4-5	• **Identifies** the purpose of the text with some peer guidance or class discussion. • Demonstrates an **insufficient** of the relevant aspects of the topic. • **Sometimes makes connections** to other topics and texts with some guidance from the instructor or peers. • **Makes inferences** about the meaning of the text, but some are irrelevant and/or illogical.	• Content, organization, and style are consistent with the Cherry Hill Writing Rubric (9-12) for this mastery level (see Appendix A).
1-3	• **Identifies** the purpose of the text with some instructor guidance or class discussion. • Demonstrates a **very limited** understanding of the relevant aspects of the topic. • **Requires guidance** from the instructor or peers to make connections with other topics and texts. • **Unable** to make inferences even with assistance.	• Content, organization, and style are consistent with the Cherry Hill Writing Rubric (9-12) for this mastery level (see Appendix A).
NJCCCS		

	Oral Communication	Preparedness
10	• Demonstrates a **clear and strong** command of grammatically correct English. Word choice enhances clarity and vividness. Vocabulary is **appropriate** for the topic and for the audience. • Vocal delivery is **clear and dynamic**, **enhancing** the understanding and interest of the listener. • Nonverbal delivery (eye contact, posture, and body language) **enhances** the understanding and interest of the listener.	• **Always** shows up to class prepared for warm-up activities. • **Always** shows up to class with the required materials, including, but not limited to, a notebook, writing utensil, and calculator.
8-9	• Demonstrates a **sound** command of grammatically correct English. Word choice enhances clarity and vividness. Vocabulary is **appropriate** for the topic and for the audience. • Vocal delivery is **clear and distinct**, **holding** the understanding and interest of the listener. • Nonverbal delivery (eye contact, posture, and body language) **somewhat enhances** the understanding and interest of the listener.	• **Usually** shows up to class prepared for warm-up activities. • **Usually** shows up to class with the required materials, including, but not limited to, a notebook, writing utensil, and calculator.
6-7	• Demonstrates an **adequate** command of grammatically correct English. Word choice enhances clarity and vividness. Vocabulary is **appropriate** for the topic and for the audience. • Vocal delivery is **clear and audible**. • Nonverbal delivery (eye contact, posture, and body language) neither **enhances nor hinders** the understanding and interest of the listener.	• **Frequently** shows up to class prepared for warm-up activities. • **Frequently** shows up to class with the required materials, including, but not limited to, a notebook, writing utensil, and calculator.
4-5	• Demonstrates an **insufficient** command of grammatically correct English. Word choice enhances clarity and vividness. Vocabulary is **appropriate** for the topic and for the audience. • Vocal delivery is **droning, indistinct, or inaudible**. • Nonverbal delivery (eye contact, posture, and body language) neither **enhances nor hinders** the understanding and interest of the listener.	• **Sometimes** shows up to class prepared for warm-up activities. • **Sometimes** shows up to class with the required materials, including, but not limited to, a notebook, writing utensil, and calculator.
1-3	• Demonstrates a **very limited** command of grammatically correct English. Word choice enhances clarity and vividness. Vocabulary is **appropriate** for the topic and for the audience. • Vocal delivery is **droning, indistinct, inaudible, or disruptive to the speaker's context**. • Nonverbal delivery (eye contact, posture, and body language) **hinders** the understanding and interest of the listener.	• **Rarely** shows up to class prepared for warm-up activities. • **Rarely** shows up to class with the required materials, including, but not limited to, a notebook, writing utensil, and calculator.
NJCCCS	• Demonstrates no oral communication skills.	

	Safety	Teamwork
10	• **Always** wears appropriate personal protection equipment in the laboratory. • **Always** practices safe handling of lab materials and equipment and **properly disposes** of waste materials. • Demonstrates a **clear and strong** understanding of the use and handling of laboratory equipment. • **Always models** good safety practices by observing and encouraging other students in the lab.	• Demonstrates a **clear and strong** understanding of each of the four roles of the inquiry team. • **Very effectively** fulfills the role(s) assigned on a team. • **Very effectively** participates in the maintenance of a fair and reasonable division of labor on the team.
8-9	• **Usually** wears appropriate personal protection equipment in the laboratory. • **Usually** practices safe handling of lab materials and equipment and **properly disposes** of waste materials. • Demonstrates a **sound** understanding of the use and handling of laboratory equipment. • **Usually models** good safety practices by observing and encouraging other students in the lab.	• Demonstrates a **sound** understanding of each of the four roles of the inquiry team. • **Effectively** fulfills the role(s) assigned on a team. • **Effectively** participates in the maintenance of a fair and reasonable division of labor on the team.
6-7	• **Frequently** wears appropriate personal protection equipment in the laboratory. • **Frequently** practices safe handling of lab materials and equipment and **properly disposes** of waste materials. • Demonstrates an **adequate** understanding of the use and handling of laboratory equipment. • **Frequently models** good safety practices by observing and encouraging other students in the lab.	• Demonstrates an **adequate** understanding of each of the four roles of the inquiry team. • **Moderately** fulfills the role(s) assigned on a team. • **Moderately** participates in the maintenance of a fair and reasonable division of labor on the team.
4-5	• **Sometimes** wears appropriate personal protection equipment in the laboratory. • **Sometimes** practices safe handling of lab materials and equipment and **properly disposes** of waste materials. • Demonstrates an **insufficient** understanding of the use and handling of laboratory equipment. • **Sometimes models** good safety practices by observing and encouraging other students in the lab.	• Demonstrates an **insufficient** understanding of each of the four roles of the inquiry team. • Only **occasionally** fulfills the role(s) assigned on a team. • **Dominates or withdraws** from the group activity rather than **participating** in the maintenance of a fair and reasonable division of labor on the team.
1-3	• **Rarely** wears appropriate personal protection equipment in the laboratory. • **Rarely** practices safe handling of lab materials and equipment and **properly disposes** of waste materials. • Demonstrates a **very limited** understanding of the use and handling of laboratory equipment. • **Rarely models** good safety practices by observing and encouraging other students in the lab.	• Demonstrates a **very limited** understanding of each of the four roles of the inquiry team. • **Rarely** fulfills the role(s) assigned on a team. • **Dominates or withdraws** from the group activity rather than **participating** in the maintenance of a fair and reasonable division of labor on the team.
NJCCCS		• Does not participate in team activities.

	Timeliness
10	• **Always** demonstrates timeliness with submission of assignments and keeping of appointments.
8-9	• **Usually** demonstrates timeliness with submission of assignments and keeping of appointments.
6-7	• **Frequently** demonstrates timeliness with submission of assignments and keeping of appointments.
4-5	• **Sometimes** demonstrates timeliness with submission of assignments and keeping of appointments.
1-3	• **Rarely** demonstrates timeliness with submission of assignments and keeping of appointments.
NJCCCS	

References

Beal, H. and J. Trimbur. "Writing as a Tool for Teaching Chemistry." *Journal of Chemical Education* 70 (1993): 478-479.

Deci, E. L., & Flaste, R. (1996). *Why we do what we do: understanding self-motivation*. New York: Penguin Books.

Kohn, A. (2006). *The homework myth: why our kids get too much of a bad thing*. [Cambridge, Mass.]: Da Capo Lifelong.

Marzano, R. J. (2006). *Classroom assessment & grading that work*. Alexandria, VA: Association for Supervision and Curriculum Development.

Marzano, R. J. (2010). *Formative assessment & standards-based grading*. Bloomington, IN: Solution Tree.

Appendix

Topics, Skills & Concepts by Mastery Indicator

Listed Alphabetically

Bonding Theory

- Valence electrons, the octet rule, and exceptions
- Ionic bonding , electron transfer, and the properties of ionic compounds
- Metallic crystals and alloys
- Shared electrons and covalent bonding
- Resonance and bond energies
- Molecular orbitals, sigma and pi bonds, and hybridization
- Bond types and physical properties

Chemical Reactions

- The symbols used in and the structure of chemical equations
- The rules governing the activity of elements, ions, and compounds
- The five types of chemical reactions
- The solubilities of reactants and products
- The relationship between reactants and their potential products

Dimensional Analysis

- Unit conversions

Electrons

- The concept of wave mechanics
- Rules and principles governing electron placement in atoms
- Quantum numbers
- Electron configurations (including exceptional atoms)
- Orbital diagrams
- Lewis dot structures of neutral atoms

Elements

- Names and symbols of common elements
- Locations of common elements on the periodic table

Gas Laws (BCGC, ideal gases)

- Charles's Law
- Gay-Lussac's Law
- Boyle's Law
- Avogadro's Law
- Combined Gas Law
- The assumptions underlying the Ideal Gas Law
- The format, units, and application of the Ideal Gas Law

Gas Laws (DLPP, GLE)

- Dalton's Law of Partial Pressures
- Graham's Law of Effusion

Intermolecular Forces

- van der Waals forces
- London dispersion forces
- Permanent and induced diploes
- Hydrogen bonding

Laboratory Technique

- Material handling and disposal
- Proper use of equipment
- Cleaning and storage of equipment
- Experimental technique

Measurement

- Metric System
- Dimensional Analysis
- Unit Conversions
- Accuracy and Precision
- Significant Figures
- Scientific/Decimal Notation

Mole Concept

- The concept of the mole
- Mole quantity conversions
- Molar mass of elements and compounds
- Concentration of solutions (and its relationship to the mole)
- Empirical and molecular formulas of chemical substances

Nomenclature

- Nomenclature and formula writing conventions for binary ionic, polyatomic ionic, and multivalent ionic compounds, as well as Arrhenius acids and bases, binary molecular compounds, and basic organic compounds

Periodic Law

- Historical development of the periodic table and Mendeleev's contribution
- Groups, periods, families, and sections of the periodic table
- Nuclear charge, penetration, and shielding
- Periodic trends

States of Matter

- Kinetic theory of matter (a model for gases)
- Properties of solids, liquids, and gases at the macroscopic and molecular level
- The various changes that can occur between the phases
- The relationships between the three phases and their temperature and pressure

Stoichiometry (MMVP)

- Relevance of the molar coefficients to the arithmetic of chemical reactions
- Use of dimensional analysis to determine the quantitative components of a chemical reaction

Stoichiometry (excess/limiting)

- Analysis of calculations to determine and analyze limiting and excess reactants
- The difference between limiting and excess reactants

Thermochemistry (calorimetry)

- Calorimetry
- Determination and application of specific heat capacity

Thermochemistry (enthalpy)

- Heats of fusion and vaporization
- Enthalpy of reaction and of solution
- Hess's Law

Thermochemistry (flow of energy)

- Endothermic and exothermic systems
- Measurement of heat flow

Lewis Structures

- Lewis structures of single-center molecules
- Lewis structures of multiple-center molecules

VSEPR Theory

- Determination of the molecular geometry of molecules
- Bond angles
- Bond and molecule polarity

Water, Aqueous Systems, and Solutions

- Hydrogen bonding and its relationship to the physical and chemical properties of water
- The solution process (solvation)
- Strong electrolytes, weak electrolytes, and non-electrolytes
- Hydrates and hydration
- Suspensions, colloids, emulsions, the Tyndall effect, Brownian motion, and coagulation
- Solubility and saturation
- Henry's law
- Concentration of solutions
- Colligative properties of solutions