Mastering the Next Generation of Science Standards

Teaching to Transform with Hands-On STEM Instruction

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* This eBook is an updated version of the eBook *"Mastering the Next Generation of Science Standards."*

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Introduction

With the introduction of Next Generation Science Standards to K-12 classrooms, teachers and administrators are searching for ways to understand the constructs of these new criteria, interpret them in their own classrooms, and apply their principles for student mastery.

In this eBook, you'll learn about:

- The STEM cycle
- What makes the NGSS tougher than previous iterations
- How the new standards link with Common Core ELA, math and arts, allowing educators to teach across the curriculum
- How the new standards affect the traditional methods of STEM instruction in the K-12 classroom (and how that change is not business as usual)
- How teachers can support the shift with robust, effective STEM resources

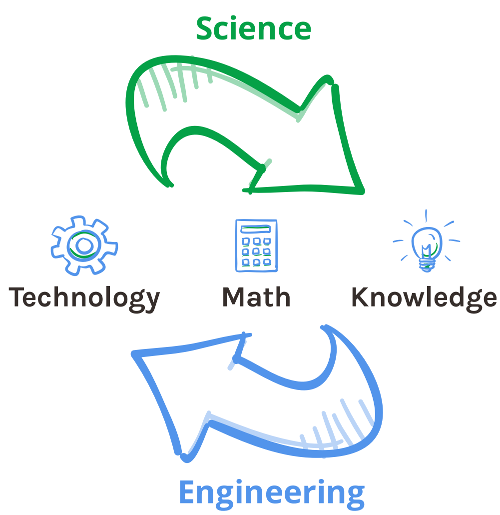
SECTION 1:

NGSS Science Standards And The Stem Cycle: A Primer

CHAPTER 1:
The STEM Cycle: A Cycle Of Innovation

It's a question a lot of educators have: **At their core, what are the Next Generation Science Standards all about? Why do they exist? Why do we even need to consider changing our approach and methods?**

It all boils down to this: the STEM cycle.



In essence, **the STEM cycle explains why 100 percent of students must be exposed to STEM—because STEM skills are life skills.** Locked in the STEM cycle are the seeds of critical thinking—creative, evaluative, and analytical thinking skills that are transferable and that make students trainable. These skills are the key to workforce development and the underpinnings of a student's future college and career opportunities.

When we think about the STEM cycle of innovation, we think about the relationships between science, technology, engineering and

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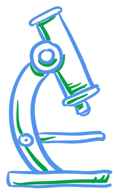
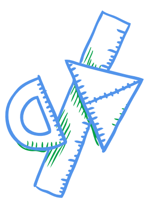
math. Those are the foundations of the Next Generation Science Standards, and the foundation of innovation and revolution in the STEM industries beyond school.



What is Science?

The Next Generation Science Standards give us a solid definition of what science is: ***knowledge from experimentation.*** Scientists ask questions, then develop hypotheses and use experiments to test those hypotheses. The purpose of an experiment is to produce data that allow scientists to reflect on a hypothesis and ultimately see if it's supported or not supported.

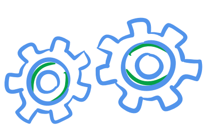
In the pursuit of answering questions using experiments, scientists develop scientific knowledge.



What is Engineering?

Engineers solve problems using scientific knowledge. It's worth noting, however, that a problem is not always something that's electronic or physical, and engineering is not always about building a bridge, designing a wind turbine or constructing a wall—it's broader. At its core, engineering is about solving a problem. The way you go about that is to identify and research the problem, survey the available materials, and then create prototypes to test. Engineers then use the data from those tests to determine whether a prototype does indeed create a solution to the problem.

Engineers produce technology to solve problems.

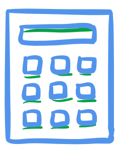


What is Technology?

Software created in the Silicon Valley is technology: it solves problems. Spreadsheets and computers solve problems by enabling humans to store, transfer and convey data at fast rates and low costs. Aspirin and parking lot lines are also technology. Technology solves problems that directly or indirectly push society and innovation further, enabling scientists and engineers to ask questions and design experiments more frequently, more efficiently, and at whole new levels.

Technology restarts the STEM cycle as new questions can be asked or answered, and new knowledge is applied to solve problems.

But why is math at the center of the cycle?



Where Does Math Belong in STEM?

As scientists or engineers go about their work, constructing procedures for testing their hypotheses or prototypes, those procedures need specific language. Math serves, helping convey specific information, capturing specific measurements and analyzing data to understand the outcomes of testing. Math therefore is a tool for communication, replicating, and verifying the claims of others.

Math is the tool for quantifying or measuring and then communicating information.

This cycle applies to STEM in the K-12 classroom as well as careers. When we look at the STEM cycle this way, we should be duplicating what engineers and scientists do in the real world—asking questions and solving problems. This means equipping students to be engineers and scientists by allowing them to create hypotheses, build prototypes, test, analyze, and then use math to quantify their outcomes and communicate that information to peers.

CHAPTER 2:

NGSS: A Three-Legged Stool of Standards

Understanding the relationship between the core STEM components in the cycle is very helpful to understanding—and applying—the three dimensions: practices, disciplinary core ideas, and crosscutting concepts that we find within the Next Generation Science Standards.

The NGSS present a clear directive for what students should get from STEM education: Effective STEM teaching will result in learning where a student can demonstrate an understanding of this standard in any relevant context.

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The crux is this: A student can demonstrate what they have learned in any related context. In this way, the NGSS performance expectation is like the seat of a stool with three legs (the three dimensions) holding it up. Those legs not only support the standard, they help form the context in which the students will be expected to demonstrate understanding.

The three “legs” are the three dimensions:

1

Science and engineering practices: This is a skills dimension, something you may be familiar within the Common Core math practices. The practices demonstrate skills specific to the discipline—in this case, STEM—and help form processes, becoming a means of accessing background content.

2

Disciplinary core ideas are the content leg. NGSS content was chosen because it’s dynamic and interacts other areas of content in a system. Many parts interrelate and pull different areas into contact such as life science and earth science. Disciplinary core ideas are intended to scaffold this way.

3

Crosscutting concepts are akin to systems thinking. They relate to how the content behaves in a system. Consider an ecosystem as a metaphor. You can think about the way matter moves in nature, between plants, animals and decomposers, and understand it as a whole or in parts. These parts interrelate as elements of the water cycle, life cycle, food chains, and food webs.

CHAPTER 3:
New Practices and New Processes in Instruction

Before NGSS, you may have used textbooks or taken a content approach centering on understanding and applying. What the new standards ask is that we go further in creating, evaluating and analyzing, so that students are not only *consuming* the content but are actually *participating and interacting* with it, working to develop it within the classroom.

This is the key: The new classroom experience asks students to play the role of scientist and engineer, take ownership of their learning, and work with the content and engage in the practices. That is how the practices connect with that disciplinary core idea. **The content background is the disciplinary core idea and the way content behaves in context is the crosscutting concept.** These are big shifts—the idea that students not only need to develop STEM skills, but that they also need to engage them as they create, evaluate, and analyze within the STEM classroom.

And the best ways to engage practices are within the content itself.

The 8 STEM Practices

Under NGSS, as a result of STEM instruction, a student must be able to:

1. **Ask** questions (for science) and **define problems** (for engineering).
2. **Develop and use models,** but not just something given to them. They must actually participate in that development.
3. **Plan and carry out investigations,** which goes deeper than just being given a procedure. They must be able to plan the investigation and plan the procedure itself.
4. **Analyze and interpret data,** applying math to hunt for the key data points that support a claim about their hypothesis or prototype solution.
5. **Use mathematics and computational thinking.** Think of this as considering scale when designing a prototype, being able to figure out resources required, conduct multiple trials, and determine sources of error and orders of magnitude.
6. **Construct** explanations (for science) and **design** solutions (for engineering).
7. **Engage in argument** stemming from evidence.
8. **Obtain, evaluate and communicate information.**

Using these practices, students are effectively engaging as scientists and engineers in their classrooms.

The effect is a classroom in which the teacher is no longer the sage distributing facts—with 30-plus students in class, it's impossible to regulate the flow of knowledge to each individual student all the time. Engaging students in the practices of science

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and engineering allows educators to instead become facilitators of a STEM learning environment where students are discussing in an organized way and interacting with content, but are also expected to engage those practices and challenges themselves to solve problems and answer questions.

The result: A much more authentic science or engineering lab experience than would often be considered under standards prior to NGSS.

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SECTION 2:

NGSS And Common Core ELA, Math And Arts

There are a number of crossovers between Next Generation Science Standards and Common Core math and ELA practices. Here are a few real-world examples of each.

CHAPTER 1:

STEM and ELA

Common Core ELA Technical Subject Standards

- Cite specific textual evidence to support analysis of science and technical texts. RST6-8.1
- Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. RST6-8.2
- Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. RST6-8.3
- Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). RST6-8.7
- Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. RST6-8.8

The first Common Core ELA technical subject standard for grades 6-8 asks that **students use evidence to support analysis of science technical texts.** As students are engaging in the Next Generation Science Standards, they have that opportunity. They should be able to accurately summarize text distinct from prior knowledge. Further, as students assume the role of scientist and engineer, they generate their own nonfiction text using the scientific process or engineering design process. At that point, they are within the research and summary-applying aspects of this standard.

Another Common Core ELA technical subject standard is to **integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.** Thinking back to the STEM classroom, as students gather data to analyze, they have the opportunity to create line graphs, bar graphs, pie charts and pictograms, even at an early age.

In fact, there are many opportunities in the creation of infographics to engage students to express information visually in the context of the Next Generation Science Standards.

Finally**, distinguishing among facts, reasoned judgment based on research findings, and speculation in a text** is an ELA standard, but it is also the culminating piece of any STEM process, whether science or engineering related. This process requires students to engage in evidence-based writing. As they come back as a class to debrief, it's also an opportunity to look at what approach they are taking with their partner, compare that to their peers' work, analyze the differences, create explanations and then reason, separating fact from opinion and reasoned judgments.

CHAPTER 2:
STEM and Math

Common Core Math Practices

1. Make sense of problems & persevere in solving them
2. Reason abstractly and quantitatively
3. Construct viable arguments & critique the reasoning of others
4. Model with Mathematics
5. Use appropriate tools strategically
6. Attend to precision
7. Look for and make use of structure
8. Look for & express regularity in repeated reasoning

Overall, math presents a huge opportunity to teach across standards. Common Core math practices very closely relate to NGSS science and engineering practices, from making sense of problems and reasoning abstractly, to constructing viable arguments, modeling with mathematics and strategically using appropriate tools.

Using tools strategically is not just about using a hammer or a saw. Calculating mean, median and mode and then choosing the proper process—scientific or engineering design—to attend to precision in that process also constitutes using tools. Further, the

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logic side of math crosses the curriculum easily, especially in processes where students are looking for and making use of structure as they develop efficient test procedures.

A common ELA process writing assignment in schools asks students to write the steps for making a peanut butter and jelly sandwich. The result is that you often get students who come back with 50-step procedures that they then mimic in class…and the outcome is hardly a sandwich. **The reality is that making use of structure in a procedure is also about efficiency and using recursive steps.** So, you can equate it with efficient science and engineering. Take computer science as an example. The core value of computer science is software engineering. And in that, a person is not only learning a language, but also learning how to solve a problem by using that language, and then structuring the directions in a way that computers can carry out an activity using the fewest lines of code possible.

CHAPTER 3:
STEM and STEAM

Math and ELA cross the curriculum lines by using science and engineering practices—critical thinking skills that are developed using the STEM practices—**but what about art?** That crossover works as well, and we call it STEAM: science, technology, engineering, arts and mathematics.

At its core, art is engineered communication. Take Pablo Picasso's Guernica, for example. Oftentimes when STEAM is referenced, the conversation is around aesthetics. Guernica is widely considered one of Picasso's most famous works, but it's perhaps not the most traditionally beautiful work of art, so how could it be considered his best? **Because it was created by a master artist who engineered communication through it, using his critical thinking skills—STEAM skills.**

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Picasso created Guernica while living in exile as a reaction to and reflection of the atrocities committed at Guernica by fascists. They later confronted him asking, *"What is it that you did here?"* His answer: *"I didn't do this. You did."* In that reply, you can see Pablo's skill and creativity reflected in the analysis he used to comment on the political context of his time. Oil and canvas gave him the opportunity to say something meaningful to a specific audience and the population at large. It's a powerful analogy, and a powerful construct: **mastering STEM practices equips students with the critical thinking skills to be better creators and more attuned consumers of art.**

The bottom line: the Next Generation Science Standards give us a tool—we must just choose to use it. It's a clear opportunity to teach across the curriculum, which is what educators should be considering in any case to get more bang for their buck when it comes to time and learning.

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SECTION 3:

NGSS And K-12: Supporting The Shift With Effective Resources

Because of the Next Generation Science Standards, the classroom experience is moving away from the traditional models of remembering, understanding and applying information. Memorizing information, like that there are solids, liquids and gasses, won't cut it anymore. The idea that we know this rock is sedimentary because it has layers isn't enough. What is going to move students forward is being able to use that knowledge to analyze a situation, evaluate a problem or create something?

The question then becomes: How do educators facilitate the development of higher order thinking skills with STEM?

CHAPTER 1:
Standards vs. Curriculum

Curriculum development starts with understanding the difference between standards and curriculum.

- **Standards** are like health department regulations: a bar that has been set and should be achieved.
- The role of **curriculum** is to articulate an experience that connects all aspects of STEM in a cohesive experience where standards are being introduced, mastered and reinforced both throughout the year and from year to year.

In the case of NGSS, where there are grade-specific standards, these **standards are not owned by each grade level's teachers.** Everyone is responsible for all the standards—for mastering what is in their grade level, but also for introducing the next level and reinforcing prior grade-level standards.

To some it might sound like a daunting task, but broken down it simply means **thinking about the context for mastery in one grade level as an opportunity for introducing or reinforcing standards from other grade levels.** Doing that, you create a robust curriculum that's cohesive from September to June but also from grade to grade, which is incredibly important in many schools, especially in those where students may be transient.

Consider a student who has entered a district at grade five, and come from an entirely different state. If the curriculum isn't designed to blend across grade levels, to introduce, master, and reinforce from level to level, gaps in learning will happen.

A new breed of STEM resources, however, based closely on the National Research Council's new definition of quality STEM instruction, helps blend grade levels and implement context-driven instruction for today's learners.

But how do you assess that? We can think about it as fresh context. The student has learned about states of matter and has that background, but now they can also use their skills to understand why a chocolate bar may have changed shape in the sun and consider what precisely has changed about it. Will they be able to look at something like dry ice and understand where it has gone when it is left in the sun? Will they be able to talk about how the change occurred? Where the heat from the sun came from? Where the solid of the ice has gone and how its mass has changed? That is engaging higher order thinking skills.

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CHAPTER 2:

A New Definition of Effective STEM Instruction

According to the National Research Council's 2011 definition of effective STEM instruction (a definition that helped lay the foundation of what would become the Next Generation Science Standards), *"Effective STEM instruction capitalizes on students' early interests and experiences, identifies and builds on what they know, and provides them with experiences to engage them in the practices of science and sustain their interest."*

The word choice in this statement is all very deliberate. To deconstruct it:

- **Effective STEM instruction capitalizes on a student's early interests and experiences,** meaning it is a nurturing process that's never one and done; it's linked systemically with curriculum, and not simply September through June, but all throughout a student's academic experience.
- **It builds,** which is to say the guideline recognizes that a multipurpose science "kit" (or other broad resource) does a disservice to students. A 1st grader is vastly different from a 2nd grader, who is vastly different from a 3rd grader. As they hit developmental milestones, their experiences change, creating an opportunity. But if the curriculum isn't designed that way, it's not a benefit; it's an Achilles heel.
- **Identifying and building on what students know** requires articulating curriculum as a team, so it's not every person for himself or herself. By approaching STEM systemically, educators have the chance to not only identify what students know, but build on that as educators support their peers below and above. Consistency is key here—as students go

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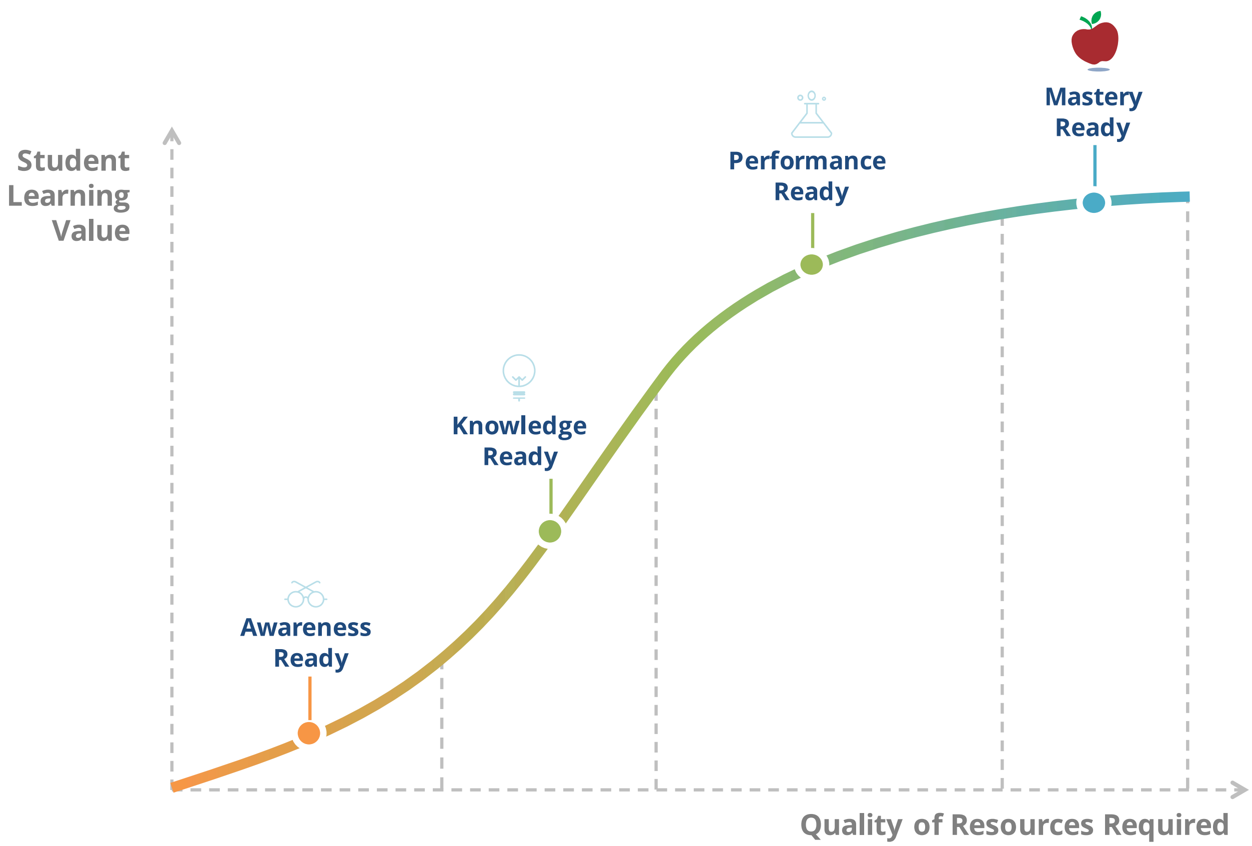
through school, if the definition of what is science, and what is engineering changes in dramatic ways, it creates confusion and impacts engagement and success.

- **Engaging students in the practices of science** means just that: making those skills real and actionable in the classroom, not presenting students with memorization or fill-in-the-blanks. It's about using skills to access content in a way that is active, attractive, and sustains interest so the curriculum keeps momentum one grade to the next.

The crux is a shift in the model of teaching: From teacher-centered where lessons are pre-configured and where students are asked to present lessons back just as they went in, to a model in which students are challenged to develop and use their skills and practice them in a novel context that engages them in problem solving and answering questions. It's achieved through resources that shift student readiness in the classroom to mastery ready.

CHAPTER 3:
Moving From Awareness To Mastery

Resources can be categorized into four levels regarding their ability to create "readiness:"



Students who are **awareness ready** are able to raise their hand and answer the questions, *Who is a scientist?* and, *Who is an engineer?* Resources that promote awareness-readiness are the types you often get from museums and public awareness programs. They are generally aimed at making students familiar with the basics of what a scientist or engineer is, or ways a company or organization applies STEM knowledge to solve problems.

The shift from awareness to **knowledge readiness** takes place with textbooks. Textbooks accomplish the goal of getting students ready to tell you all about what scientists have discovered and what technology or problems engineers have developed. This, however, is simply knowledge. Students aren't actually engaging in science or engineering, and the reality is, textbooks don't have much of a place in the new standards.

Performance readiness comes from things like common science kits, which are geared toward putting a specific situation in front of students and having them learn. For example, if you want to find out how hard a rock is, you do a scratch test. And if you're asked, "How hard is a rock?" you know how to do a scratch test. This is real experience, but it's very context-specific.

To move from performance readiness to **mastery readiness,** students must develop transferable skills—skills that focus on problem solving or answering questions in any context, which is different from performance readiness.

For example, how often in life will someone be asked how hard a rock is? Unless they're a geologist, seldom, if ever. Instead, a more appropriate context might involve thinking about a contractor building a kitchen:

Builders have a lot of different materials they can choose from—some organic, some synthetic, some rock and mineral. If the contractor wants to decide which countertop is the most durable, could the student help?

This type of problem solving demands that a student really consider the question and use their STEM practice skills to explore the properties of each material. There are many dimensions to such a scenario such as: how do we define durability? Does the material scratch? Fracture? What happens when it gets hot or cold?

Students should then be able to develop their own model to gather data and support their answer to the question—**something that is evidence based.**

For instance, if the question is about durability and scratching, a student may suggest taking a sample from each of the materials and go about scratching it with items or materials that are often placed on countertops. The goal is to collect data that can be used to answer the question, and in this case, the building materials, determining which are more durable.

Superior STEM resources address mastery readiness—as do the Next Generation Science Standards. So, when you go about choosing and developing resources, you must think past identification and information and toward context and bringing content to life. The ultimate goal is giving students the ability to perform all expectations in class and take ownership and full responsibility, not simply absorb information and repeat it or perform a specific task in a linear, narrow way.

The problem is, many STEM resources on the market have recently rebranded themselves as Next Generation Science Standards resources. Be wary: many are not, and are not geared at the full release of responsibility to develop those skills.

So, what now? Know what your curriculum needs to create: those contexts, grade-specific mastery, introduction to further levels, reinforcement of previous levels, and it must enable the student to engage in the practices to access the content.

CHAPTER 4:

Guidelines For Choosing NGSS-Ready STEM Resources

Smart STEM curriculum enables the teacher to create an environment where students receive the nonfiction background necessary, have the deep discussions as a class, and then work in small teams to define questions, prototype solutions and communicate outcomes.

Fully NGSS-appropriate STEM curriculum engages students as full-on scientists and engineers with content and hands-on materials designed to enhance and deepen the discussion.

Integrated, collaborative STEM curriculum is consistent and complete September through June and includes continuous professional development that helps teachers map their existing skill sets to what's required in NGSS.

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KnowAtom believes a quality science, technology, engineering and math education is essential to turning students into critical thinkers with the problem-solving skills to change the world. We give schools everything they need to teach STEM and partner with teachers so that they have more time to engage with students and collaborate with peers. This gives students the ability to be scientists and engineers in the classroom.

KnowAtom's approach teaches students to analyze and evaluate, question and create. These skills aren't just useful in a science classroom. They're applicable to art, ELA, math, and social studies, as well as to college and career. Here, STEM is a way of thinking. Teaching is a way of transforming lives. And good resources are the tools that help everyone focus on what matters in the classroom.

Want to see how your current curriculum measures up?

Download this free rubric.

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