How to Maximize *Student Engagement* with Phenomena

KnowAtom™
Focus on what matters.

Table of Contents

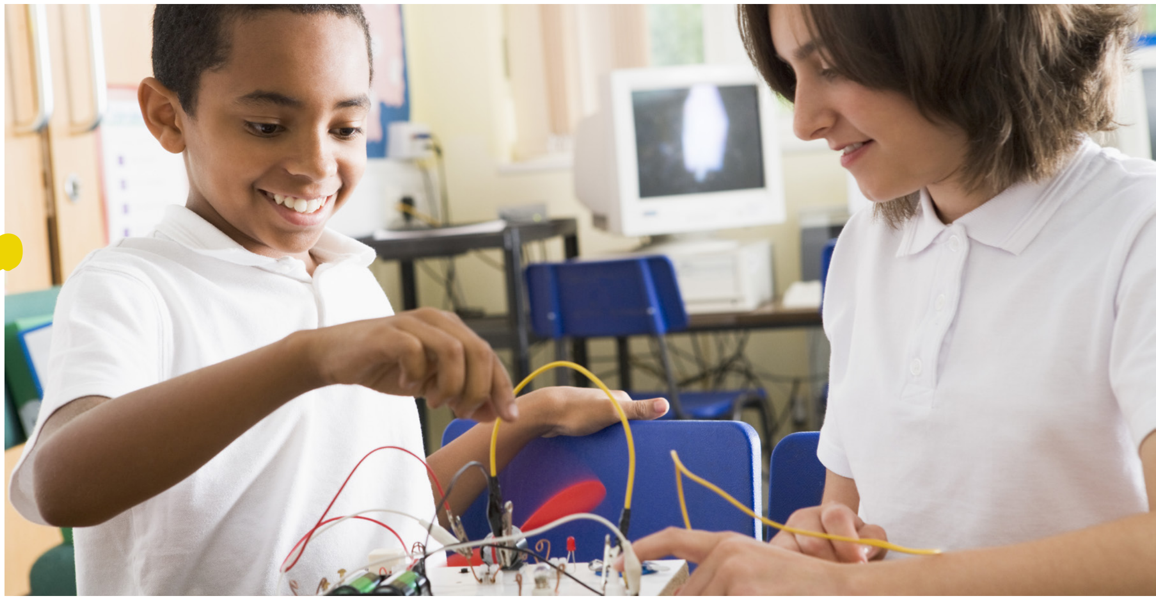
* This eBook is an updated version of the eBook *"Using Science Anchor Phenomena Effectively."*

KnowAtom™
Focus on what matters.

Introduction

The Next Generation Science Standards are all about students being scientists and engineers every day in the classroom. And if a student is going to be a scientist or engineer in the classroom, if that's going to be the mode of learning, there needs to be a purpose.

That's where phenomena come in.



Phenomena provide the real-world context for learning. When combined with the science and engineering practices (one of the dimensions of the NGSS), phenomena are a powerful way to engage students as scientists and engineers in the classroom.

Understanding the relationship between phenomena and the practices dimension of NGSS, and how that relationship shapes classroom teaching and learning, provides a framework for understanding how to master these new Next Generation Science Standards, whether you live in an adaptive or an adoptive state.

In this eBook, we will make the case that phenomena are central to a next generation-aligned instructional model because they allow students to develop and use all of the practices in a variety of contexts. We'll explore how the practices change teaching and learning in a science classroom, how the evidence statements provide evidence of the importance of phenomena to that teaching and learning, and how phenomena-driven learning is different from more traditional isolated tasks.

We will then describe a five-step process that educators can follow in their classrooms to pull phenomena through everything that they're doing, so that it is really the mode of teaching and learning.

KnowAtom™
Focus on what matters.

CHAPTER 1:

Why Phenomena Are Important with NGSS

The whole idea of using phenomena as part of the next generation inquiry environment is as a context to engage students as scientists and engineers.

We'll begin by defining phenomena and then explore the relationship between phenomena-based learning and the science/ engineering practices.

What Are Phenomena?

Phenomena are real-world contexts, and they're important because they give purpose to the work of scientists and engineers.

For scientists, a phenomenon is an observable event, a complex, real-world context that is something like coastal flooding, coral bleaching, or glaciers receding. All of these examples are complex, real-world phenomena related to climate change.

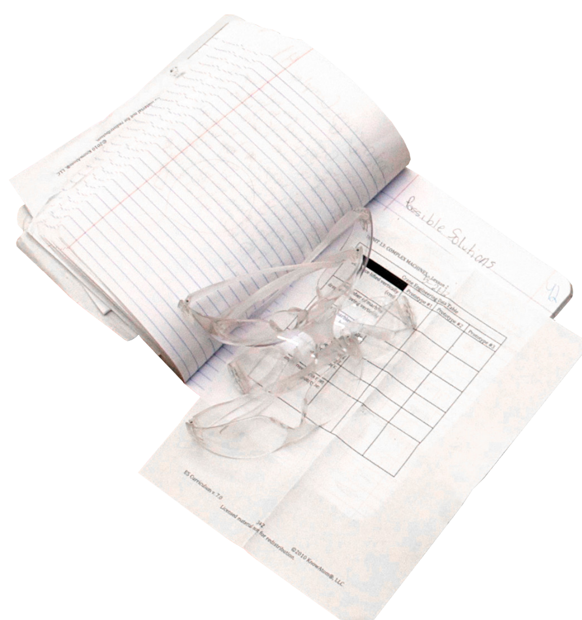
KnowAtom™ Focus on what matters.

Other phenomena include slipping and falling on a winter's day; organisms eating; seasonal light patterns; and computers crashing. These are all observable events, and they provide a context that scientists can develop and explore.

For example, a scientist could develop a question about coastal flooding—the observable event—and attempt to answer that question by testing a hypothesis with an experiment. Scientists use experiments to better understand the phenomena by gathering data and then using the data in an evidence-based conclusion.

For engineers, phenomena have to do with a problem that may be solved by extending their knowledge of science. Taking the example of coastal flooding, a scientist might be trying to understand why coastal flooding occurs, while an engineer's interest would be in trying to figure out how they could use their scientific knowledge to actually solve the issue of the water coming inland and perhaps flooding homes or businesses.

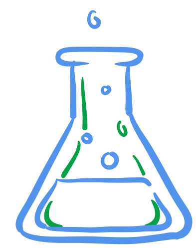
In other words, scientists answer questions through experimentation, and engineers solve problems through prototyping.



3 Ways Phenomena Transform Classrooms

In an educational setting, using phenomena as the foundation for learning transforms classrooms in three important ways.

1. STUDENTS ARE ENGAGED AS SCIENTISTS AND ENGINEERS.



If you want to engage students as scientists and engineers, you must create a shift so that students go from *doing* science to actually **being** scientists. This shift can also be thought about as a shift from learning *about* something to actually figuring out aspects of a context.

It is impossible to engage students as scientists and engineers so that they are figuring out questions to answers and solutions to problems if they aren't engaged in real-world scenarios—which are the phenomena.

This leads to the second way that phenomena transform classrooms:

2. STUDENTS ARE EMPOWERED TO BUILD A FRAMEWORK OF UNDERSTANDING ABOUT THE WORLD AROUND THEM.

As educators, we need to empower students to build a framework of understanding out of something that is actually happening or has actually happened.

The real world is literally the world around us, which means phenomena are events that students see and experience every day. For instance, Superstorm Sandy is a real historical event that is complex, and it creates a rich context in which students can begin to unpack and build a framework of understanding. Using

examples such as this can generate a variety of questions that students can approach as scientists as well as an abundant opportunity for them to problem-solve as engineers.

When students explore something that is real-world, there is an inherent relevance to their lives. They start to understand that connections they make in the classroom extend beyond the walls of the classroom, which means the skills they are developing also extend beyond the classroom.

If real-world phenomena drive what students learn, then students will analyze, evaluate, and create in the context of the real world. By doing that, the real world around the students is actually the anchor for their understanding. It becomes a rich context, which students can use as a "filing system" for the skills they've developed, which can then be generalized and applied more broadly and in deeper contexts.

3. **STUDENTS IDENTIFY STEM AS AN OPPORTUNITY TO UNDERSTAND AND SHAPE THEIR WORLD.**

When students understand the relevance of what they're doing, they start to realize that they can apply the same skills they are developing in the classroom to the rest of their lives. This becomes a significant source of empowerment because it gives students the tools and skills to engage in science and engineering so that they can make sense of their environment and their lives.

How Phenomena Relate to the Science and Engineering Practices

As we've discussed, phenomena are the foundation for next generation instruction. However, they are only truly effective when they are coupled with students developing the science and engineering practices.

The science and engineering practices are really the key to turning students into scientists and engineers and achieving these three transformations because they are the skills that students need to develop to approach problems and questions with an eye toward solutions and answers.

These practices are very specific, involving eight steps that work together to give students the ability to engage successfully with phenomena and situations that they have not encountered before.

1. **Asking** questions (for science) and **defining problems** (for engineering)
2. **Developing** and using models
3. **Planning** and carrying out investigations
4. **Analyzing** and interpreting data
5. Using mathematics and computational **thinking**
6. **Constructing** explanations (for science) and **designing** solutions (for engineering)
7. Engaging in **argument from evidence**
8. **Obtaining, evaluating** and **communicating information**

In a next generation classroom, content is not enough anymore; it is the formation of skills, and the ability to develop and use content, that is so vital to the classroom experience today. Students need to be engaged in a context, the phenomenon, and through that, they will be challenged so they develop the necessary skills.

The role of the educator in this next generation classroom is as coach, setting expectations for students to use these skills and helping them understand what the skills are and what they mean.

This means being interested in the students' ideas, asking questions that require higher order thinking—creating, evaluating, and analyzing—in order to push students to develop and use that phenomena-based context further, and to push them into new areas of thinking.

This is where students build these skills to ask questions, and define problems, to develop models, to plan and carry out investigations, to not only interpret data but analyze it, gather it, think mathematically, construct explanations, design solutions, argue from evidence, and obtain, evaluate, and communicate information.

All of these skills happen in the context of the phenomena.

What the Evidence Statements Say

The standards themselves emphasize the importance of using phenomena to develop the practices, along with the other two dimensions—the disciplinary core ideas and crosscutting concepts.

NGSS and adaptations of those standards are performance expectations, so as a result of mastering a standard, a student needs to be able to perform the expectations of that standard.

The evidence statements break down the expectations of the standard.

Observable features of the student performance by the end of the grade:		
1	Supported claims	
	a	Students make a claim to be supported about a phenomenon. In the claim, students include the idea that plants and animals have internal and external structures that function together as part of a system to support survival, growth, behavior, and reproduction.
2	Identifying scientific evidence	
	a	Students describe* the given evidence, including:
		i. The internal and external structures of selected plants and animals.
		ii. The primary functions of those structures
3	Evaluating and critiquing evidence	
	a	Students determine the strengths and weaknesses of the evidence, including whether the evidence is relevant and sufficient to support a claim about the role of internal and external structures of plants and animals in supporting survival, growth, behavior, and/or reproduction.
4	Reasoning and synthesis	
	a	Students use reasoning to connect the relevant and appropriate evidence and construct an argument that includes the idea that plants and animals have structures that, together, support survival, growth, behavior, and/or reproduction. Students describe* a chain of reasoning that includes:
		i. Internal and external structures serve specific functions within plants and animals (e.g., the heart pumps blood to the body, thorns discourage predators).
		ii. The functions of internal and external structures can support survival, growth, behavior, and/or reproduction in plants and animals (e.g., the heart pumps blood throughout the body, which allows the entire body access to oxygen and nutrients; thorns prevent predation, which allows the plant to grow and reproduce).
		iii. Different structures work together as part of a system to support survival, growth, behavior, and/or reproduction (e.g., the heart works with the lungs to carry oxygenated blood throughout the system; thorns protect the plant, allowing reproduction via stamens and pollen to occur).

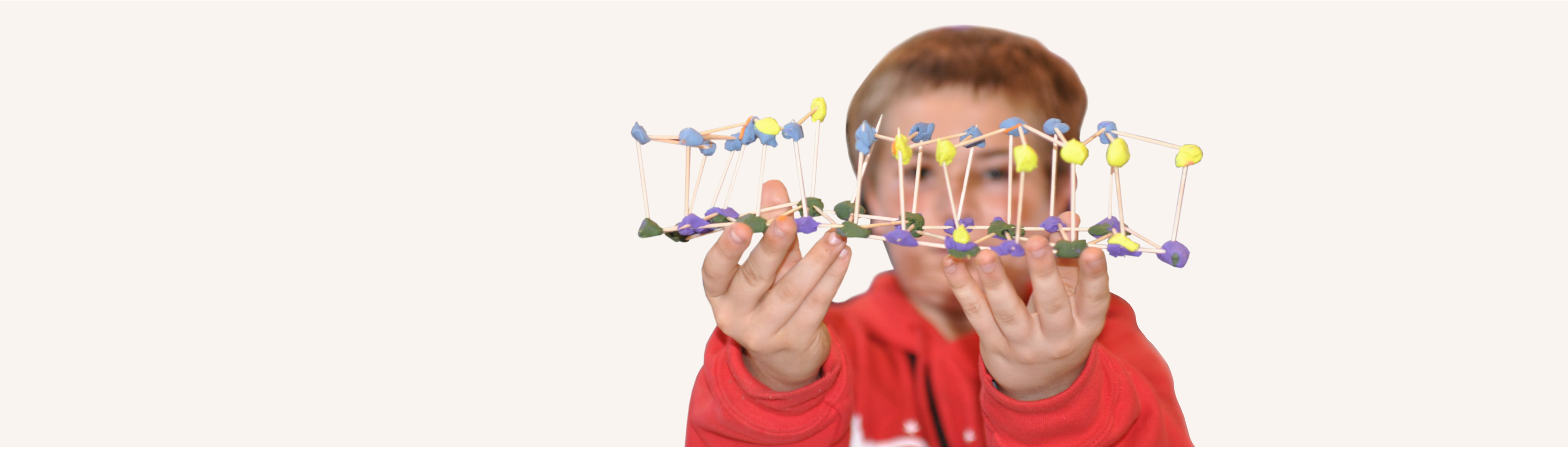
This image is an evidence statement from the Next Generation Science Standards for a 4th grade life science standard.

What you see here is that a student who has mastered this particular grade four life science standard has to be able to support their claim, which means they also need to have made a claim.

They also need to be able to identify scientific evidence, and evaluate and critique the strengths and weaknesses of evidence.

A student who can demonstrate mastery needs to not only make a claim, gather evidence, and use that evidence to evaluate and critique their own work and others', but they also need to come to an evidence-based conclusion about something.

These evidence statements highlight the importance of phenomena. Students will never be able to perform the expectations of the standards if they have not learned in context, if they have not had the opportunity to develop and use knowledge in order to answer questions and solve problems the way scientists and engineers do, because that is where students actually develop the science and engineering practices, it's where they connect the disciplinary core ideas, and where those disciplinary core ideas gain relevance, and it's where the crosscutting concepts comes to life right in front of them.



Isolated Tasks vs. Phenomenon-Driven Tasks

From a practical standpoint, an instructional environment that effectively uses phenomena and the practices to drive teaching and learning will not have students carrying out isolated tasks that don't use phenomena and therefore often lack any sort of relevance for the student.

For example, a common task asks students to count a tree's rings and calculate its age. This can be hands-on, using a real tree core sample. However, if students aren't developing their own ideas and using critical thinking skills, the learning is superficial.

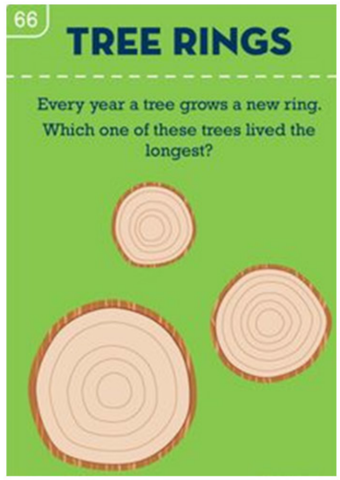


Image credits: Pinterest, Angell-Halabu Our Class Blog

Think of it from a student's perspective. They're asking themselves, "What's the purpose of this task, and why should I care?" These are questions that we as teachers need to ask ourselves as well.

Without any sort of phenomena to contextualize this task, student learning is happening in isolation. They aren't making connections to their own experiences, and they aren't developing the eight science and engineering practices.

Isolated tasks are a holdover from traditional standards and classroom instruction that are focused exclusively on content, without any room for the development of skills.

In contrast, phenomena-based learning begins with a real-world context. For example, it might involve a forest in which a number of trees are brown, perhaps dead.

Students, coached by the teacher, can begin to have a rich discussion around that, putting ideas forward, and then beginning to pull on what they know. Perhaps they remember the requirements for life and ask, “What do plants need to live? Is it possible these trees could no longer access one or more of these requirements? What if there was a drought?”

With this context, students can begin asking themselves, “Why are these trees brown? Are they dead? If so, why are they dead? What’s causing them to die? How long did they live?”

That is a very different way of approaching a task like counting rings because a student may then go from that level of questioning to say, “Well, how old are the trees? Perhaps they have reached the end of their life cycle.”

Or, “Perhaps it’s a cycle of drought, and we could look at the thickness of the rings.”

Now a task like counting rings has purpose based on the phenomena and the discussion that students have had as a group.

KnowAtom™
Focus on what matters.

A Teaching Process that Takes Time

It's important to note that learning to teach this way takes time, even for experienced teachers. It's an art. Art is engineered communication, and so learning to communicate and ask questions in the ways that is required to push students to plan appropriately, develop models without telling students, or to help them connect with the relevance, without trying to tell them the relevance of something, because that doesn't work, takes time.

It also requires trust. It requires trust in your students, and in yourself as an educator because it requires a release of responsibility.

If the release of responsibility doesn't occur, then the opportunity for the thinking, the opportunity to engage the rigor, to make appropriate mistakes, and to learn from those is not something students ever get to engage in, because somebody took control and didn't create that opportunity for them to grow in their knowledge and understanding.

KnowAtom™ Focus on what matters.

CHAPTER 2:

Anchor and Investigative Phenomena

When thinking about phenomena, it's important to understand the difference between the two kinds articulated by the National Research Council and NGSS: anchor and investigative phenomena.

Anchor Phenomena

Anchor phenomena are those observable, real-life contexts that form the basis of a question or a problem to be solved. They are very complex. They represent questions we can't answer in a single experiment or problems we can't solve in one round of prototyping. This context gives the lesson its overarching focus, but is nevertheless too broad to define a single lesson.

An example of that might be flooding in New York City. There are many reasons that New York City could experience flooding, so the topic isn't something that can be "solved" or "answered" in a single session. Rather, it provides a frame for the lesson.

When it comes to anchor phenomena, student questions and connections drive the teaching and learning. If students are really given the opportunity to, they will come up with plenty of testable questions and solvable problems, which become the investigative phenomena that narrow the scope.

Investigative Phenomena

Investigative phenomena are what students observe as a result of testing answers to questions about the anchor phenomena, or what is observed as a result of prototyping solutions to the problem identified in that anchor phenomena. In other words, the investigative phenomenon is an offshoot of the anchor phenomenon.

An example: if we once again use as anchor phenomena the flooding in New York City, then the investigative phenomena related to that might be how soil and ground cover affect water seepage because that is an element that affects flooding. It may be a part of answering the question of why flooding is occurring or solving the problem of alleviating the flooding.

When choosing phenomena, think about the anchor phenomenon first because it will give the lesson that overarching focus. Then hone in on the investigative phenomena that will form the true meat of each lesson.

One of the key points about investigative phenomena is that students must be able to observe them as a result of their investigation. And in order to observe something in their investigations, they need to be able to investigate; they need to be given an opportunity to run with their own idea and apply the science and engineering practices in a logical framework.

In other words, it's important to give students the freedom to investigate their own ideas. A student-centered investigation is really about giving students the freedom to have their own ideas and create their own connections to themselves, other concepts and the world around them, within some boundaries. The result is variation between one student's approach and ideas and thinking and another's, or one team's and another's.

It's not about a single linear path; in fact, it's much more the channel in a harbor. The boats have to stay between specified structures, but there's a lot of breadth in terms of where they can be.

Concept to Concept, Concept to Self and Concept to World Connections

In doing so, students will create a wide variety of connections that help them understand the anchor context in multiple dimensions, and eventually meet those performance expectations in all three dimensions.

This is because the use of investigative phenomena encourages direct connection between the student investigation and the student's preexisting knowledge and skills to understand the anchor context.

When student questions and connections drive teaching and learning, you immediately have a much richer context in which students can learn. When they observe real-world anchor phenomena and are then given the opportunity to explore them through more individualized investigative phenomena, you have dramatically increased the chances that they will forge those valuable concept-to-concept, concept-to-self, and concept-to-world connections.

CHAPTER 3:

5 Steps to Effectively Use Phenomena in Your Classroom

How can we use phenomena most effectively in the classroom? Here at KnowAtom, we've found that following a specific process is an essential part of teaching and learning—an approach recommended by the National Research Council and NGSS.

A quick note here: process is not the same as routine. For example, at an elementary school level, a routine might involve students coming into the classroom, taking off their coats, hanging them up, getting their book, and then going to their seat. There's a certain order that students follow.

However, changing the order of the elements in the routine does not change the outcome. It might make things a little chaotic, but a coat can still be hung on the hook after a student got their book, for example.

In contrast, all process is replicable, logical, and scalable, and its purpose is to help communicate and replicate findings. A process also has dependencies, which means that as you go from one element of a process to the next in learning, you're gaining momentum and adding value to the next part of the process.

That momentum is key. The Next Generation Science Standards really benefit from process, and that's why these practices are referred to in the National Research Council literature and in the

Achieve literature as being applied in process. They stop short of saying what that process is, so KnowAtom has its own process, which we've found to be most effective operationally in class.

Our process can be described in five steps, which KnowAtom users already follow but anyone can adopt in their own classrooms.

1

Step 1: Find a real-world anchor phenomenon.

The first step is to find real-world anchor phenomena, and use that phenomenon as the basis to start the process. If you're a KnowAtom user, you don't need to find anything because phenomena are the basis for all of our lessons.

If you don't use KnowAtom, that's fine. These are all things you can do in your class.

Remember that anchor phenomena are complex, real-world contexts. A phenomenon can be anything. You can look out your window any time of day or night and you will see real-world phenomena happening.

Remember that this anchor phenomenon has to be something that's too complex to replicate, just like that picture of the woods with the dead trees. You can't build a forest in your classroom, but students can encounter the phenomenon through informal observation in their everyday lives, through nonfiction text, through video, through environmental interactions.

KnowAtom™ Focus on what matters.

The anchor phenomena should relate to one or more of the standards you plan to explore in the lesson/unit, so the evidence statements are a good place to start for understanding what exactly is expected of students.

The anchor phenomenon you choose will form a thread through the lesson that guides student learning. Whatever students discuss and investigate should serve the goal of unpacking part of the anchor phenomenon to better understand it.

2 Step 2: Use the phenomena as the platform for Socratic dialogue.

We want students to become dissatisfied with their level of understanding about elements of the phenomenon. This often occurs as a result of collaborative reflection on the phenomena. That's how students get the value out of it and engage in the practices. It also encourages academic honesty because it may highlight the fact that we may think things for which we lack evidence.

The best way we've found to engage students in the phenomena so that they become dissatisfied is to transition from the introduction of the phenomenon (such as through nonfiction reading and/or video) into a Socratic dialogue. If you're not familiar with Socratic dialogue, it's a form of questioning that focuses on higher order questions that require students to create, evaluate, and analyze in order to respond.

The point of Socratic dialogue is to train students to bring their ideas forward, to do so with academic honesty, and to appropriately build on the ideas of others or have a dissenting opinion.

As the teacher, remember that your role is coach because Socratic dialogue is something that should be student-centered. You're training your students to ask those questions of each other.

This is key. If you have done any work in your schools with accountable talk, this is similar. It's changing the role of teacher from a sage on the stage, the content expert handing out facts and pre-teaching content, to "Let's engross the students in that anchor phenomenon right away, and then let's pull from them and teach them how to pull from each other using higher order questions, the relevance and connection to it, and let's expose a level of dissatisfaction with what we know. Let's expose the limits of what we know."

Through this process, students engage in a majority of almost all eight of these practices here. Students ask questions, define problems, and develop conceptual models. They analyze each other's opinions, the data being presented, elements from reading or video they may have seen in the unit, and so on.

What we're doing is maximizing students' opportunity to engage with the ideas so they can build on those ideas, find personal relevance in those ideas, and engage in the practices of science and engineering.

3 Step 3: Facilitate students arriving at a question or problem they can investigate.

After the Socratic dialogue, students come to that dissatisfaction, to the problem that hasn't been solved, or a belief for which there is no evidence yet, and this leads to a question or a problem.

Your role as teacher is to facilitate students arriving at a question or problem that they can investigate. That means arriving at a central question or problem as a group, which you can facilitate by asking the right kinds of questions.

It's usually best to do this as a class so you have a trajectory of questions and a reasonable boundary for the investigation. You want to be able to hold students accountable and create an environment where they can compare their findings to others' results.

The question or problem becomes the platform for what students investigate. For students to be scientists, they will need to develop a way to answer their question with evidence. For students to be engineers, they will need to identify a problem, and then pursue that problem to an evidence-based solution through prototyping.

Under the Next Generation Science Standards, mastery of a three-dimensional standard, which all the standards are, requires this kind of process approach.

4 Step 4: Coach students as they carry out their plan and gather authentic data.

The fourth step is coaching students as they carry out their plan and gather authentic data through investigative phenomena. As students move from their question or problem toward creating a plan, you coach them in that creation process by being an interested skeptic.

This doesn't mean asking a question, telling an answer, or saying an idea is right or wrong. Ask questions such as: "Is that how a scientist would do it?", "Is that consistent with what we read about?", or "Do you agree with your partner's idea?"

By asking these types of questions, you start to get students mixing ideas and perspectives. Again, you're role is as coach and not expert in this. You're skillfully creating the environment for inquiry here.

There are many decisions that need to be made before students can actually carry out their task. This is why it's important to put the phenomena front and center, rather than putting the task first. If you put the task first, it doesn't really have a lot of relevance and it doesn't require the kind of thinking that is so foundational to these new standards. It's just something to observe.

Going back to the tree ring analogy, if we were using that phenomenon to guide learning, at this point, students may have decided the question they were investigating was whether there were cycles of drought and flooding in the tree's past.

They would then have to determine how they would find an answer. They would have to explain how they were going to take a slice of a tree and count the tree rings. Are they just going to count them?

KnowAtom™
Focus on what matters.

Are they going to count the dark ones and the light ones? Only the dark ones? Only the light ones? Are they going to measure the thickness of the rings, or sort rings of different size into different categories?

If the task fits its purpose, and students understand the purpose of it, then what that task yields has relevance. Equally importantly, the investigative phenomena process engages students in almost every science and engineering practice as they're going through all of these elements.

Using Checkpoints as Students Plan

This planning process can have three to four checkpoints, which act as a formative assessment for both teacher and students. These checkpoints give the teacher the opportunity to be the interested skeptic, and the student an opportunity to present their thoughts and to get feedback.

The teacher can see where the student's content understanding is, how they've used vocabulary, and their depth of thinking through what they've done, as well as the student's science and engineering practices being played out.

After they've seen a couple of teams check in, the teacher has an opportunity to redirect the class if they need to at that point.

And the students have an interested skeptic who asks questions, redirecting them skillfully, and also holding them accountable for their thinking.

For example, you may ask one student to explain how a fact listed in the research section is relevant to the question being explored. And if the student can't explain how it's relevant, then it's not acceptable.

The student will need to go back and discuss it, or to change it, because those are the expectations. Then once they pass that checkpoint, they get to progress further in their planning.

5 Step 5: Be an interested skeptic as students use their data to form a data-based conclusion and reflect back on the anchor phenomena.

The last step also involves being an interested skeptic, helping students use their data to form defensible, logical, data-based conclusions.

This process creates the opportunity for students with different conclusions to not only engage in reflection of their own work, but also to collaborate and to compare their work to others' work, and to consider others' ideas.

The purpose of going through this whole process is to leave that investigative phenomenon with data that students can use to form an evidence-based conclusion.

Students need to reflect back on the initial problem or question because that's what the conclusion is about, but they also need to reflect back on the overarching anchor phenomena.

Remember, that's how this whole process began. As a class, students looked at something complex that they wanted to understand, or a problem they wanted to solve. Once they became dissatisfied with what they knew or the solutions that were available, they came up with a problem they wanted to solve or a question they wanted to answer.

They were able to gather evidence around what they thought may be the answer or solution in that prototype. Then as a result of the data they gathered, they now know more about it, which helps them know more about how that problem could be solved in the anchor phenomena, or question about the phenomena be answered.

Evidence-based conclusions are the result of experimentation or prototyping. They are specific, logical, defensible, and they have to be data-based. They're what students use to reflect back on the anchor phenomena.

And the data should vary from team to team. Students have different ideas, but they also make mistakes, and they measure things inappropriately. If all of the data are identical, you've missed learning opportunities, and you've missed opportunities for authentic engagement and discussion.

This is because with varied data, there are different opinions in class, and the data that underlies that opinion can be brought out, and we can think through that as a group. This is particularly rich context for discussion.

In the end, what will determine student success—and ongoing contributions to scientific knowledge, technological innovation, engineering advancement and mathematics—is whether or not students are prepared to think critically when faced with new scenarios.

At the end of the day, if you want to prepare students to engage with real-world phenomena and succeed, it starts with bringing that phenomena into the classroom and giving students access to it on their own terms, unfettered, free to make mistakes and learn and contribute, as individuals, to the world's knowledge.

KnowAtom

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.

617.475.3475 | www.knowatom.com
27 Congress St. Suite 410 | Salem, MA 01970

Subscribe to our blog: knowatom.com/blog

Focus on what matters.