McConnell, T. J. (2022)
The Hoosier Science Teacher, *45*(2)
DOI 10.14434/thst.v45i2.34836

Open Access

Adapting to the New Indiana Science Standards: A 3D Lesson Planning Template

Tom J. McConnell

Abstract

The new Indiana Science and Computer Science Standards (IDOE, 2022) have created a lot of questions among teachers about what "three-dimensional" teaching is, and how to implement the new standards. The 2022 standards are very closely aligned with the Next Generation Science Standards (NGSS Lead States, 2013), with standards presented using the same terminology focusing on phenomena, Practices, Disciplinary Core Ideas and Crosscutting Concepts. While this may feel new, the NGSS was published in 2013, and some features of the national standards were incorporated in the 2016 standards. In this article, the author draws from previous experience writing science learning materials to align with NGSS to offer a model to help teachers modify their lessons to fit the new standards.

Keywords: 2022 Science Standards, NGSS, Three-dimensional learning, Lesson planning

Introduction

In June of 2022, the Indiana Board of Education approved a new set of Science and Computer Science Standards (IDOE, 2022). Very little discussion of the standards appeared in the news and social media prior to the release of the new standards. However, there is a growing discussion among science educators in the state about what the new standards mean. The Hoosier Association of Science Teachers, Inc. (HASTI) has been quick to address the uncertainty among teachers by offering workshops to help educators shift to the updated standards.

My own observations have shown two main threads of online discussion about the standards. One of these threads is about the adoption of the three-dimensional framework of the Next Generation Science Standards (NGSS Lead States, 2013). Many teachers posting in social media groups about science teaching are not well-versed in the NGSS framework, so they have important questions about what three-dimensional science teaching looks like. This article is intended to address this issue and try to help present an explanation and an example for educators.

The second thread of discussion is about the shift in grade levels at which content is addressed. An early review of the new standards certainly shows that some content standards have moved to different grades. This raises questions about how schools should transition to a new curriculum as they match curriculum maps to the new standards. This problem is not a new one. Teachers address issues like this with each new set of standards, so I trust that we will navigate the move to the new standards in time, and teachers will adapt just as we have in the past.

In this article, I will focus on an approach for thinking about the science concepts and skills we teach that should make the new Indiana Science and Computer Science Standards less intimidating to show that much of what we see in effective science classrooms will fit very well with our revised standards.

The NGSS Framework

Some of the more surprising comments I have seen online talk about the "new" NGSS framework. The National Research Council first published the *Framework* a decade ago (NRC, 2012), followed by the *Next Generation Science Standards* (NGSS Lead States, 2013), published the following year. In these documents, the NGSS presents a "three-dimensional" framework for how we do and learn science. The dimensions include the

Full listing of authors and contacts can be found at the end of this article.

Published by the Hoosier Association of Science Teachers, Inc. (https://hasti.org/) ISSN 2475-451x
© McConnell, 2022. **Open Access** This journal is distributed under the terms of the Creative Commons Attribution NonCommercial NonDerivative 4.0 International License (http://creativecommons.org/licenses/by-nc-nd/4.0/), which permits unrestricted use, distribution, and reproduction without revision in any non-commercial medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license.

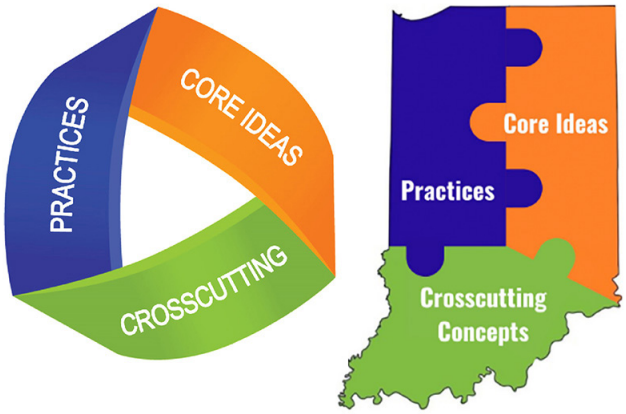

Figure 1. The NGSS Three-Dimensional Framework (NGSS Lead States, 2013; IDOE, 2022)

Practices, *Disciplinary Core Ideas*, and *Crosscutting Concepts*. Those dimensions are reflected in the graphic seen in so many NGSS publications and the new Indiana Standards (Figure 1). More discussion of those dimensions and how they are reflected in the 2022 Indiana standards will follow.

Many states adopted the NGSS standards, and the National Science Teaching Association (NSTA) has been publishing resources for teachers since 2014 that focus on using the NGSS. In fact, the editors at NSTA Press, began began integrating the NGSS into nearly all their publications in 2014 to help educators implement the new standards. This has been part of most of the books published by NSTA Press for the last eight years.

Seeing the NGSS in Indiana Standards

Here in Indiana, the NGSS have also been an important influence on our curriculum. Indiana's prior standards, published in 2016, were not a wholesale adoption of NGSS, but the "Science and Engineering Processes" featured in those standards (IDOE, 2016) are a direct link to the "Science and Engineering Practices" (SEPs) from the NGSS, almost verbatim. The new Indiana standards have changed terminology to directly align with the NGSS, including the addition of the Crosscutting Concepts. These Crosscutting Concepts (CCs) present a series of themes that are universal to all the sciences. The science concepts previously labeled as "Content Standards" are now called "Disciplinary Core Ideas," or DCIs. These three dimensions are the core framework created by the writers of the NGSS. They reflect a view of how scientists do science, based on extensive research. The revised terminology may take a little getting used to unless teachers have been immersed in NGSS language prior to 2022. Figure 2 shows a representation of these elements of the new Indiana standards.

In addition to these three dimensions, the NGSS presents "Performance Expectations" – in essence, behavioral learning objectives that describe how students will use the practices to learn the concepts embodied in the DCIs. The text of the Performance Expecations includes the verbs teachers us in objectives. Many teachers will view these as the "standards," but the NGSS hopes teachers will use these as the learning outcomes students will achieve as they learn about the DCIs and put the Practices into action.

Phenomena – Making Science Relevant

Another element from the NGSS that may seem new to Indiana teachers is the "Anchoring Phenomenon." These are examples from the real world that can be explained using the science concepts, can be studied or observed using the practices, and can be connected to the Crosscutting Concepts of science. It is important to note that the phenomena are practical representations of the DCIs.

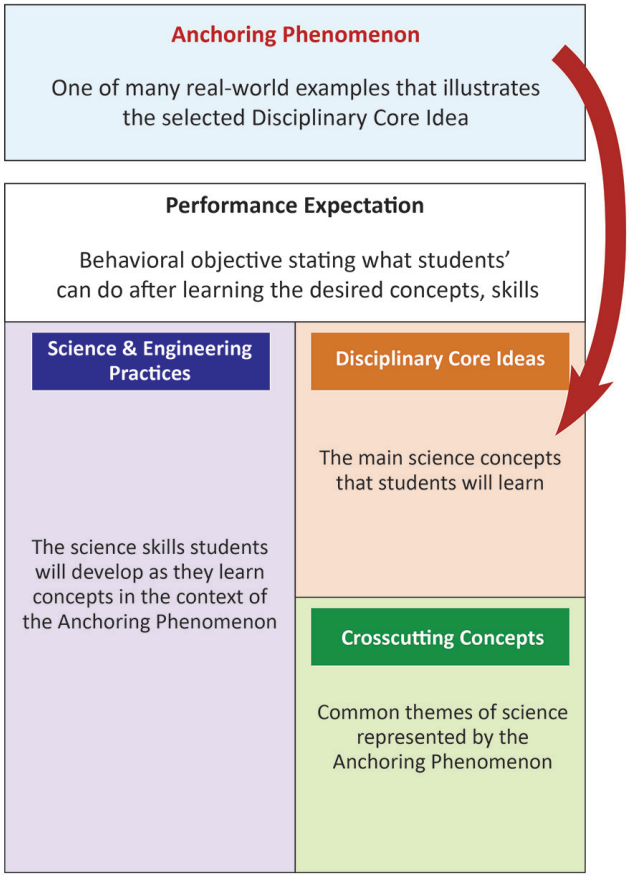

Figure 2. The 3-D framework for thinking about "doing science" (IDOE, 2022).

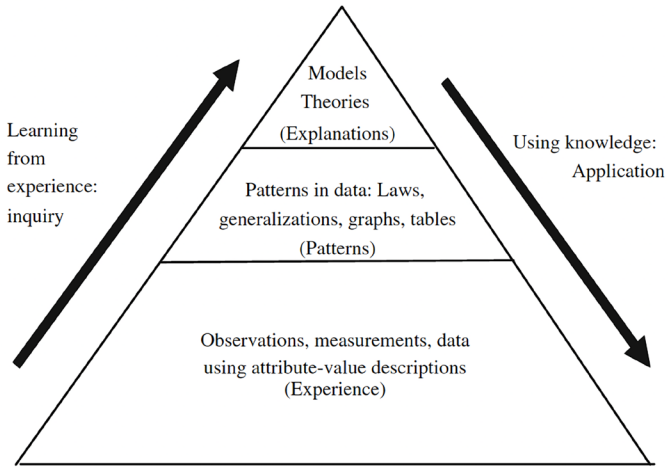

Figure 3. The EPE model (Sharma & Anderson, 2003)

There have been previous conceptual models for how scientists work and how students learn science. One of the models that seems to have influenced the NGSS was published in 2009 by a team of researchers at Michigan State. The EPE model (Sharma & Anderson, 2009; see Figure 3) suggests that we learn about science by learning about multiple Examples of science concepts ("Experiences" in the EPE model) . For instance, learners may see many different examples of gases expanding or contracting as pressures change – balloons, flower colors and scents that attract pollinators, visible signs of a chemical reaction, etc. Observation of examples ("Experiences" can help learners recognize Patterns in nature that we describe as scientific laws, like Boyle's Law that says that volume of a gas decreases when pressure increases. Studying the mechanism behind that pattern can help scientists develop an Explanation, or theory, of why this pattern occurs. In the gas law example, the theory is based on the spacing of gas molecules as the force behind pressure and an increase in pressure when molecules are pushed together to increase the rate of collisions. The sequence – Examples, Pattern, Explanation – is what we describe as inductive reasoning.

The common characteristic between the EPE model and the NGSS is the importance of basing our lesson on real-world examples – the Anchoring Phenomenon seen in Figure 2. For any concept found in the DCIs, there are many different phenomena that can serve as examples of the concept. While the NGSS does not list these phenomena, the authors of the NGSS are clear that teaching the standards should begin with an "anchoring phenomenon" (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014) to help learners related to the concepts we teach. This part of the lesson plan gives teachers a great deal of freedom to find the best examples to help their students make sense of the concept. In the *PBL in the Science Classroom* series (McConnell, Parker & Eberhardt, 2016), we used this approach to present activities that begin with these types of phenomena, but we also described the importance of teachers selecting relevant phenomena to fit the needs of their own students. Science educators have been talking about relevance for many years (Stuckey, Hofstein, Mamlok-Naaman, & Eilks, 2013). But the NGSS makes the need to select locally relevant examples an explicit part of the curriculum.

As an example, a teacher in California can describe food webs by using a set of organisms that are completely unfamiliar to students in Indiana. We can help students learn about life cycles by observing the development tadpoles, caterpillars, mealworms, or plants. The concepts that students learn are the same, regardless of which examples the teachers choose. Ideally, presenting multiple examples can help strengthen learner's understanding because they can notice Patterns in the Experiences (Sharma & Anderson, 2004).

The brief examples I have mentioned so far may help illustrate the connections between phenomena and the standards but planning a true "three-dimensional" lesson is more than just finding a good example. Let's explore a bit more deeply how a teacher might plan a three-dimensional lesson or unit.

A Structure for Lesson Planning

Describing what a three-dimensional science lesson includes is a first step in helping teachers adopt this approach. This approach to planning a lesson may be new to you, so it may help to show additional examples of the process.

As a science teacher educator, I have been sharing lesson plan templates for years. The templates I use have evolved over time. With these new standards, I saw a need to change the template, this time to more directly reflect the structure of the NGSS and three-dimensional framework. As I mentioned earlier, most of the revisions relate to terminology. Surprisingly, the changes in the template were not as significant as I first expected.

The **3D Learning Plan Template** (see Supplemental File) was tested with teachers at a summer workshop during the summer of 2022. Participants at that workshop developed lessons to use in the 2022-23 school year, spanning science teaching across the K-12

spectrum, including lessons in Art and ENL (ESL). Students in my science teaching methods classes will also use the template as they plan for teaching.

I share this with readers of this journal knowing that experienced teachers do not always create such detailed plans for their classroom. Some may jot down a sentence or a few phrases in a planning book while the majority of their planning is done in their heads. But teachers are also increasingly expected to submit detailed plans to building administrators for accountability purposes. Perhaps this template can help with that process, or even with departmental planning of curriculum maps as the new standards are implemented in your school districts. The template is flexible enough to be useful for a one-day lesson or multi-day unit plan.

One of the main features of this planning template is the "Anchoring Phenomenon or Problem." Previous versions of the template used this space for the "big idea," the "driving question," or the "key concept" as a starting point for the plan. As teachers adapt to the new structure of the standards, this element of the plan may help teachers think more explicitly about the type of phenomena that might help students relate to the lesson. This may also help you plan for that ever-present question: "Why do I need to learn this?"

As you plan a lesson, think about authentic and local phenomena that can be explained using the DCI you are targeting. You may want to think of more than one phenomenon and be ready to adjust as you find out what ignites your students' interests. One approach to this step is to keep an eye out for news stories that relate to the DCIs. For instance, a recent press release on the phys.org website (Indiana University, 2022) reporting that researchers at Indiana University have discovered a type of bacteria that can help honeybee larvae get more nutrition from their food to help avoid colony collapse. This story could help lead into a lesson about symbiotic relationships between the microbe and the bees and between bees and flowers.

Most of the other components of the "Learning Goals and Assessment" section of the template can be drawn directly from the standards. The cells in the template are color coded to match the sections in the NGSS and Indiana Standards, making it easier for teachers to cut and paste from those sources.

Page 2 of the template features the meat-and-potatoes portion of the plan. It prompts teachers to include what the teacher will do, a list of materials needed for the lesson, student handouts or files that need to be included, and a list of the products students will create. The template shows three "activities," letting the teacher add or delete activities as needed. Teachers can also use other resources without re-inventing the entire plan.

A Sample Lesson Plan Outline

Let's dig a bit deeper into this three-dimensional approach to planning a science lesson. I chose to draw from my own teaching experience as a high school teacher in Biology and Environmental Science. The reasoning I describe is a model for how to think about lesson planing in any science subject. In Figure 4, I present a graphic organizer with the Anchoring Phenomenon and a screenshot from the Indiana Science and Computer Science Standards (IDOE, 2022). It may also help to open the 3D Learning Plan Template file to help visualize my comments about assessments and activities.

Learning Goals as a Starting Point

As an educator who guides pre-service teachers to use the "backwards design approach" (Wiggins, Wiggins & McTighe, 2005), I should begin with my learning goals. A good place to identify these is found in the standards. The "Performance Expectations" are behavioral learning objectives. Figure 4 shows the Performance Expectation for HS-LS2-6, a standard that addresses Ecosystem Interactions, Energy and Dynamics. That box is NOT at the top of Figure 4, though. That choice is deliberate on my part; I chose to highlight the phenomenon. To ensure that the phenomenon I choose is appropriate, I started by selecting the Performance Expectation – my objectives or learning goals that tell what students should be able to do.

In that standard, you can also see the Disciplinary Core Idea (DCI) in the orange box. This is a statement of the science concept that is the focus for this lesson or unit. There may be other DCIs that can be taught with the same performance expectation, or more than one performance expectation that addresses this DCI. But for now, let's focus on this one standard. The DCI will help me focus on the science concept as I think about how to help my students understand this in the context of the community in which we live.

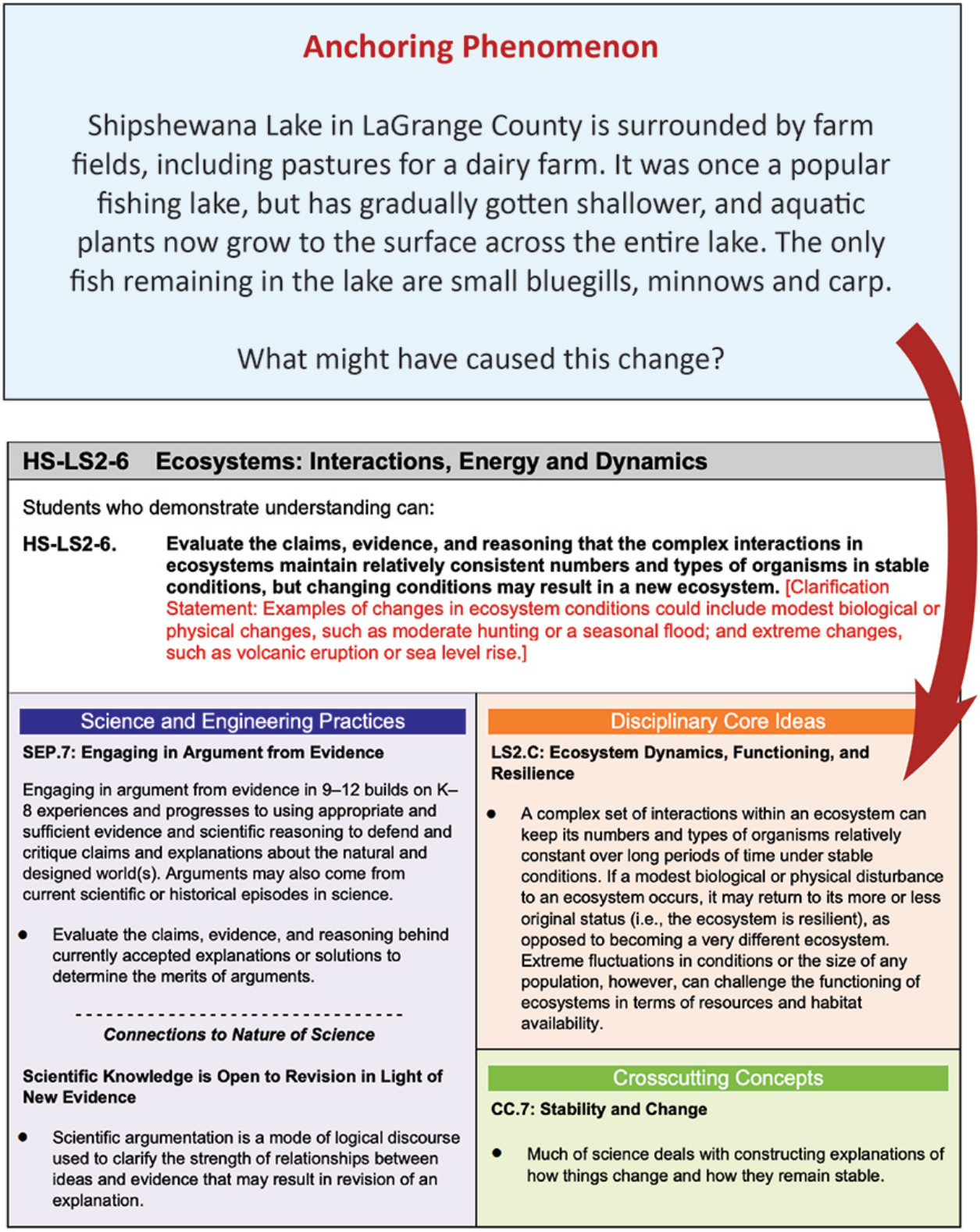

Figure 4. Example of the 3-D Framework for a locally relevant lesson structure (IDOE, 2022).

Selecting an Anchoring Phenomenon

For the DCI in Figure 4, I can think of several examples from Indiana that illustrate the way an ecosystem can be altered by changes in various factors. In an age in which signs of climate change are all around us, there are many from which to choose. But I taught in northern Indiana in the region known for glacial lakes. Most of my students lived on or within sight of a lake, and the health of those lakes is an important factor in that community.

I selected a real situation in a community my students would know. When picking a phenomenon to anchor your lesson, it is very helpful that it be authentic – either a real situation or a very realistic one. My choice to describe Shipshewana Lake is based on my own personal experience. If you live in another place, you can certainly choose locally relevant examples. They may be right outside your school, or you may have seen a story in the local newspaper about a related situation.

Note that the red arrow points to the DCI. It helps to ask if the phenomenon you chose is a reasonable case that can be explained by learning the concept described in the DCI. As the teacher writing the plan, it is up to you to do this check. The standards deliberately do not include a phenomenon, a choice made in the NGSS because the NRC wants you to make this choice. If you try out the lesson for a couple of years and it gets stale or outdated, change the phenomenon. It will still help students learn the desired concepts.

Thinking About the Practices

Science concepts are not the only thing we want our students to learn. I personally place a high value on the Practices. These are the skills we use to do science, and I'd like all my students to at least know how scientists go about their craft as they develop the theories, laws, and technologies we use.

The next thing I look at are the practices that students can develop as they learn about the concept described in the DCI. If you refer to Figure 4 again, the Practices are listed in the blue box on the left side of the standard and in Figure 5. For this Performance Expectation ("Evaluate the claims…"), the main Practice listed is SEP 7 ("Engaging in argument from evidence") This implies they are also using SEP 8 ("Obtaining, evaluating and communicating information"), so I can add that to my list of Practices in my plan.

However, I'd like to add some practices. I know that I can have students do water quality tests on a local lake (or even Shipshewana Lake) to measure phosphates, nitrates, dissolved oxygen, turbidity and more. If they do that, they are also using SEP 3, 4 and maybe 5 when they collect data, analyze it, and create graphs to compare results. There is a chance to also work on SEP 6 if I ask students to offer in their own explanations or design a solution to the problems they are studying. So in a single lesson, I can address at least one DCI and six of the eight Practices, all with a single local example.

By the way, the first time I ever taught this lesson with this example was 1999. I did not create a new lesson. I adapted the way I describe an older lesson. This is the type of process you can do as you plan activities you probably already use in your science classroom – there is no need to start over as you implement the NGSS and new Indiana Standards.

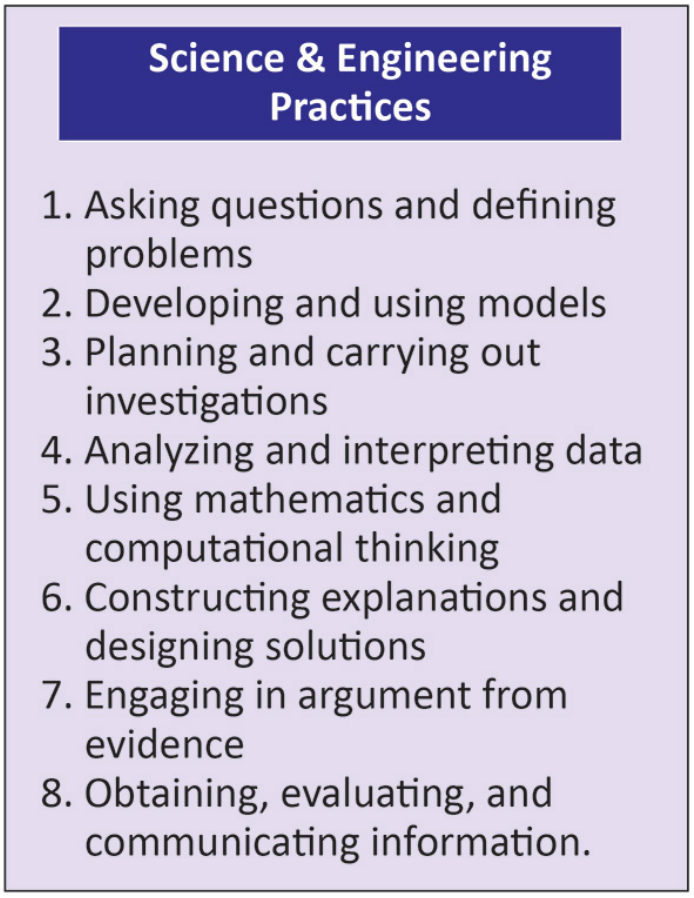

Figure 5. Science & Engineering Practices (IDOE, 2022)

Crosscutting Concepts

Now it is time to think about the green box in Figure 4, Crosscutting Concepts (CCs). This is the "new" feature from NGSS that has been added to the Indiana Standards. What do we do with that? This question has been discussed in the literature and national conferences since 2013. The authors of the NGSS say your science lessons become truly three-dimensional when you plan to address *and* assess all three components of the Framework. We will get to the assessment boxes in the template soon. For now, let's talk about the CCs.

The CCs are a list of scientific "themes" that are seen in all the science disciplines. In the old AAAS Benchmarks (AAAS, 1993), these were called "overarching concepts." The NGSS suggests you be explicit in talking about which of the CCs (see Figure 6) can be seen in the Phenomenon you select, and the DCI included in the standard. There may be more than one that applies. You should also plan to include at least one assessment that asks students to discuss something about that CC to show that they have made a connection to this concept.

In the sample lesson plan (Figure 4), the standards identify CC 7 ("Stability and Change") as the connection for this concept, but just as with the Practices, I am free to list more of the CCs. In the Phenomenon I described, there is a clear "Cause and Effect" relationship to learn about, and the DCI can also reinforce the idea that Systems and System Models have inputs that can alter the outputs, so I would also list CC 2 and 4.

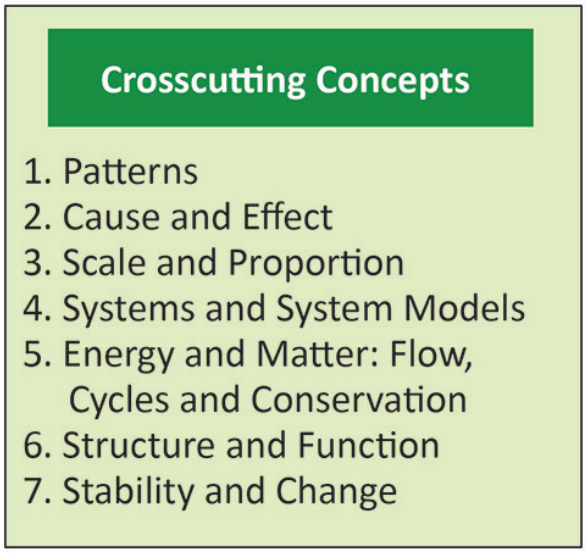

Figure 6. Crosscutting Concepts (IDOE, 2022.)

Planning for Assessment

As we think about this lesson, we also need to plan to assess the outcomes. Hopefully you noticed that beside each "Performance Expectation" space in the template (Figure 4), there is a place to describe how I will assess each objective. And remember that the author of the NGSS discuss the need to assess all three dimensions, so let's look at that part of our sample lesson.

Assessing content (DCI). Let's begin by assessing content. How will I know if students understand the answer to the problem I posed in this phenomenon? If I focus on the terms in the Performance Expectation, I need to ask students to evaluate the interactions in the Shipshewana Lake phenomenon. They need to explain what factors caused the lake to become shallower with a thick growth of aquatic plants and a loss of most of the fish species that used to be in the lake.

How they explain that is open to the teacher's and students' creativity. They could write answers to an essay prompt, or create a presentation, poster or some other performance assessment. The details are for the teacher to outline, and there are multiple "right" ways to do this. But I should expect students to apply concepts they learned in class. This is an appropriate place to create a rubric for the concepts I want to see in students' presentations or papers, such as the role of nitrates and phosphates from the farm fields on the growth of algae, the impact of decomposition on dissolved oxygen levels, and the resulting effect on certain fish species. There are several science concepts we can include.

Assessing Practices. Explaining the science concepts is not enough. I also expect students to show that they can use the Practices. Recall that the main Practice is "Engaging in Argument from Evidence." In other words, the guidelines for whatever assessment I assign should require students to use supporting evidence. This could mean citing sources or using data they collected when they tested some lake water. ("We found that the lake next to the cow pasture has a lot of phosphates in it from the manure….") If I include Practices 3-7 in my plan, I might also require students to explain why the selected certain samples, compare data from different sites, and tell me if the differences are large enough to be significant.

With a single project or paper, students can show that they understand the DCI and the Practices. This is a good way to address two of the three dimensions. And I still have the flexibility of using a variety of different assessment strategies. We all know that it helps to have multiple assessments during the work students do for the lesson rather than relying only on a summative assessment.

Assessing Crosscutting Concepts. This is the dimension that has generated the most confusion for teacher, in my experience. How do we assess this dimension? Won't it show up in the other assessments? That may happen, but you cannot take this for granted. In some cases, it is natural for students to write or talk about "Stability and Change" if they explain what happened at Shipshewana Lake. It helps to have one or two prompts, or maybe a rubric row or a discussion question that helps you elicit your students' ideas about the Stability and Change theme. I'd like my students to know that a healthy lake ecosystem goes through many changes during the seasons or after rainstorms and droughts. But I'd like to make sure they mention that the dynamic balancing act of an ecosystem can be thrown out of whack if one variable changes drastically. In our selected phenomenon, that means the fertilizer runoff that causes algae blooms and lower dissolved oxygen in lakes.

To complicate this even more, a normal process of ecological succession in a glacial lake in northern Indiana will cause the lake to fill in and change into a marsh or swamp ecosystem. The change in Shipshewana Lake might be natural. My students are not likely to think about that unless I toss them a question and ask them to write or talk about it.

In a discussion I had with one of the NGSS authors some years ago, his suggestion for such a case was different. He felt it was important to ask students to describe some other phenomenon that shows a similar pattern of "Stability and Change" to show that they can transfer the idea to a different scenario.

I think all of these ideas have merit, and I will continue to support the idea that teachers need to have the freedom to adapt how they assess the three dimensions. Use the tools you have at hand, and draw from your experience, and you will be able to build a lesson that teaches and assesses the three dimensions.

Inserting Activities into the Template

In an effort to follow the backward design approach, now is the time to think about the sequence of activities. I've identified my learning goals and considered ways to assess whether students learn what those ideas. Now I can build a plan to help student learn the concepts and practices and explain the connections to the crosscutting concepts.

Page 2 of the 3D Learning Plan Template has space where you can build your own sequence of activities. That page allows you to add or delete rows to build as much or as little as you need – from a one-day plan to a multi-week unit. In each "Activity," you can add new labs, lectures, videos or projects as you see fit. The boxes for each activity give you space to include your list of materials, the handouts you need to provide, and the products that students will turn in for a grade. The most important part is your outline of what the procedures for the lesson.

And yes, I still recognize that most teachers do this work in their heads. The template gives you a place to jot down ideas to help you organize your work. This may be a good tool to create the plans to submit to your administrators.

For the sample lesson, I would begin my unit with a discussion of the phenomenon. I can collect photos or video from the lake to show students the location. I might also plan for a discussion of the problem to let students ask questions, propose possible explanations, plan what they should look for in the coming days, and organize a way to record some water testing data.

In the following class sessions, I would plan time to do some library or online research, so I might need to reserve the computer lab. I also would like to test water from Shipshewana Lake and maybe another location at the local park. I might also look for a good online simulation of a lake ecosystem that lets students change levels of nutrients to see the effect on living things in a lake. If so, the template helps me store the URL so I can share it with students more easily when the time comes. The template helps me a map it all out.

On Page 3 of the template, you will find space to attach files, insert URLs, and paste references. These spaces are there to record the set of materials you will use, including the files you already have from previous years. This last page is based on the recognition that you likely have good lesson activities from textbooks,

workshops, websites, and other valuable resources. Again, you are encouraged to use what you have while leaving room to adopt new activities and materials.

Discussion

It can be challenging when the state adopts new standards. The change creates more work for teachers who must align their curricula to a new set of expectations. This is especially true when the framework or language in the new standards looks and sounds different than what you've grown accustomed to using. My hope is that this example can show that the process of re-aligning your curriculum to the new Indiana Science Standards is not as drastic as you might think.

The teachers I know already teach science in ways that reflect the Three-Dimensions described in the NGSS, and now in the Indiana Standards. The terminology used to describe it is new to Indiana, but the concepts are not. While we may be uncomfortable with a new set of standards, I encourage you to look at the activities you already use, and modify the labels.

The one change some teachers may need to consider is building your plans around a locally relevant and authentic "Anchoring Phenomenon." Some of you, though, probably already do this, even if you use some other term for them. Maybe the realignment will be a chance to revisit those examples and update the Phenomena you use in your teaching.

I hope the 3D Learning Plan Template will make that transition a bit easier. Modify it as needed and share with others. We are all working through the same issues, so we can help each other through it. As you try new things and find ideas that work, bring them to a HASTI Conference or submit them to The Hoosier Science Teacher. We can all learn from your successful move to 3-D Science Teaching.

References

American Association for the Advancement of Science [AAAS]. (1993). *Benchmarks for Science Literacy*. New York: Oxford University Press.

Indiana Department of Education [IDOE]. (2016). *Indiana Science and Computer Science Standards*.

Indiana Department of Education [IDOE]. (2022). *Indiana Science and Computer Science Standards*.

Indiana University. (2022, June 27). *Microbe protects honey bees from poor nutrition, a significant cause of colony loss*. Phys.Org.

Krajcik, J., Codere, S., Dahsah, C., Bayer, R., & Mun, K. (2014). Planning instruction to meet the intent of the Next Generation Science Standards. J*ournal of Science Teacher Education, 25*(2), 157-175.

McConnell, T. J., Parker, J. M., & Eberhardt, J. (2016). *Problem-Based Learning in the Life Science Classroom, K-12*. Alexandria, VA: NSTA Press.

National Research Council [NRC]. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting concepts, and Core Ideas*. National Academies Press.

NGSS Lead States. (2013). *Next Generation Science Standards*. Washington, DC: National Academies Press.

Sharma, A., & Anderson, C. W. (2009). Recontextualization of science from lab to school: Implications for science literacy. *Science & Education, 18*(9), 1253-1275.

Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of 'relevance' in science education and its implications for the science curriculum. *Studies in Science Education, 49*(1), 1-34.

Wiggins, G., Wiggins, G. P., & McTighe, J. (2005). *Understanding by Design*. ASCD.

Author

Tom J. McConnell (tjmcconnell@bsu.edu) is a Professor of Science Education in the Department of Biology at Ball State University, Muncie, IN, USA.