# Implementing what we know about learning in a middle-school curriculum for widespread dissemination: The Project-Based Inquiry Science (PBIS) story

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**Abstract:** Project-Based Inquiry Science (PBIS) is a comprehensive technology-enhanced science curriculum for grades 6 through 8 (ages 12 – 14), designed based on foundations in the learning sciences. Most of its units were developed during the 1990's at Georgia Institute of Technology, Northwestern University, and University of Michigan. Over the past five years, researchers at these universities (and others) have been working to pull the units together into a curriculum that can be disseminated nationally (in the U.S.). During the last two years, we have been working closely with the publishing company, It's About Time, to bring the curriculum to publication. We present the research foundations of PBIS along with the pragmatics of incorporating individual units into an integrated curriculum appropriate that addresses the diverse requirements of 50 states while also addressing the diverse needs of learners.

## Introduction

PBIS is a comprehensive 3-year science curriculum for middle school (grades 6 through 8; ages 12 – 14), designed based on foundations in the learning sciences. It is comprised of 15 project units, 5 for each of the three science disciplines covered in the middle grades (earth, life, and physical sciences). It infuses software use for data mining and visualization, modeling, and simulation. Most of its units were developed during the 1990's at Georgia Institute of Technology, Northwestern University, and University of Michigan in the context of a set of learning sciences research projects (the Learning by Design project (e.g., Kolodner et al., 2003a) and the LeTUS endeavor (e.g., Edelson et al., 1999; Kanter et al., 2006; Krajcik et al., 1998)). Since 2003, researchers at these universities (and others) have been working to pull together the units into a comprehensive science curriculum usable throughout the United States. Since 2005, we have been working closely with the publishing company, It's About Time, to bring the curriculum to publication. Parts of the curriculum have been adopted by school systems; other parts are currently being piloted (tried out). We will have the full curriculum ready in the 2008-2009 academic year.

When we began our collaboration, we expected that it would be time-consuming but straightforward to pull the units together into a curriculum. Conceptual foundations behind units developed in each of our research groups were highly compatible. We had all done extensive materials development in collaboration with teachers who piloted our units in their classrooms, developed professional development materials and programming, and collected significant data about student learning (e.g., Kolodner et al., 2003; Kanter et al., 2006). Each of the research groups was committed to having students learn through inquiry sustained over many weeks of working on a compelling challenge or big question and having students engage in science the way scientists do – using the same kinds or reasoning and similar tools. Two of our three groups designed our approaches based on the cognitive model implied by case-based reasoning (e.g., Kolodner, 1993; Schank, 1999). We all meant our units to be implemented through a cognitive apprenticeship (Collins et al., 1989). When we looked across the content of our units, we seemed to be covering most of the science content for middle school. We were excited that across our units, learners would experience a whole range of investigative methodologies used by scientists (experimentation, modeling, simulation, data mining) and that we had the opportunity to foreground systems thinking, varied roles of models and modeling in science, and explanation construction across the sciences.

But we were naïve about the work that would be involved in integrating our units into a cohesive curriculum. As individual units, each covered content without concern about integrating that unit into a curriculum that had to cover an entire three years of standards. Each of our research groups had interpreted project-based, inquiry, case-based reasoning, and other things differently, and each had called similar practices by different names. Units developed in the southern U.S. alluded to things that kids in the northern U.S. might not have experienced, and *vice versa*. We found that taking locally-developed curriculum units into a nationally-appropriate coherently-organized curriculum was more challenging that we had imagined, both in intellectual and logistical ways.

In the process of our development activity, we have learned a lot about bridging the gap between a researched-based curriculum design and the realities of middle school settings, the marketplace, and the publishing industry. We have addressed challenges that have arisen in ways that have allowed us to keep our basic design of 6-to-8 week units with sustained inquiry around a set of inter-related science concepts, covering mandated standards while maintaining the story line of each unit. The curriculum implements a cognitive apprenticeship and provides foundations for engaging children in three years of knowledge building (e.g., Scardamalia, 2002) as they participate in project-based inquiry science. Our curriculum provides a coherent view of inquiry across all of the units. We present our goals in designing PBIS, its learning sciences foundations, our design process and the challenges we faced, and the framework we've devised for our integrated effort.

## Our Goals in Designing the Project-Based Inquiry Science (PBIS) Curriculum (and criteria and constraints we have had to meet)

Overall, our goal in designing PBIS has been to contribute to creating a generation of citizens who understand what it means to think like a scientist. We want them to understand basic science content and have experience using it to reason, to recognize the relevance of science to their live, and to know some science deeply and to become curious about other science. We want them to see science as a systematic way of thinking, a way of thinking that is always seeking the best understanding possible of phenomena, that questions why things are happening and how trustworthy evidence is, and that uses trustworthy evidence to draw conclusions and generate explanations. We want learners to understand where evidence comes from and how systematic one must be to collect good evidence. We want them to recognize that science knowledge is learned through investigation, is backed by evidence, and comes from trying to make sense of and synthesize across multiple investigations. We want learners to appreciate the investigation and reasoning that goes into generating agreed-upon science knowledge and to recognize that we come to know new things through a cycle of generating questions, investigating, collecting evidence, analyzing, and drawing conclusions based on what is already known and the new data. We aim to help learners move from novice ways of carrying out such reasoning to more expert ways.

There is controversy across states and school districts about whether to focus on depth or breadth, to what extent to focus on content and on thinking like scientists, and how well students should be able to think like scientists. In the US, management of education and educational requirements is done by states, and within states, by school districts. Each school district decides how to cover the content mandated by their state, what books to use, and how to train teachers. Standards in some states focus, as PBIS does, on depth over breadth when "covering" content and on students coming to think like scientists. Other states focus more on breadth of content and less on students thinking like scientists. Within states, different school districts have preferences about ways of covering their standards. We cannot expect every state or school district in the U.S. to have goals consistent with those of our curriculum. We do, however, want any school district that shares our philosophy to be able to argue for adopting our curriculum. For this, we have had to be cognizant of the coverage requirements of different states and have had to make sure our materials provide breadth of coverage, for those that need it, within the allotted time.

This great amount of diversity requires great flexibility in published materials. Some states cover science in a disciplinary way – earth science in one grade, life science in another grade, and physical science in another. Some cover in an integrated way – some of each of those curricula in each grade. Whichever approach, topics can be covered in different grades, at different times during the year, and in different orders. Taking a project-based approach means that our curriculum groups topics according to the ways they are needed to solve a big question or challenge, often quite different than the taxonomic sequencing of topics curriculum leaders may have developed.

We have therefore had to design PBIS so that units can be done in different sequences, so that the same unit might be used in 6$^{th}$ grade (age 12), 7$^{th}$ grade (age 13), or 8$^{th}$ grade (age 14), and so that they can be used in schools with computers in each classroom and in schools with computers only in labs, in schools with plenty of money for purchasing electronic equipment and in schools that do not have the money for that, in schools that have money for producing copies of charts and in schools where students have to draw charts by hand on their own paper, and so on. Some school districts offer more days of professional development to teachers than others, and we have also had to design with this in mind. We have needed to take all of this diversity into account in addition to designing for the huge range of experiences and capabilities of teachers, learners, and cohorts of learners.

Given this wide diversity, it might seem that instead of a publishing textbooks, it would make more sense to publish units on the web with advice about how to adapt them to the needs of one's students, school, or state. The pragmatics of school and the realities of teaching as a profession argue against this. School systems need the reliability of indestructible textbooks that they can order and receive in bulk. Schools need to be able to easily order and receive resources for carrying out science activities. Even the most energetic teachers do not have time to create curriculum materials from pieces, and most middle-school teachers are not expert at the full range of middle-school science topics. All of this suggests the need to partner with a publisher in creating curriculum materials and means of supply, that materials need to be constructed as books, and that curriculum materials and training for teachers need to be supplied hand in hand.

## Foundations in the Learning Sciences

PBIS is grounded in the principles of many different literatures. From the cognitive literature (see, e.g., Bransford et al., 1999), we focus on the need to help learners build mental models or schemas, the iterative nature of mental model construction, the need to tie the concrete and the abstract to each other well for transfer to occur, and the need for repeated deliberative practice (Ericsson, 1993). In particular, we draw from the model suggested by case-based reasoning of processing learners need to do to extract rich mental models from their experiences and to label or index those schemas so that they can be recalled later, and the variety of experiences they need applying those schemas in new situations, explaining their failures, and debugging them (Schank, 1999; Kolodner et al., 2003b). PBIS sequencing is designed to help learners reflect on their experiences in ways that afford identifying lessons they might extract and provides multiple opportunities to apply what they are learning, identify what they still need to understand better, and get help with debugging their understanding. We also take very seriously the notion that learning can only happen on the edges of what we know (Bruner, 1966, Vygotsky, 1978). For these reasons, PBIS sequencing includes activities that help students identify what they think they know, discuss these things to identify the things they disagree about, and generate questions.

The socio-cognitive and socio-cultural literatures tell us the importance of helping learners identify roles they might play, feel that they have permission to participate in those ways, value those ways of participating, get practice participating, and feel ownership of the goals they are achieving and their ways of achieving them (see, e.g., Bandura, 2001; Cobb, 1996; Engle, 2002; Greeno, 2006; Holland et al., 1998; Lave & Wenger, 1991; Wenger, 1998). PBIS consistently treats students as "student scientists," helping them understand the relationship between what they are doing and what scientists do and providing them support they need to act as scientists would. PBIS's "laucher units" introduce learners to the roles they might play and the value in playing those roles (Kolodner, 2007). PBIS not only has many venues for participating with others, but its student materials include support for participating effectively in those activities. Repeated activity structures are introduced early on, and each time each is carried out, the student text helps students know what they should focus on both when actively participating (e.g., presenting) and when more passively participating (e.g., while listening).

The science education literature (e.g., Driver, 2000; Duschl, 2002; Herrenkohl, 1998) tells us what it means to do science and to treat children as students scientists. The science education literature tells us what learners need help with (e.g., knowing what to talk about, help with carrying out what they are doing, good instructions for making things work); that explorations early on can help learners identify what they need to learn and make predictions; that combining exploration, prediction, investigations, explanation and application with each other can lead learners to see science as a system (refs). The Project-Based Science literature (see, e.g., Blumenfeld et al., 1991; Krajcik, et al., 1998) suggests that students should learn science through engaging in the same kinds of inquiry practices scientists use, in the context of scientific problems relevant to their lives, and using tools authentic to science. Learning by Design (Kolodner et al., 2003a; Kolodner, 2007; Ryan & Kolodner, 2005), which derives from Problem-Based Learning (Koschmann et al., 1993), suggests sequencing, social practices, and reflective activities for promoting learning from design activities. The LBD team suggests ways of (i) getting middle-school children to engage in appropriate reflection; (ii) helping participants become comfortable with sequences of scientific practices; (iii) how to help students connect the phenomena they experience to science content; and (iv) how to create a culture of collaborative learning and rigorous thinking in the classroom.

## Designing PBIS

PBIS's design has required all of the authors of this article and others. Early on (2004), in our weekly work groups, we laid out foundational principles, then worked on specifics of creating a common "look and feel." Each unit would follow a pattern of, first, helping students understand and engage with the big question or challenge, then a variety of "learning sets" that each focus on a different set of issues needing coverage to address the challenge or question, and then a section to pull it all together. We wanted each learning set to engage learners in asking questions, pursuing answers, sharing answers, making meaning, and then applying that meaning back to the big question or challenge. We then identified practices for each that would be included in PBIS. We also identified practices for maintaining continuity within each learning set and unit. We then identified templates we might use for each that would support student and teacher success and ways of organizing student texts so that students would recognize the purposes and sequencing in what they were doing. Together with the publisher, we put together an advisory team to read every unit, keep track of what they were covering and what they could cover, and advise developers about how to revise their units to fit into a curriculum. Developers revised their units and handed in drafts. Our advisory team became a development team and made the next pass on writing each unit or worked with unit developers to make the next pass. We also identified standards from 10 states that we covered and had missed. In 2005, we began piloting and field testing the curriculum. At this point, new issues arose. Not every unit worked within the framework we had developed. Many units were missing sequencing. Others had big questions or challenges that students did not find engaging enough or could not connect to, or that teachers found too hard to carry out in their classrooms. We were missing whole units. Units developed in some parts of the country were not as easy to use in other parts of the country. Units that were easy to cover when researchers were available to help were harder to enact when teachers had only a few days of professional development available. All of the units were missing content required by state standards. The work was too much for two people to do. Our publisher began hiring writers – for revising the student texts and the teacher guides.

We have learned a lot about bridging the gap between researched-based, theoretical curriculum design and the realities of middle school settings, the marketplace, and the publishing industry. We have had to find creative solutions and guiding principles for realizing the goals of both entities without sacrificing needs of either. We list below the challenges we have had to address in our design.

- *Sustaining interest to enable sustained inquiry.* It is often hard to help students maintain momentum through the long period of a unit. It is often hard doe teachers to be excited about spending so much time on small sets of concepts. Yet we know how important sustained inquiry and iterative refinement of one's understanding are.
- *Promoting reflection and articulation among middle school students.* Doing is fun for children ages 12 to 14; reflecting on what they have done to learn from their experiences is not as interesting. Nor are teachers always confident about facilitating discussions that would lead learners to reflect in ways that are needed for learning.
- *Promoting development of understanding over time: Repeated deliberative practice to learn the practices of scientists.* Iterative refinement of understanding and progressive development of reasoning capabilities are central in PBIS but the ability to facilitate such development is not always in the repertoires of teachers, who are used to students mastering content or capabilities before moving on.
- *Managing scope and sequence in each unit.* The units in PBIS each center around some big question or challenge designed to be personally-engaging for the students. Each unit requires going deeply into some content and affords familiarity with other content. But our units do not always cover everything about a topic in a unit. We have the challenge of maintaining an approach centered on an engaging question and providing coverage of topics at the same time. It is quite difficult to cover all topics and maintain the flow and momentum of a challenge.
- *Sequencing units into a curriculum.* This issue was presented in the introduction. Different states require topics to be covered in different years and at different times.

## The Design of PBIS

The result of our design work is a 3-year science curriculum made up of 15 units (see Table 1). But PBIS is not merely a set of 15 project-based inquiry units. Central to PBIS's design is that students are put into the role of "student scientist." Everything they do, and every decision we've made as designers, centers on this notion. Students learn science, as scientists do, in the context of answering a big question (e.g., How can I prevent my friends from getting sick?) or solving a big challenge (e.g., Design a device that can lift a shipment of supplies to the top of a cliff.). They break that into smaller questions and then carry out investigations and read about what scientists know to develop explanations that will answer the smaller questions. Then they use what they have learned to try to answer the big question or solve the big challenge. Along the way, students share what they are learning with each other and have the kinds of discussions that allow them to make meaning together.

<u>Table 1: PBIS Units (sequenced by discipline)</u>

| **Earth Science Units** | **Life Science Units** | **Physical Science Units** |
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| ***Digging In*** launcher unit for Earth Science; focuses on experimentation and simulation and modeling as investigation methods; content includes erosion and weathering, and it introduces rocks and minerals and earth processes (volcanos); students design and model a system for managing the erosion and water flow on a hill above a basketball court. | ***Animals in Action*** launcher unit for Life Science; focuses on observation and interpretation as an investigation method; content includes structure and function, and the way those and the environment affect animal behavior; students design enclosures for zoo animals that will allow them to communicate or feed as they would in the wild. | ***Diving Into Science*** launcher unit for Physical Science; focuses on experimentation as an investigation method; content includes gravity, air resistance, how forces combine; students design whirligigs and parachutes that fall to the ground as slowly as possible. |
| ***Planetary Forecaster*** Students are challenged to decide where on a newly-discovered planet a new colony be located. The planet is in a solar system a lot like Earth's, and the colony should be where temperatures are between 5 and 30 degrees C. Content includes heat transfer, temperature, climate, weather, global warming. | ***Good Friends and Germs*** Students focus on practices for preventing their friends from getting sick. Content includes cells, bacteria, viruses, spread of disease, body organs, body systems. | ***Moving Big Things*** Students are challenged to design a device that can lift a load of supplies to the top of a cliff. Content includes forces, work, mechanical advantage. |
| ***Earth Structures and Processes*** Students explain why new islands are developing and mountainsa re changing their shapes. Content includes earth's layers, earth's processes, earthquakes, volcanos, topographic maps. | ***Living Together*** Students give advice to a city council about the conditions under which they should allow a new industry to move to the town. Content includes ecology, food chains, watersheds, adaptation, pollution. | ***Air Quality*** Students examine the air quality in their neighborhood and make recommendations about improving it. Content includes basic chemistry, mixtures, solutions, acids, bases, pollution. |
| ***Underground City*** Students decide where on the newly-discovered planet a large underground facility can be placed. Content includes rocks and minerals, rock cycle, reading several types of maps, folding, geologic time, fossils. | ***Genetics*** Students give advice to the Rice for a Better World Institute about developing a rice plant that can grow in draught conditions and is resistant to caterpillars. Content includes genetics, reproduction, DNA, natural selection, artificial selection, evolution, genetic engineering | ***Vehicles in Motion*** Students are challenged to design a vehicle and its propulsion system that can travel over a hill and beyond. Content includes forces and motion, Newton's laws of motion. |
| ***Astronomy*** Students identify collisions that might be about to happen in the universe. Content includes the planetary system, forces on space objects, movement of space objects. | ***I, Bio*** Students advise the school about providing healthy lunches. Content focuses on body processes, homeostasis. | ***Energy from Trash*** Students are challenged to design a foot-controlled (Rube Goldberg) device that can turn the lights off in a room when someone leaves. Content includes types of energy, energy transformations, conservation of energy, energy from natural resources, conservation of natural resources. |

PBIS units are designed to support learners in participating successfully as student scientists. Students begin each year with a "launcher unit" (Holbrook & Kolodner, 2000; Kolodner, 2007) that serves a variety of purposes: (i) introducing practices of scientists and classroom practices, (ii) promoting creation of community among students, (iii) promoting a culture of collaboration and collaborative learning and setting expectations for rigorous scientific discourse, and (iv) providing a context for teacher and students to get to know each other and develop rapport. Launcher units help the class learn to work together, help learners become familiar with the ways scientists think and have discussions, and introduce learners to the activities and tools they use throughout PBIS. The practices introduced and reviewed in launcher units (cultural practices, discourse practices, science practices, project practices, and learning practices) are repeated and built on over the course of the school year.

There are many different supports in each unit that help learners successfully address big questions and challenges. (a) At the beginning of each unit are activities that help learners understand the big question or challenge. Activities are designed to help learners think about what they already know that might help them address the challenge and some of the new things they will need to learn. (b) A *Project Board* helps learners keep track of their learning. They use a new Project Board for each big question or challenge and keep track of what they think they know, what they need to investigate, what they are learning, the evidence that supports what they are learning, and how that helps them answer the big question or challenge. (c) Each unit is composed of 4 to 6 *learning sets*, one for each of the smaller questions that needs to be answered to address a big question or challenge. They begin each learning set with some activity that helps them identify what they know that can help them answer the smaller question and what they still need to learn more about, and they record that on the Project Board. Investigations and readings in each learning set are aimed toward answering the question for that learning set, and after each set of activities that makes important points, students return to the Project Board and record what they are learning and their evidence. (d) At the end of each learning set, students apply what they have learned to the big challenge or question, and they record on the Project Board what they have been able to glean so far about the solution to the question or challenge. This sequencing is designed to sustain continuity and interest in the big question or challenge throughout the course of a unit. The activities done at the end of each learning set allow learners to see the progress they are making and recognize next steps they need to take in moving closer to a solution. The Project Board, a constant fixture in the classroom, is a place for recording progress and a constant reminder of how far students have come in addressing the challenge and what they need to be doing to complete it.

Within each learning set is sequencing and support for answering the learning set's question. (a) Activities include several different kinds of investigations and explorations – designing and running experiments, designing and running simulations, designing and building models, examining large sets of data, examining examples, and reading case studies. (b) Like scientists, they read about science they are learning – a little before carrying out investigations, but most of the reading they do is to help them understand what they've already experienced in an investigation. Each time they read, the text includes *Stop and Think* questions to help them guage how well they understand what they've read. (c) When they are addressing a design challenge, they engage in design and construction work as part of a learning set, applying what they are learning to some part of the challenge. (d) They make explanations on a regular basis. The materials help them make claims (what they think they know), identify evidence from investigations that support their claims, identify science knowledge they've read that supports their claim, and then construct a statement that describes why their claim is so – i.e., why something is the way it is or behaves the way it does. They might make recommendations, as well, and they are told that a recommendation is a special kind of claim that, like any other claim, needs to be supported with evidence, science knowledge, and explanations. (e) Each activity is accompanied by "science journal" pages that are designed to provide scaffolding for the small-group activities and places to record data, observations, claims, and explanations.

One of the most important things the curriculum materials do is help learners reflect. PBIS materials include many different tools for promoting reflection. (a) *Stop and Think* questions help them make sense of what they have been doing or what they have just read. (b) *Reflec*t questions help them connect what they've just done with other things they've done or read earlier. (c) *Analyze your Data* advice helps them make sense of data they've collected, providing hints about what to notice in the data and how to detect trends. (d) *Messing About* sections provide guidance about how to explore materials or discover new ideas. (e) *What's the Point?* subsections summarize content in a section.

Perhaps the most important tool for reflection in PBIS is the guidance students are given for collaborating with each other in small groups and sharing their small-group work and what they are learning with the whole class. In general, students work with each other in small groups to make meaning before discussions with the whole class. PBIS has in its sequencing abundant opportunities for sharing small groups' findings, ideas, and discoveries with the class, and student text includes guidance about what to present and share when and how to do it. (a) In *Investigation Expos*, small groups report to the class about investigations they've done. For each Investigation Expo, groups make a poster detailing what they were trying to learn from their investigation, what they did, their data, and their interpretation of data. The text that goes with each Investigation Expo provides hints about what to present and what to pay attention to and ask questions about in the presentations of others. Investigation Expos are always followed by discussions about what they've learned and how to do science well. (b) *Briefings* are presentations of works in progress. They give small groups a chance to get advice from their peers that can help them move forward. The student text that goes with each one gives advice about what to present and what to listen for, and briefings are followed by discussions of what's been learned and how to move forward. (c) *Solution Showcases* are for showing finished products. Presentations during Solution Showcases include in them a presentation of how the solution to the question or challenge was reached and the evidence that was created and used along the way. (d) Discussions around the Project Board provide opportunities for collaborative meaning making. (e) *Conferences* are short discussions in small groups before more formal whole-class discussions. While in whole-class venues, only some class members participate, in small-group discussions, everyone has a chance to participate.

This sequencing and support together promote both reflection and iterative development of understanding. Students present to each other at times when they have the need to learn from each other or to get help with their reasoning and ideas before moving forward. Launcher Units give learners experience recognizing the value of presenting to and getting help from their peers, so learners come to value those opportunities. To inform their peers and to get good advice from their peers requires presentations at an appropriately-rigorous level. This, in turn, requires the kinds of reflection that help learners identify what they have done and what they are learning.

Iterative refinement of understanding and progressive development of capabilities are built into this same fabric. Development of understanding is promoted through embedded sequences of activities: students identify what they think they know, make predictions, carry out investigations, make claims, read, create explanations to connect claims to their supporting evidence and science knowledge, attempt to apply claims, identify where claims fall apart, revise their claims, and raise new questions. Revisiting the challenge between learning sets promotes taking a variety of perspectives on the big topics of each unit. Important practices of scientists are practiced repeatedly in each unit, always in contexts of authentic need. Venues for public practice of science practices and skills and for use of science content are opportunities for students to work together to debug their understanding and capabilities.

Another issue the sequencing addresses is assessment. A common plea we hear from teachers is to help them with assessment – grades they have to give individual students – without inserting quizzes into student activities. PBIS has a huge variety of opportunities for individual assessment in the context of small-group activities. Homework assignments ask individual students to prepare for the next day's activities or to reflect on and summarize something they have just done or learned. Though students work in groups, they keep records individually. After group presentations, it is always appropriate to ask individuals to write up their work – in e.g., lab reports. At the ends of units, after groups have achieved the challenge together, it is always appropriate to ask individual students to write up their solutions or critiques of the group solution. Not all students have strengths in writing; when possible, we advise teachers to ask students to draw or find other ways to present what they are learning. A picture dictionary is one means of doing that.

How do we deal with coverage of topics and sequencing of units? We have solved the problem of coverage by making decisions in each unit about which topics will get focus in the unit, and we add small text boxes to units in places where becoming familiar with some other content would not be out of place. Longer topical discussions are put into asides in places where they do not hurt the flow. *Good Friends and Germs*, for example, emphasizes the respiratory, circulatory, digestive, and immune systems in the main text. After students learn about those systems and make recommendations about preventing spread of disease, there is an optional set of pages about other body systems. We solve the problem of sequencing with several tactics. First, our materials cover some topics in more sophisticated ways than others. We've also identified the units that build on each other. The sequencing in Table 1 takes both into account. When coverage is by discipline, we advise doing the units in the sequence they appear in the columns of Table 1. When coverage is interdisciplinary, we advise using those towards the top of each column earlier in middle school and those towards the bottom in later grades.

Managing scope and sequence also means identifying themes that are important to science and that connect units to each other, e.g., use of modeling as an investigative method, systems thinking. We have used a variety of methods for managing thematic connections: recurring types of text boxes and margin notes for some (e.g., technology connections), header/subheader sequences for some (e.g., all kinds of investigations are called investigations at the header level, with the particular type of investigation (e.g., experiment, simulation) in a subheader), and recurring vocabulary for some (e.g., systems).

Our teacher materials and programming aims to treat teachers as learners. It is common for teacher materials to be in the form of "Teachers' Editions" (TE's), books where student pages are miniaturized and put on pages, and teacher hints for managing the classroom and learning are around the edges. We are designing PBIS "Teachers' Planning Guides" (TPG's) differently. The TPG for each unit is designed to help teachers plan classroom activities in detail, review what needs to happen in class, and glance during class for reminders about what comes next. They are designed for use by teachers new to PBIS and by those who are more experienced. They are designed so that we (the writers) can provide for teachers what we think they need and so that teachers have space to write notes as they are planning.

## The Future

We have been field testing our materials over the past several years throughout the US. Initial evaluations show that students are learning significantly. At present (March 2008), all units have been piloted, and most have been field tested, and 10 of the 15 student books are near publication. We are working on completing the other student books and on revising teacher materials. We are looking forward to working with evaluators to evaluate the strengths and weaknesses of our published curriculum, and we are looking forward to others using PBIS classes as venues for carrying out investigations of learning.

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