PROBLEM-BASED LEARNING IN THE LIFE SCIENCE CLASSROOM

K–12

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CONTENTS

CATALOG OF PROBLEMS

Problem	Page Number	Keywords and Concepts	Grade Band			
			Grades K–2	Grades 3–5	Grades 6–8	Grades 9–12
CHAPTER 5: ELEMENTARY LIFE CYCLES PROBLEMS						
1. Baby Hamster	68	Mammalian life cycle, needs of living things	•	•		
2. Wogs and Wasps	75	Insect and amphibian life cycles, needs of living things	•	•	•	
3. Humongous Fungus	83	Fungus life cycle, needs of living things		•	•	
4. Baby, Baby Pear	89	Plant life cycles, needs of living things	•	•		
CHAPTER 6: ECOLOGY PROBLEMS						
1. Where's Percho?	106	Competition, food webs		•	•	•
2. Lake Michigan—A Fragile Ecosystem	114	Competition, food webs, invasive species			•	•
3. Bottom Dwellers	121	Eutrophication, water quality indicators, water pollution, human impacts on the environment			•	•
4. Bogged Down	132	Ecological succession, plant dispersal, competition in plants			•	•
5. The Purple Menace	138	Competition, invasive species		•	•	•
CHAPTER 7: GENETICS PROBLEMS						
1. Pale Cats	154	Genotype to phenotype, inheritance of traits			•	•
2. Black and White and Spots All Over	162	Codominance, inheritance of traits			•	•
3. Calico Cats	169	Sex-linked and multigenic traits			•	•
4. Cat Puzzles	176	Patterns of inheritance, genotype to phenotype, codominance, sex-linked and multigenic traits			•	•

Problem	Page Number	Keywords and Concepts	Grade Band			
			Grades K–2	Grades 3–5	Grades 6–8	Grades 9–12
CHAPTER 8: CELLULAR METABOLISM PROBLEMS						
1. Torching Marshmallows	189	Cellular respiration		•	•	•
2. Mysterious Mass	202	Photosynthesis		•	•	•
3. Why We Are Not What We Eat	212	Digestion, biosynthesis			•	•

1

DESCRIBING THE PROBLEM-BASED LEARNING PROCESS

As a science teacher, you probably use a variety of approaches and strategies in the classroom. On any given day you may lecture, lead group discussions, teach an inquiry-based lab, assign projects, ask students to complete individual reading and writing assignments, and perform many other types of tasks. All of these strategies have a legitimate purpose, and we encourage teaching that employs a diverse range of activities.

Why Problem-Based Learning?

In this chapter, we will discuss why problem-based learning (PBL) is one of the many tools you should keep in your teaching toolbox, ready to be used at appropriate times during your teaching. We will also give you some background information about how PBL was developed, background on how it works in a range of disciplines, and a basic framework for a PBL lesson. In later chapters, we will provide further detail on the "nuts and bolts" of teaching a PBL lesson and how to develop and facilitate learning activities using this strategy. The advice we will offer and the science problems we will share in later chapters come from our own experiences in using PBL to teach concepts to teachers. Many of the lessons have also been used with students across a wide range of age groups.

The reason we have used these lessons is because of a driving philosophy that it is imperative to help students develop the ability to inquire, solve problems, and think critically and independently (Barell 2010). Many of the thinking skills directly taught in the PBL process are included in the goals of 21st-century skills (Barell 2010; Ravitz et al. 2012). PBL is well suited to achieving the goal of developing thinking skills because it presents learners with authentic stories that require application of scientific concepts to construct and evaluate possible actions. In the process of solving problems, students plan, gather, and synthesize information from multiple sources or from investigation findings, evaluate the credibility of their sources, and communicate their ideas as they justify their claims. Students are guided by a set of simple prompts that help them organize information and generate questions and hypotheses.

In our experience, learners quickly adopt this framework as a habit of mind, and they begin to apply this critical-thinking strategy to other problems and real-world situations. The framework becomes a habit because the process is easily internalized and uses simple language. Asking the question "What do we know?" is easy for most students to remember and use, and the rest of the framework is just as direct and intuitive. This process also resembles KWL (McAllister 1994), a formative assessment strategy used widely in elementary classrooms. In KWL, students are asked to verbalize and record a list of what they "Know," what they "Want" to know, and what they have "Learned." The feature added by the PBL framework that makes it so "scientific" is the inclusion of hypotheses, leading students to make predictions and justify them.

Teachers in the professional development program for which these problems were developed very quickly adopted the language and turned "PBL" into a verb. When they encountered new problems, they initiated the process with phrases like "Let's PBL this." K–12 students are just as quick to adopt the cognitive framework. This is one of the benefits of using PBL in your teaching.

Historical Background of PBL as a Process

PBL's origins are rooted in this same desire to help learners solve real-world problems. PBL was originally a strategy for developing content knowledge in the context of assessing and diagnosing patients (Barrows 1980). Medical students had been very successful in memorizing information, but when asked to use the information to diagnose a patient, they were unable to apply their knowledge. What was lacking in their understanding was how the ideas they had memorized were useful in diagnosing and treating patients in an authentic "problem" they would encounter as a doctor. The challenge for medical school faculty members was finding a way to teach students to think like doctors, not like students preparing for a test. PBL also presents opportunities in such a contextualized manner, so medical schools began using this strategy. PBL was shown to be effective in helping medical students learn anatomy, pathology, and medical procedures and helping them apply this knowledge to medical cases. Thus, PBL became widespread in medical schools.

The same issues seen in the field of medical education are important concerns for science students, too. Just as second-year medical students struggle to transfer what they learn into practice, science students struggle to understand how memorizing metabolic pathways is helpful in explaining real-world issues, or how life cycles in different species are similar. Bransford and Schwartz (1999) suggest that transfer of knowledge is enhanced if the concepts are shown in a variety of contexts, rather than always presenting them in the same or very similar contexts. They also recommend using metacognition to support the transfer of knowledge across contexts. One of the strengths of PBL is that the framework we will present is a metacognitive structure—students are expected to be aware of what they know and what they need to know to solve the problem.

Bringing PBL to Other Disciplines

Since its beginnings in medical education, PBL has been adapted to business, law, law enforcement, and other subjects (Hung, Jonassen, and Liu 2008) and has been modified for science teaching (Allen et al. 2003; Gordon et al. 2001). Research by Hmelo-Silver (2004) suggested that PBL leads to increased intrinsic motivation of learners to become more self-directed. Another study reported that teachers who use PBL in their classroom teach more 21st-century skills (Ravitz et al. 2012).

In this book, the model presented for using PBL to teach science content has features similar to the PBL activities from other subjects, but it has been refined through research-based evaluation of the process when used for teaching science content in the PBL Project for Teachers (McConnell et al. 2008), as described in the next section.

The PBL Project for Teachers

The context in which the materials presented in this book were created was the PBL Project for Teachers, a National Science Foundation–funded teacher professional development program (McConnell et al. 2008).[1] The PBL Project was designed to accomplish several goals, including deepening K–12 teachers' scientific understanding, developing inquiry-based science lesson plans, and facilitating a form of reflective practice that applied the same PBL principles to the study of teaching.

In this program, K–12 teachers spent three days of a two-week institute learning science content surrounding standards they had identified as areas of need in their curriculum. Facilitators for each of the eight content strands planned PBL lessons to address those specific standards. These facilitators were experts in their respective science content areas who worked in teams of at least three. The teams wrote PBL problems that addressed the science standards teachers identified, and then shared these problems with peers for review. The problems were then tested and revised in an iterative fashion over four cohorts of teachers. The final versions were the basis for the problems found in this book and those to be included in future volumes in the PBL series.

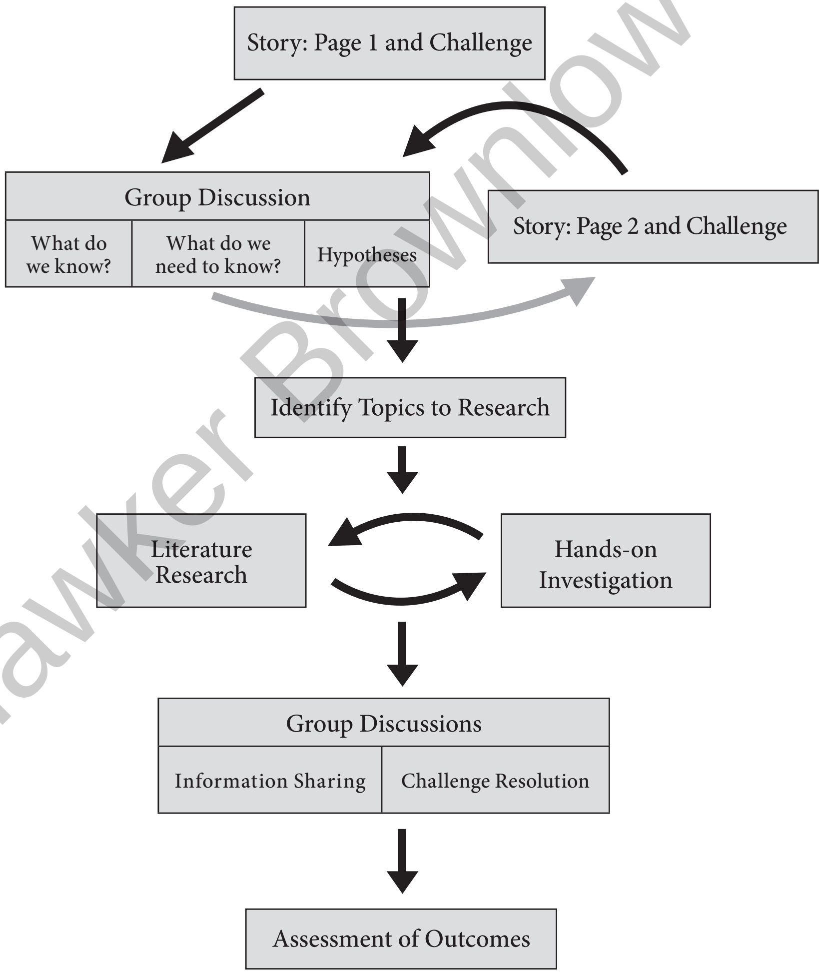
The activities were modified for use in the K–12 classroom, with a focus on problems for life science, Earth-space science, and physics. These modifications included changing the context of the story to relate more to students in specific grade bands and changing the reading level to match the target audience. The concepts addressed in the problems remained consistent, in part because pre-assessments with teachers revealed very similar prior understandings as K–12 students, especially for teachers who were not science majors. Research to assess content learning showed that most of the teachers gained a deeper understanding of their chosen content as a result of the PBL lessons (McConnell, Parker, and Eberhardt 2013). Participants then used the content knowledge they gained to develop inquiry-based lesson plans and used PBL to analyze problems in teaching practice. Many of the problems have also been tested in K–12 and college courses, with revisions made to address any difficulties encountered.

[1] National Science Foundation special project number ESI-03533406, as part of the Teacher Professional Continuum program.

The PBL Framework

Throughout the PBL Project for Teachers, we used the same framework for designing and facilitating the PBL lessons that we used for the problems presented in this book. This framework draws from the guidelines described by Torp and Sage (2002) and the model used by the Michigan State University College of Human Medicine (Christopher Reznich, personal communication, October 11, 2004). In this model, students are presented with a problem, usually in the form of a story divided into two parts (Christopher Reznich, personal communication, October 11, 2004). There can be more than two parts to the story, but the key feature is that information is presented to students in stages. Figure 1.1 shows a representation of the PBL process.

Figure 1.1. The PBL Process



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One of the keys to PBL is to develop a problem that is open-ended and ill-structured (Gallagher 1997; Torp and Sage 2002). By *ill-structured,* we mean a problem in which not all the information needed to solve the problem is presented to the learner, and some of the information presented may not be needed. In the real world, problems do not present themselves with a set number of variables or with a value for every variable provided but one. So the PBL lesson starts by presenting one of these scenarios and expecting students to unpack the problem and construct a path to solve the problem, as Dan Meyer (2010) describes for teaching math when he cites Albert Einstein: "The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill." PBL offers a way to engage students in thinking about the problem, developing a strategy to solve the problem, and exploring the content knowledge needed to achieve a solution.

Torp and Sage (2002) also use language to describe the scenario presented by the teacher that is common to most literature on PBL. They refer to the story as the *dilemma*. In the PBL Project for Teachers, we used the same language, but for this book, we have changed the terms. The origins of the word *dilemma* suggest that there are "two answers" to the scenario, but in reality a good dilemma is likely to have (at least at first glance) far more possible answers. So we have elected to call our scenarios *problems.* We will present the problems in the form of a story that ends in a *challenge*, which helps define the task students will take on and launches the research and analysis that follows. The challenge then serves as a focal point that defines what successful completion will require.

Structure of the Problem

In Chapters 5-8, we present PBL problems, which are the lessons that we have developed to share with teachers. Each chapter focuses on a content strand that fits within the life science discipline. These chapters begin with a description of the learning goals (Big Ideas) and the conceptual barriers students often face as they learn the concepts the problems address.

We have also included some interdisciplinary connections for each chapter. For elementary and middle school teachers, it may be helpful to demonstrate to administrators that students are developing more than just science content during the lesson. Our lists are by no means exhaustive, so feel free to make other interdisciplinary connections as well.

The pages that follow the opening discussion include the problems. We have developed a consistent structure for each problem to help you find and use the resources you need. The main components of each problem are listed below and briefly described in the following subsections; see Chapter 3 for more details on facilitating each component.

- Alignment With the *NGSS*
- Page 1: The Story
- Page 2: More Information

- Page 3: Resources, Investigations, or Both (not included in every problem)
- Teacher Guide
- Assessment

Alignment With the *NGSS*

The first page of each problem presents an overview of the problem and the alignment with the *Next Generation Science Standards* (*NGSS*; NGSS Lead States 2013). The table presented on this page lists the performance expectations, science and engineering practices, disciplinary core ideas, and crosscutting concepts that are addressed in the lesson.

Below the table is a list of keywords and concepts and a short description of the context of the problem. The items on this page are intended to help the teacher select problems that best suit his or her curricular needs.

Page 1: The Story

In the next component, a very brief story presents an authentic scene that sets the context for the problem, followed by a "challenge" statement making it clear what the learners are expected to accomplish. In our model, Page 1 is the "engagement" activity to draw students into the learning situation and show them a real-world reason to know some science concepts. The Page 1 story ends with "Your Challenge," a question or series of questions that presents the students with a problem they need to resolve.

This page is the starting point to a whole-class discussion of the problem using a highly structured analytical framework. This framework prompts students to generate ideas and questions within three categories: "What do we know?" "What do we need to know?" and "Hypotheses." Table 1.1 gives an example of the framework as it might appear when used in The Purple Menace problem in Chapter 6, "Ecology Problems." In Chapter 3, we present in more detail how the teacher facilitates this discussion, but one product of the initial discussion will be an analysis of the Page 1 story.

Table 1.1. Sample PBL Analytical Framework: The Purple Menace Problem

WHAT DO WE KNOW?	WHAT DO WE NEED TO KNOW?	HYPOTHESES
• Purple loosestrife has increased from 1 to 50 plants in 10 years. • Cattails live in the marsh. • The purple loosestrife is near the boat ramp.	• What is purple loosestrife? • What defines "successful" in plant populations? • Why is purple loosestrife a problem? • What eats purple loosestrife? Cattail?	• Cattails will be harmed if purple loosestrife spreads. • Purple loosestrife will attract new animals to the marsh, making the marsh more diverse.

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