Problem-Based Learning

In Your Homeschool

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Chapter 2

A Medical Miracle

...it is important to keep in mind the principle objectives of [problem-based learning: the] acquisition of an extensive, integrated knowledge base that is readily recalled and applied to the analysis and care of...problems.
PBL Initiative, www.pbli.org

Back in the 1960s, medical school educator Howard Barrows of McMasters University faced a problem curiously similar to Debbie Reid's. Like Sarah and Jason, his medical students did not seem to have the desired reasoning skills or curiosity. True, the young doctors had thousands of facts at their fingertips—facts that were essential to proper patient care. True, they performed well on licensing tests and seemed well-qualified. But even though they could recite reams of information, gather a patient history, and give a physical exam, they didn't know how to use the information to decide upon a diagnosis. That is to say, they knew what doctors should know, but they could not think the way doctors should think. Conversations with colleagues at other institutions revealed that the problem extended well beyond McMasters University. The realization that many young doctors knew a lot but could not think was troubling; it led to a concerted effort to integrate questioning and reasoning into the curriculum.

The McMasters team started watching doctors at work, inviting dozens of them to diagnose the same simulated patient. They wanted to define the thinking process that led to diagnosis—what they called *clinical reasoning*. They recorded the doctors' questioning patterns and discovered that a patient interview unfolded much like an extended game of "20 Questions," in which questions start broad but quickly narrow:

Doctor: What seems to be the matter?

Patient: My shoulder hurts.

Doctor: What kind of pain is it: sharp or dull?

Patient: Dull.

Doctor: What kind of movements make it hurt?

Patient: It's really bad when I lift something and sometimes when I point using that arm.

Doctor: When did it start?

Patient: Last week.

And so on. Interviews completed after the exercise reinforced the observation that the doctors' line of questioning was neither random nor generic; the questions were selected to test a possible diagnosis. If the patient answered that the pain was sharp, the doctor would follow up with a question to discriminate between a fracture and joint pain. If the pain was dull, he or she would ask a different set of questions. Occasionally, an unexpected answer caused the doctor to backtrack and consider entirely different options. Throughout, the doctors blended their medical knowledge with patient information to inform their line of questioning.

When their interviews with the doctors were finished, the McMasters team had a model of how doctors think. They discovered—or rather, confirmed—that doctors spend their entire careers chasing down mysteries, sorting through an array of symptoms, deciding which symptoms are connected and which aren't—all in trying to figure out the problem. Skill in following hunches or making good hypotheses is imperative because a bad assumption can cause a doctor to ignore clues vital to the patient's case. The doctors knew when it was time to narrow from exploration of possibilities to consideration of specific, precise ideas.

The McMasters team realized that practicing physicians followed Whitehead's rhythm of learning: a patient's complaint is the romance, the alluring problem. Precision—careful questioning and analysis of patient information—is needed to understand the exact nature of the complaint. After settling on a diagnosis, the doctors started questioning all over again, trying to determine which of the many possible treatments best fit the needs of that particular patient. Successful treatment, the solution to the problem, was the doctors' form of generalization. Medical knowledge was useful insofar as it could help the doctors sort through a mystery, piece together the clues to create a diagnosis, and then match the diagnosis with effective treatment.

Barrows and his colleagues noticed something else: the best doctors were highly self-aware. They monitored their thinking, keeping track of the directions they pursued, assessing whether they were missing clues, and ensuring that they were considering all necessary options. These doctors were willing to be *uncertain*, despite all of their knowledge. In addition, the most effective doctors were committed to ongoing self-education so they could stay abreast of new developments in their field. It seemed that problem solving, self-reflection, and lifelong learning were vital to skilled medical practice—yet virtually absent from medical school training. Medical students were schooled in being certain instead of being uncertain; rarely were they provided with practice in contending with ambiguity.

How could educators insert problem solving, self-reflection, and lifelong learning into medical school without sacrificing crucial medical content? Having just finished watching dozens of doctors, the answer was evident: medical school should look like medical practice long before students reach their residencies. Students should meet patients (simulated patients)—lots and lots of them. In a bold move, Barrows and his colleagues began transforming their students' everyday experiences from book learning to a carefully orchestrated series of simulated patients. They started with complex, paper-based case studies but quickly incorporated actors trained to act out different diseases. The simulated patients introduced the same information contained in textbooks, but in a real-world setting. While testing this approach, Barrows and his colleagues found that students enjoyed the mystery-like process of chasing down clues. Moreover, the romance of the chase led to increased rigor in investigation and higher-quality patient care.

Putting the problem at the beginning of learning reintroduced romance; what remained was to cultivate the students' awareness of their own thinking. To accomplish this, students were clustered in small tutorial groups. As they worked together to analyze patient cases, the medical faculty focused deliberately on reflective reasoning and critical thinking. Throughout their studies, the students framed their learning with four questions essential to any field of endeavor:

What am I assuming? (And how might that affect my thinking?)

What do I already know?

What do I need to learn?

How can I go about learning what I need to learn?

Results of the transformation were quickly apparent. Medical students in this problem-based learning (PBL) curriculum generally learned as much or more than students receiving traditional instruction. In addition, the PBL students acquired skills in questioning, collaboration, research, and self-directed learning; they even showed increased compassion and attention to patient communication.

Howard Barrows and his colleagues sparked a revolution in medical education. Problem-based learning spread through medical schools in the U.S. and Europe. It is one of the most thoroughly researched educational approaches anywhere, with hundreds of published studies demonstrating its effectiveness in many dimensions of learning.

Before long, other educators began to notice the medical school revolution. The thinking process that the McMasters team called clinical reasoning is valuable in all walks of life—not just for doctors but for detectives and scientists, artists, cooks, historians, mechanics, journalists, pilots, even parents searching for lost car keys. This makes PBL an essential training ground for students of all ability levels and across all subjects. Because of its roots in medical education, PBL carries a level of legitimacy that other inquiry-based approaches lack. Medical educators voluntarily underwent a radical change—successfully; they took the challenge of creating 21st-century thinkers seriously, and eventually their ideas caught the attention of K-12 educators. Projects experimenting with PBL in K-12 classrooms began at every grade level, age group, and subject area. These experiments also have been successful, some producing award-winning curriculum. Adjusting PBL to large classrooms is possible but requires some adaptations that aren't necessary in homeschool environments. In fact, as Debbie Reid is about to discover, the homeschool can be an excellent setting for problem-based learning.

Does PBL Really Work?

Learning the Subject

Many studies report that PBL students learn as much content as traditionally instructed students (Dods, 1997; Gallagher, 2001; Gallagher & Stepien, 1996; Geban, Sungar, & Ceren, 2006; Hmelo-Silver, 2004; Verhoeven et al., 1998). However, research also shows that student learning in PBL isn't automatic. In order to attain equal (or greater) achievement, the problem must be carefully designed toward learning outcomes (Goodnough & Cashion, 2003; van Berkel & Dolmans, 2006). Student achievement increases as students become more self-directed (van den Hurk, 2006) and when the teacher has a thorough understanding of the problem or skill in facilitating self-directed learning.

Thinking Skills

In addition to learning content, PBL students show improvement in higher-order thinking skills (Cruickshank & Olander, 2002; Feng, VanTassel-Baska, Quek, Bai, & O'Neill, 2005), problem finding (Gallagher, Stepien, & Rosenthal, 1992), ability to make inferences (Sheldon & DeNardo, 2005), interdisciplinary thinking, flexible thought, and adaptability (Hmelo & Ferrari, 1997; Norman & Schmidt, 1992).

Attitudes

PBL students report higher levels of engagement and more satisfaction with their learning experiences, and they seem to continue to like the subject under study more after PBL. Students enjoy PBL more when they feel supported as they acquire self-directed learning skills (Greening, 1998). Most studies of K-12 classrooms also report higher satisfaction and engagement among PBL students as compared to traditionally instructed students (Hmelo & Ferrari, 1997).

Chapter 3

Problem-Based Learning Explained

Students should be given problems—at levels appropriate to their maturity—that require them to decide what evidence is relevant and to offer their own interpretations of what the evidence means.... Students need guidance, encouragement, and practice in collecting, sorting, and analyzing evidence, and in building arguments based on it. However, if such activities are not to be destructively boring, they must lead to some intellectually satisfying payoff that students care about.
Rutherford & Alghren, 1990

Debbie Reid was about to start a unit on plant growth, soil pH, and the effects of fertilizer on plants and the environment. Typically she would assign background reading, discuss the nature of fertilizer (with the help of someone from the garden center), and help the children with an experiment testing soil pH before and after fertilization. She'd finish the unit by assigning a brief research paper on the effects of fertilizer on the environment. Afterwards, she'd give Sarah and Jason some form of assessment to see what they remembered. This approach requires that Sarah and Jason remain dependent learners, waiting for Debbie to tell them what to learn, when to learn, and why to learn. There isn't much opportunity for them to experience the kind of curiosity Kishana Jackson has in her work.

Debbie has decided to give PBL a try. She reorganizes the unit, writing a problem that will lead the children to the study of plant growth and fertilizer. She also arranges for Jason's friend Dominic to join the children for the unit. Instead of assigning a reading to start the unit, she asks the children to gather at a large whiteboard. She's divided the board into four sections to create a Learning Issues Board like the one on page 72. Then Sarah, Jason, and Dominic receive a copy of the following opening scenario:

The Golf Course

A warm spring sun promises a busy day at the golf course in Pinehurst, North Carolina. The course has been in operation for just over a year, and you have been superintendent of it for six months. You can see one of the workers mowing over on the green of the third hole. The grass looks beautiful, and up until yesterday, that seemed like a good thing. But when you checked your mail yesterday, that all changed. A petition containing 100 signatures was enclosed in one of the envelopes. The letter that came with the petition was from *the head of the Citizens' Action Committee for a Safe Environment. According to the letter, the people who signed the petition think that the fertilizer used on the golf course is polluting the local water. Boy was the boss mad! He was all red in the face. "That's just NONSENSE!" he shouted, and then he said, "Prove they're wrong, or fix it NOW!"*

You now look at the names on the petition and think, "I sure hope it's nonsense. My family drinks the local water, too!" You know you have to get started quickly; the boss wants a report by Wednesday. Well, you think, where should I begin…?

The children look at Debbie, waiting for instructions. "What seems to be going on?" Debbie asks. As the conversation unfolds, she makes entries in the appropriate sections of the Learning Issues Board.

Sarah: What is polluting the water?

Debbie: Why do you ask that question?

Jason: Because the petition says that the water is being polluted.

Debbie: I see. So your hunch, or assumption, is that the petition is accurate. Let's write that down. (writes *The petition is accurate* next to "Hunches") What information do we have that makes you think that the petition is accurate?

Dominic: Well, lots of people signed it.

Debbie: How many?

Jason: Sixty.

Sarah: No, it's 100.

Jason: Is not!

Debbie: How are you going to figure this out?

The children refer to the sheet in front of them, and Jason reluctantly concedes that the petition contains 100 signatures. Debbie writes *100 people signed a petition* under "What We Know."

Dominic: The people are right that golf courses use fertilizer.

Debbie: How do you know that?

Dominic: Well, I saw some workers spreading some last time we played golf.

Debbie: (writes *Golf courses use fertilizer* under "What We Know") Let's think about the connection. Does the fact that golf courses use fertilizer automatically mean that the golf course is responsible for the polluted water?

Children: No.

Debbie: Then what do you need to know to test the assumption that the petition is accurate when they say that the golf course is causing the water to be polluted?

Sarah: Well, we need to know how much fertilizer is used.

Debbie: Why?

Sarah: Because if there's too much, it might get into the water.

Debbie: (writes *How much fertilizer is used?* under "Learning Issues") What other information would we need to test these hunches?

Jason: What kind of fertilizer do they use?

Debbie: How would that question address our hunches?

Jason: Well, it tests the hunch that the pollution is from the golf course, because if they use a type of fertilizer that pollutes, then maybe they're polluting the water, but if they're using a type of fertilizer that doesn't pollute, then it's not their fault.

Sarah: But maybe they're wrong!

Debbie: Maybe who is wrong?

Sarah: The people who signed the petition. Maybe it's someone else!

Debbie: Aha…we have another hunch to pursue—a hunch that the pollution is coming from somewhere else. What facts do you have that suggest that this might be true?

Sarah: Well, none really—but we could get some.

Debbie: What information do you need to know to find out if that's true?

And the conversation continues.

Sample Learning Issues Board after Problem Engagement

Hunches: (1) The petition is accurate. (2) Fertilizer from the golf course is getting into the water. (3) The water is polluted from somewhere else. (4) The water may be okay. (5) The petition may be from crazy people.

What We Know	Learning Issues	Plan of Action
• This is a new golf course. • We are the golf course superintendent. • The grass looks good right now. • 100 people signed a petition. • Golf courses use fertilizer. • The petition was from the Citizens' Action Comm. for a Safe Environment (CACFSE). • The people think the fertilizer from the golf course is polluting the local water. • The boss is mad about the petition. • We have to do something about the situation. • Our family drinks that water.	1. **What other places in the area could be polluting the water?** 2. **Is the water actually polluted?** 3. What is a golf course superintendent? 4. What does a golf course superintendent do? 5. **What is the CACFSE, and what are these people asking us to do?** 6. How do you test water safety? 7. **What kind of fertilizer do golf courses use?** 8. How much fertilizer is used? 9. If the water is polluted, what is in the water: fertilizer or something else? 10. What else could be used to keep the grass good for golf?	Talk to a golf course superintendent about the fertilizer they use. **Dominic** Get a sample of the water to test. **Mom** Research grass fertilizer at a home improvement store. **Jason and Dominic** Look on the internet and in books to see if there is a connection between fertilizer and pollution. **Sarah (and Mom)** Find maps. **Mom** Look at a map to see where else the pollution might come from. **Sarah and Dominic**

By the end of the conversation, the Learning Issues Board contains a list of questions that will create the learning agenda for the next few weeks (see page 15). The children are excited, and Debbie is, too. She did not say a word about what the children "had" to learn; all she did was ask questions! The questions the children asked created the learning agenda.

That is how a PBL learning adventure begins. Children ask questions about an ill-structured problem. Sarah, Jason, and Dominic do not need to know that Debbie wrote the problem so that they would ask the questions she wanted them to ask; all they need to know is that their questions are crucial.

We will come back to Debbie and the children in a little while. First, we will differentiate the elements that combine to make problem-based learning an engaging and effective form of learning.

Essential Elements of Problem-Based Learning

Three elements combine to make PBL a unique multidimensional learning experience: (1) using an ill-structured problem to initiate learning, (2) requiring children to adopt a single stakeholder role, and (3) emphasizing "coaching" over traditional teaching as the primary form of instruction.

A Simple Reversal: Starting with a Problem. Most curriculum units begin with a reading, a lecture, or a demonstration. Children are expected to figure out which facts are important, often by following an instructor's pointed lecture or outline, and to commit those facts to memory. With luck, this will get them through the unit test.

In PBL, the order is reversed. Children encounter a problem first and then figure out what they need to learn in order to solve it. Reversing the order by putting the problem first brings the emotional allure of the unknown back into the curriculum. The problem creates a context in which the children's questions can drive the learning experience while still ensuring that they learn meaningful content. Because their questions drive the direction of study, children experience the intrinsic motivation of feeling in charge of their education. Using the problem as a touchstone, the children decide what information is necessary—useful information helps solve the problem; other information, however interesting, is not pertinent. Questions about relevance melt away.

Using Ill-Structured Problems. Initiating learning with a problem will not work if the problem contains no mystery. Many textbook problems are designed to be clear and straightforward. They have little or no inherent mystery to excite curiosity; they are merely puzzles meant to test a specific memory or set of skills. In education parlance, these are called *well-structured problems* precisely because they lack ambiguity.

PBL problems are *ill-structured*, ambiguous, and unclear, like the first chapter of a mystery. The sense of story inherent in an ill-structured problem automatically increases children's interest in learning, and also the likelihood that their learning will endure (Bransford & Vye, 1989; Brown, Collins, & Duguid, 1989; Witherell & Noddings, 1991).

Ill-structured problems are uniquely suited to reveal that true wisdom lies in interpreting information, not memorizing facts. Research gives evidence that children who learn using ill-structured problems are more likely to: (1) learn

Well-Structured and Ill-Structured Problems

	Well-Structured	**Ill-Structured**
Example	Which car travels farthest when one travels 70 miles per hour for 3.75 hours and another travels 60 miles per hour for 4.25 hours?	You are a member of a state legislature. A bill has been proposed that would reduce the speed limit from 70 to 60 miles per hour. How will you vote?
Educational Goal	Learn to think with available information to find a right answer	Learn to ask questions, research for reasons with discovered information, construct viable solutions, and defend one as the best choice in the given circumstances
Characteristics	The problem is complete; all necessary elements are described within the problem statement.	The problem statement is incomplete; more information is needed to understand the exact nature of the situation.
	The problem can be solved with a high degree of certainty; experts usually agree on a single right answer.	Experts often disagree about the solution, often because they disagree on the criteria to use to judge the best solution. The disagreement can continue even after the problem is "solved."
	Engages the mind	Engages mind, imagination, and emotion
	Often draws from only one subject	Often interdisciplinary
	Requires discrete skills and formulas	Requires sophisticated thinking skills, including self-reflection

significant content, (2) use that content well, (3) consciously regulate their thinking and feelings, and (4) develop defensible, evidence-driven arguments for their solutions (Shin & McGee, 2003). Ill-structured problems are also inherently interdisciplinary; children naturally begin to integrate information from different disciplines. As they learn to look for ideas in unusual places, they simultaneously broaden their perspective. The contrasting characteristics of well-structured and ill-structured problems are summarized in the table on page 17.

A Carefully Constructed Ill-Structured Problem. The term *ill-structured* suggests an unpredictable, perhaps chaotic learning journey. Not so! A PBL problem is designed to be ill-structured from the children's point of view, not the instructors'. When properly constructed, a PBL problem directs learning through a fairly predictable chain reaction: the problem evokes questions; questions initiate research; research leads children to required content. A carefully constructed ill-structured problem ensures that content coverage will occur by virtue of questions children are compelled to ask. Adult "coaches" should be able to think through the chain of events and see how it leads children to a particular body of knowledge (Barrows & Tamblyn, 1980; Gallagher, 2008a, 2008b, 2008c; Ross, 1997; Stepien & Pyke, 1997). For example, when Dominic finds out that fertilizer can affect the water table, he is likely to ask, "What harm does it do?" When Jason realizes that golf course fertilizer is causing the pollution, he's bound to wonder, "How does it get in the water?" Who wouldn't?

Questions children ask about the opening scenario motivate them to read, research, and analyze information; they want answers! Flexibility comes in the methods children use to research and analyze the questions they've asked and the different options available as solutions. All professions deal with ill-structured problems, so PBL works in all subject areas. Examples of ill-structured problems that have been developed for different subjects appear in the table on page 22.

The Stakeholder: Defining Perspective. The opening scenario of a PBL unit introduces the ill-structured problem and sets the stage for learning. Requiring children to adopt the perspective of someone invested in solving the problem—i.e., a stakeholder—further immerses them in the problem. Children of all ages generally enjoy "suspending their disbelief," pretending that they are a character in the story; that alone can be highly motivating. Asking children to step inside the problem instead of taking an objective stance makes learning more personal. They are not solving a problem; they are facing *their* problem. The stakeholder role serves other functions as well. The choice of which stakeholder the children will become affects the content they learn. The role of golf course superintendent is useful for a science unit because someone in that position has to understand the science of plant growth, recognize the possible impact fertilizer has on the environment, and weigh equally valid concerns of personal and economic well-being. If, instead, the stakeholder for this problem was a member of the city council, the children would view the situation from a very different perspective, grappling with a different set of problems.

The stakeholder role also can give children a deeper appreciation of different careers. Often, children are curious about the nature of certain jobs, and acting as a stakeholder can help them to learn that being professional requires not only knowledge and skills but also appropriate behaviors, effective communication, and values inherent to their position. Children might be surprised that a golf course superintendent knows about different kinds of grass, chemistry, meteorology, interpersonal relations, business management, and even how to write. The job might be about golf, but the responsibilities require interdisciplinary knowledge.

The use of a single stakeholder distinguishes PBL from other forms of simulation in which each child takes on a different role and acts out the interplay between various stakeholders. The single role may seem to limit PBL, but it actually increases opportunities for children to reflect together about the way in which a job or role that someone holds can influence problem solving and affect the scope of the problem, tools used to solve the problem, and even attitudes toward different elements of the problem. Sharing this vantage point allows children to have a common "apprenticeship," in which they learn how to "think like a golf course superintendent." What parts of this problem does someone in this job take on? How does a golf course superintendent balance the immediate need to earn a living and the needs of the larger community? The children also consider together how they will approach others who have a different but equally valid interest in the problem. A golf course superintendent is not likely to find a satisfactory solution unless he or she tries to understand the point of view of the townspeople who signed the petition. Over time, by taking different stakeholder roles in different problems, children learn to think like a biologist, mayor, reporter, business owner, or author and get an inside view of all aspects of a discipline, from facts to ethical practice.

Coaching, Not Teaching. PBL instructors are supposed to tutor or "coach" their students. Just like any other coach, the PBL coach helps children move from dependence to independence, from other-directed learning to self-directed, reflective learning so that ultimately they can:

> *…take the initiative, without the assistance of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes.* (Knowles, 1975, p. 18)

Because it was originally conceived for medical schools, PBL instruction takes place in small groups so that the coach has time to watch and listen closely as the children work together. Time is set aside for reflection, and the coach has opportunities to work both with individuals and with the group as a whole. The coach uses this time to question children's assumptions, prompt attention to different aspects of the problem, and introduce learning strategies as needed. This intensive, personal tutorial environment is particularly well-suited to the homeschool environment, where adults usually work with a small group of learners.

Would you expect a basketball coach to sit his team on the bench from the beginning to the end of every practice, lecturing his players about skills and plays but never letting them handle the ball? Would you expect a choreographer only to show videos of a ballet to teach her principal dancers a *pas de deux?* Of course not; the picture is ridiculous. The coach and choreographer use active teaching methods, drilling, practicing, and refining techniques while encouraging continually more sophisticated performance. They are preparing for a time when the power forward or the principal dancer will perform on his or her own, independently.

Metacognition: Thinking about Thinking. One of the most important skills children learn through PBL is how to pay attention to their own thinking habits. The term commonly used for thinking about thinking is *metacognition.* When children learn to reflect on their thinking habits, recognizing the skills they use well or the ideas they resist, they build the capacity to direct their own learning. The PBL coach helps children appreciate the value of being self-aware by modeling self-reflective, metacognitive comments such as:

- *Am I taking a broad enough view of this?*
- *Have we considered all of the possibilities, or are we limiting our options too soon?*
- *I get really angry when I read things like this. I'd better calm down so I can stay open-minded.*
- *We seem to have hit a wall. What should we do now?*
- *What happens when one person dominates the conversation? How can we make sure that everyone is heard?*
- *What strategy should we use to analyze this information? Perhaps I need to learn a new way of looking at this.*
- *How can we ensure that we won't make (x) mistake again?*

Model, Coach, and Fade. Self-directed learning requires a toolbox of intellectual skills and emotional dispositions. The PBL coach is responsible for helping children build the toolbox by modeling a skill, coaching children as they practice, and then fading into the background as the children use the skill on their own. Of course, it takes a long time to become fully self-directed, and most PBL coaches, particularly of young children, will find that they spend more time modeling and coaching than they do fading. Regardless, it is always important to keep in mind that the ultimate goal of the PBL coach is to become obsolete.

The Synergy of Problem, Stakeholder, and Coach

Each PBL element makes a unique contribution to an authentic, sophisticated learning environment. The ill-structured problem provides engagement and mystery while discreetly directing children to important educational goals. The stakeholder role enhances investment, encourages fuller immersion in the problem, and increases appreciation for the full nature of different professions. Engaged, motivated, and ready to learn, children benefit from the presence of a coach who helps them acquire the skills they need to gather information, interpret their findings, make well-considered decisions, and most importantly, become independent, self-aware learners. A summary of the essential elements of PBL is included on page 23.