Developing Problem-Based Learning Science Lessons for Local Contexts

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Abstract

Problem-based learning (PBL) is a transformation approach to teaching that positions students as problem-solvers. While PBL has been used for many topics including medical education, law and history, this paper focuses on using PBL to teach science.

Rather than giving student information as in a direct teaching approach, instructors present authentic, ill-defined problems that are relevant to learners. PBL features a structured framework for analyzing a problem and seeking information. Students use the framework in collaborative groups to identify important facts and questions, propose hypotheses, and search for additional information. Learners then present and defend their proposed solutions to the class.

The design of problem-based learning activities permits teachers to develop PBL lessons that address real-world local issues. The sample problem included in this paper represents an example of a PBL lesson that can engage students in a problem local to western Kenya and follows a lesson design format featured in the *PBL in the Science Classroom* series of books published by the National Science Teachers Association.

PBL is offered as a strategy to transform education from an expository teaching model to one of student-centered learning to help students learn to apply the content they are learning to real-world contexts.

Full Paper available at http://tjmcconnell.weebly.com/publications

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In many traditional science curricula, students are required to learn concepts across many different concepts, often through memorization. Student achievement is measured through standardized or curriculum-specific tests. Learners are typically successful is they are able to answer knowledge-based questions or application questions based on generic contexts. Application questions on standardized tests usually provide the test-taker with exactly enough information to find the correct answer if the individual knows the proper formula or logarithm to solve the problem.

But in the real world, scientists, engineers, technicians and technologists typically do not see problems presented in a similar fashion. Real-world problems are messy. Problem solvers have to formulate questions based on their observations of authentic phenomena. The individual is presented with information that may later prove irrelevant. At the same time, the problem solver may not have all the facts or information needed to find a solution. There may be more than one answer, so a problem solver will likely need to defend a solution, or perhaps compare alternative solutions.

When we consider this realistic picture of the type of problems adults face in the community and workplace, we should question whether school adequately prepare our students for the real world. The current emphasis on preparing students for high-stakes assessments presented as multiple-choice questions has driven curricula across the globe to return to a model that emphasizes direct teaching, memorization of facts, and practice in taking tests. At the same time, research shows that about 70% of human resources staff and CEOs in businesses assess high school graduates' applied skills such as critical thinking and problem-solving as "deficient" (Casner-Lotto & Barrington 2006). It should be no wonder that employers are expressing concerns that students just leaving high school are unprepared for real-world problems – we teach them to succeed in a completely different context.

As we think about transformation changes to educational systems and curricula, educational leaders need to emphasize teaching strategies that lead to content learning, but also support the development of critical thinking skills, and collaborative creative problem-solving as students learn about mathematics, science, reading and writing, information technology applications, and other outcomes we know are needed for success after graduation. For some subjects, this type of learning is a natural fit. In STEM education, presenting students with authentic problems and projects is not a new idea. Inquiry-based learning, with its many pedagogical variations, is a tried and tested way to help students learn to think critically with system strategies for solving problems. If we are to transform education to better prepare learners to excel in an ever-changing world of messy problems, education – and especially science education – needs to provide students opportunities and tools for authentic problem-solving.

Problem-Based Learning

Problem-based learning (PBL) is one of the teaching strategies that help students develop critical thinking skills (Barell 2010; Hmelo-Silver 2004) as they collaborate with classmates to solve real-world problems. Our own research has shown that educators with varying levels of prior experience in science subjects learn science concepts effectively when engaged in problem-based activities (McConnell, Parker & Eberhardt 2013b). Students then use a structured framework to analyze the problem, compile lists of known and relevant unknown information, and hypotheses – proposed solutions to the problem. Groups of students then search other sources for additional information to construct their proposed solutions. Students share their solutions with the class and discuss the merits of each proposal. The process imitates the problem-solving process as seen among working professionals in many different types of workplaces.

This form of PBL was first developed in the medical education field (Barrows, 1980). Medical schools recognized that first-year students were good at memorizing facts about diseases, but they struggled to assess and diagnose an illness if presented with a realistic case. In response, they designed the structure to help students learn apply their knowledge to real-world situations. Over time, educators in other disciplines, including science, began to adapt the strategy to content learning in their specific disciplines (Hung, Jonassen & Liu 2008).

One of the advantages of PBL is that nearly any given science concept can be presented in several different "stories." This permits a teacher to develop quality problems that reflect a context that is relevant to any group of students. It also can work in a classroom with limited resources, given that the teacher can provide current articles or websites to students, even if they are pre-selected and printed.

We posit that PBL can be a valuable strategy for transforming education in any country. Teachers and curriculum developers should be encouraged to develop problem-based lessons that address authentic situations in their local communities. In this paper, we present an example of this approach as we have applied it to the Kakamega area in western Kenya. The structure we have used to create the sample PBL lesson is the same one that we present for teachers in the *Problem-Based Learning for the Science Classroom* series of books (McConnell, Parker, & Eberhardt, 2016-2018) published by the National Science Teachers Association.

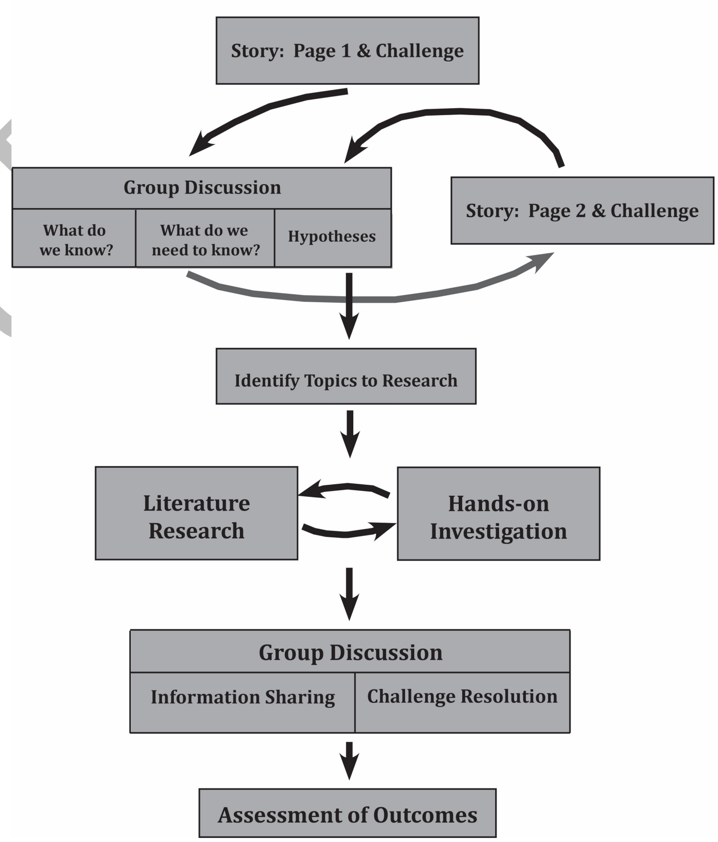
PBL Problem Structure

The problems are presented in the form of a 2-page "story" writing to engage students. The story features an authentic, ill-defined problem. The authenticity of the problem refers to a key feature of the lesson – the problem presented to students needs to be real, or a fictional story based on real phenomena. We call the problem "ill-defined" because the story does not provide learners with all the required facts. The stories may also include information that is not needed to solve the problem. This structure helps learners discover that real-world problems require them to apply more than just a formulaic logarithm for solving a problem. When problems always give students *all* the necessary information, and *only* the necessary information, learners fail to learn the persistent problem-solving skills they will face in the real world (Meyer, 2010).

Students then address the problem through the use of a structured problem-solving framework. A graphical representation of this process can be seen in Figure 1.1. Page 1 of the problem has only a small amount of information, primarily to help students understand the problem at hand. After reading Page 1, the class discusses the information given, and generates three lists of ideas, recorded on the board by a teacher/facilitator. These three lists can be recorded in a poster page, whiteboard, chalkboard or interactive whiteboard. The ideas students are asked to generate should be recorded on one of the three lists: What do we know? What do we need to know? Hypotheses. The facilitator records students' ideas on the lists.

After the class discusses Page 1, the teacher hands out Page 2, and the class repeats the process. Some of the new information on Page 2 may help answer some of the questions students generate after reading Page 1, and hypotheses written may be ruled out by information from Page 2. But new questions and hypotheses may arise in the second discussion.

Figure 1.1: *The PBL Analytical Framework. From McConnell, Parker & Eberhardt 2016, p. 4)*



Once the class has exhausted their ideas about Page 1 and Page 2, students then identify the "Need to know" issues that are most important to research or investigate. If students have access to the Internet, they may search for relevant pages to help address their questions. If not, the teacher can offer pre-printed resources, and students can select the ones they feel are most useful. Student might also use library resources or even hand-on experiments and investigations to help collect more information. The teacher can adapt the way this phase is implemented based on the available resources.

The research-investigation phase is followed by another class discussion. In this final discussion students (or groups of students) share the information they found and a proposed solution to the question posed in the problem's original story. When different students offer alternative solutions, the class may debate the solutions, with an emphasis on using evidence and literature sources to support their positions.

Learning to Facilitate a PBL Lesson

The teacher's role in the PBL lesson is to serve as a facilitator of the discussion. The facilitator sets guidelines for discussion, keeps the discourse on task, and helps record students' ideas under the three categories described above. It is important that the facilitator not answer students content questions or rule out ideas based on his or her content knowledge. The goal is to let students propose ideas, even inaccurate ones, and later eliminate ideas as new information emerges to contradict those ideas. In this way, students are learning content based on evidence.

The facilitator's role is not always easy to learn. It takes practice, and some teachers struggle with the desire to give students more information when they struggle. In our experience, though, students' success in overcoming obstacles helps build their sense of self-efficacy as a problem solver. The process of facilitating a lesson in described in much more detail in the *PBL in the Science Classroom* books mentioned above, in hopes of providing teachers with tips based on our own experience with PBL.

PBL Problems - The Importance of Context

In addition to describing the facilitation of PBL lessons, the *PBL in the Science Classroom* books include four chapters with PBL problems we have written. The problems span the entire grade spectrum for public schools and are organized based on content topic or "strand." The problems can be modified for other grades by adjusting writing or the amount of information in the story, the level details students are asked to include in their solutions, and the type of resources provided. However, the problems were written for students in the United States. The contexts of the stories may be very unfamiliar to students in other parts of the world. For instance, problems like "Humongous Fungus" and "The Purple Menace" (Life Science), "Keweenau Rocks" and Cooper Moon" (Earth and Space Science), and "Rube Goldberg Machine" (Physical Science) include phenomena, locations, and cultural references that would likely not make sense for students outside the United States.

For many years, educational psychologists have understood the importance of context in teaching any subject (Carey 1986). Educators need to provide examples, models, and phenomena to which students can relate. The learner needs some familiarity with a concept in order to assimilate new ideas into existing schema. In a PBL problem, the story (Page 1 and Page 2) provide that context. The story introduces characters, phenomena or cognitive dissonance that focuses the learners' attention and drives students' analysis, research, investigation and learning. This makes the story an extremely critical element in a PBL lesson.

The cultural and geographic contexts highlight one of the most important aspects of an effective PBL problem – the ability to engage students in a compelling problem. The best PBL lessons start with stories that relate to students' lives and experiences or relate problems that are important to the learner. Many of the sources we selected when writing the problems featured in the *PBL in the Science Classroom* series are based on local problems or stories that students have likely heard about in the news or on TV.

As educators around the world consider how PBL might help transform teaching and learning in their own schools, an important factor will be their ability to adapt problems to the students they teach in their own schools and classrooms. This is true for students in different parts of the United States – local problems and revisions to the setting of each story may help learners relate to the problems. This need to customize lessons to the local context is even more pronounced when we think about learners in different parts of the world who may experience different climate, environmental concerns, access to technology or language used to describe phenomena.

As an example, let's consider one of the assessment questions included with a problem in the Earth and Space Science edition of the series, "Leave It to the Masses." In this problem, students learn about the forces that influence formation of different air masses as they learn about weather. One of the assessments to test students' learning of the topic asks the learner to explain "lake effect snow," a phenomenon in which large bodies of water like the Great Lakes of the northern U.S. create moist air masses that deposit enormous amounts of snowfall when they move over colder land masses. A student in Finland may be able to relate to a problem about "lake effect snow," but a student from Brazil or the Cook Islands would struggle to connect to this problem. A teacher in these locations should write different assessments or different problems to help learners engage in the problem and connect their ideas to familiar phenomena.

Still, we hope the books may serve as examples for the type of information a teacher can include in a problem, the resources they can use, how to fit a PBL lesson into an existing curriculum, and how to assess students' ability to apply their knowledge to new problems. To help educators accomplish this, Chapter 9 in each of the books is a guide for creating or modifying PBL lessons.

Modifying or Designing PBL Problem for Local Contexts

In order for educators to adopt problem-based learning as one of the strategies to implement in the science classroom, teachers need resources that engage learners in problems to which they can relate, or that connect with existing schema. While teachers have repeated requested that we provide PBL lesson plans with pre-written stories, we know the importance of modifying those stories to fit each specific group of learners – or to write entirely new problems that reflect appropriate contexts. We have already discussed examples that highlight this need.

As we developed the *PBL in the Science Classroom* series, we were very conscience of this need, so we include a chapter titled "Modifying and Designing Your Own Problems." In this chapter, we offer tips for teachers to help them create problems that meet the specific cultural and contextual needs of their own classrooms. As we think about how PBL can help educators around the world transform teaching and learning, we should focus on Chapter 9 as a resource to address the importance of customizing problems to learners. Our hope is that teachers, teacher educators, curriculum developers and textbook authors might use the resources we offer to create a wide range of new problems that can help schools in their region more effectively teach the type of critical thinking and problem-solving skills identified as an important learning outcome.

Steps in Designing PBL Problems

The steps we advocate for developing PBL lessons is based on systematic reflection and revision of the process we experienced as we designed professional development for teachers planned to help strengthen content understanding. Teams of teacher and teacher educators wrote PBL lessons, tested them with teachers, and reviewed the effectiveness of the problems. Discussions across teams help identify design issues, and the writers revised and retested the problems. Over the course of four years, the team developed PBL problems that became the basis for those included in the *PBL in the Science Classroom* books. The steps described below represent the process by which educators can write and test their own problems.

The steps we suggest include:

1. Selecting a topic
2. Writing assessments
3. Writing a story
4. Integrating investigations
5. Identifying potential resources
6. Writing a model solution

Selecting a Topic

A natural starting point is to select a scientific concept or topic for which a PBL problem might be developed. Topics should be concepts already included in the curriculum. One of the easiest starting points in selected a topic is to examine the standards or curriculum map established for your school, state, or national education program. Experienced educators might recognize topics that are difficult for students to understand, or concepts that need a more engaging approach to help spark students' interest.

A good topic for a problem should also be one that helps explain a phenomenon with which students are familiar. Teachers should consider the local context of the students who will use the lesson. Students in agricultural regions may connect to different stories about ecology or technology than students in urban areas. The context is also influenced by the age and the cognitive development of the learners. A problem should be challenging, but not so far above the knowledge of the learners that the problem becomes incomprehensible. A lesson about the cellular processes that explain photosynthesis may be appropriate for high school students but is likely too abstract for young children. Students in primary grades may be appropriately challenged to compare the life cycles of insects and vertebrates, while high school students might find the task too simple to be engaging.

Some educators may easily identify strong topics for a PBL problem, but others may need some inspiration to guide this step. Members of our writing team found inspiration from newspaper stories, television news, local problems, and even questions from students. Even popular movies might present scientific problems that can spark ideas about a PBL lesson topic. However, what a teacher finds engaging may not be as exciting or interesting to students. We suggest that teachers who write lessons ask students (possibly from previous classes) if they find a topic or story interesting. With experience, educators will develop a sense of what kind of problems will grab their students' attention.

While selecting the topic, the teacher should identify the desired learning outcomes. What ideas or concepts should the learner gain from the lesson? What kind of skills should students practice as a part of the lesson? What will successful learning look like? Our process was influenced by a "backward design" approach to lesson planning (Wiggins & McTighe 1998). According to this approach, identifying outcomes should be considered before other steps in the planning process

Assessments

Also in accordance with a backward design approach, we have placed assessment planning early in the process. Once the educator has identified outcomes, it is important to plan how you will assess student learning. The assessment plan will then help the teacher ensure that the activities truly address the desired outcomes.

The type of assessments that work best for a PBL lesson can vary based on the teacher's goals, but our experience has resulted in a list of assessment types we find most helpful in understanding what students are thinking as they progress through a PBL lesson. Our assessment items include open-response questions in two types of formats. "General" questions are written to elicit an overview of a students' ideas about a problem. For instance, one of the teachers in our PD program developed a middle school (Grade 8) lesson about the impact of greenhouse gasses on the growth of poison ivy, a nuisance plant found in the U.S. Her general assessment question was "How would changes in CO2 levels affect the growth of plants?" This question led to brief summary responses that helped her identify large gaps in understanding and familiarity with important concepts.

If the teacher needs more information about the details of a student's understanding, we suggest a second format of question – an "Application" question. These questions present a specific context that can explained using the concept identified as the central topic for the problem. This question often includes some details of the context and asks the student to give certain types of details in their answer. See the example below from the middle school problem about greenhouse gasses.

> *"The National Aeronautics and Space Administration investigated the use of plants as a source of food and oxygen for long-distance space travel. The found that plants grow faster in enclosed spaces where animals or bacteria are also living. Explain why these plants grow faster than plants grown in a chamber by themselves. Your response should include the material a plant needs in order to carry out photosynthesis."*

The prompt referring to the type of details students should include came from our research on the assessment item structure. We found that without these prompts, learners more often wrote about tangential aspects of the problem or let out details that later interviews found they knew but chose to omit (McConnell, Parker, & Eberhardt 2013a). With the prompts, more details were included in written responses, giving facilitators more information about the accuracy and depth of the respondent's understanding.

Other forms of assessment presented in the lesson plans include a summary of the Transfer Tasks, and Common Beliefs inventories. The problem solution summaries are written responses elicited from each learner after completing the analysis and discussion of a problem. This assessment allows instructors to check each student's understanding rather than relying on a group response to assess learning. Transfer Tasks are open-response questions that ask students to apply the same concept learned in a problem to explain a new problem or scenario. Many students struggle to transfer concepts they have learned to related but unique phenomena. The transfer task is a way to assess whether students understand how a specific science concept is connected to multiple contexts. Common Beliefs questions are True/False questions that also prompt students to explain the reason for their answer. The Common Belief items are statements that reflect some accurate ideas and some common misconceptions related to the concept that serves as the focus of the problem. When given as a pre-post assessment, the Common Beliefs inventories are another tool to help teachers diagnose learning and conceptual challenges.

For each of the assessment items, we encourage the teacher to write a model response – an ideal answer with the ideas, vocabulary and examples you expect students to write if they have a complete and accurate understanding of the science concept. For each assessment offered in the books, we include a model response. Teachers can use the model responses to create rubrics or scoring guides for the assessments they use in the classroom.

To help teachers in their attempts to write their own PBL lessons, Chapter 9 in each book also includes a PBL Lesson template that prompts the writer to include the elements described above. We also offered a "PBL Lesson Talk-through," a page of questions to prompt the writer to think about how engaging the lesson is from the perspective of the student, and how well the lesson fits the teachers' curriculum needs. These two resources are also available at on line "Extras" page as downloadable files in MS Word format. These tools can help the teacher create new PBL lessons or modify existing lessons to meet the particular needs of their own students.

A Sample Problem

The information and resources provided in Chapter 9 of the *PBL in the Science Classroom* books are intended to help teachers develop their own PBL lessons. We contend that teachers and curriculum developers should generate new PBL lessons that are designed to address local contexts and cultures as a way to best meet the needs of learners. The Sample Problem can be found on pages 19-21.

To help illustrate how locally designed PBL lessons can address this need while contributing to an effort to transform teaching and learning, we have written a sample PBL problem based on an authentic problem in the region surround Kakamega, Kenya, the host of the conference at which this paper is presented. The problem includes Pages 1 and 2 of the story, and a partial list of resources students can use in researching the topic. For the sake of time, assessment questions and hands-on activities were not added to the story. It should be noted that this problem was written by individuals who have not lived in or even visited Kakamega. Thus, some of the details, the language and the types of resources offered to the students could be improved if a team of educators from the region were to modify the lesson and add additional assessment questions and resources.

"Seeing the Forest for the Trees"

In this problem, students explore a complex and potentially controversial topic – reforestation efforts in and near agricultural areas in western Kenya. Like so many other areas around the world, human impact on the environment is a major concern. When humans utilize natural resources and populations grow, there is inevitably going to be a conflict between a need to protect natural environments and the need to provide food, housing materials, clean water and air, and the economic opportunity needed to support local residents.

In western Kenya, one of the ways this problem is revealed is in the issue of deforestation. People living in the area have used cut down trees to clear potential farmland and use the trees for lumber and fuel. As human populations rise, deforestation reaches an ever-growing area. Some scientists and conservation groups have been raising concerns about loss of wildlife habitat, erosion, climate change connected to deforestation. In some areas, reforestation is an important strategy for reclaiming once-forested habitats. If those efforts move into agricultural areas, people often resist reforestation efforts out of a need to maintain a certain level of income from growing and selling crops.

Several potential strategies are currently being promoted to address this problem. Examples include agroforestry, multi-cropping, and experiments in agri-business based on products from naturally diverse forests. Still, some people whose livelihood depends on agriculture resist the efforts to reclaim farmland for reforestation.

A traditional approach to teaching about an issue like this might focus on direct teaching about ecology, crop rotation, and the types of products from tropical trees, and other science concepts. But solutions to the deforestation problem, if they are taught at all, are still presented to students based on the teacher's (or the national curriculum's) specific position on the issue. If those ideas clash with the local views of the students or their families, the concepts taught in school are unlikely to make lasting changes in local practices.

Discussion

We propose that lasting transformation of local practices must also includefchanges in how we teach about authentic issues like deforestation. "Seeing the Forest for the Trees" is a PBL lesson that presents students with a realistic situation and engages them in learning and discussion of possible solutions. The lesson is written for high school students. As learners discuss the story and the facts known, they construct their own list of important learning issues. When they eventually start to research the problem, they are more likely to be personally invested in finding answers.

Page 1 of the story presents a scenario of children discussing conversations with reforestation groups and their families about the impact of planting trees on their farms. The characters in the story introduce just enough information about conflicting proposals to make the problem understandable, but without giving readers a list of details solutions. In the discussion of Page 1, the teacher can facilitate the discussion while finding out what students already know about the debate over reforestation and agriculture.

In Page 2, more details are given about alternative approaches to the problem. The young characters mention terms like multi-cropping without giving complete definitions. This can guide learners to ask about these terms. In the research phase, the students can read more about the practice of multi-cropping and apply the new ideas to the scenario presented in the story.

The list of resources offered on Page 3 is a very cursory list. If the teacher decides that students need more information to help them find, the lesson allows for more information to be introduced in the research phase. If students have access to the Internet, they can use the websites listed, or search for their own resources. If they do not have Internet access, the teacher can print classroom sets of the files or find other print resources. There are several strategies listed in the *PBL in the Science Classroom* books for managing students' access to those files.

Students also learn to use evidence to support their proposed solutions. In essence, learners are gaining scientific knowledge as they learn to use that information in an authentic context. Students practice both written and oral language skills, connect scientific ideas to local civics, and in some cases, apply their mathematical skills to the problems as well. For instance, in this problem, students may be able to find data about profits from agricultural products over a period of time and use that to project the impact of their proposed solutions on the families featured in the story.

Conclusions

We have proposed that Problem-Based Learning can be an effective strategy to contribute to transformative change in learning and teaching. This proposal builds from Cranton's definition of transformative learning – "a process by which previously uncritical assimilated assumptions, beliefs, values, and perspectives are questions and there become more open, permeable, and better validated" (Cranton 2005, p. 630). In a PBL lesson, students do not learn to reiterate facts and assumptions taught to them from a book or a teacher. They are led to think critically about a real-world problem in a way that encourages sharing of competing ideas followed by analyzing and critiquing those ideas against evidence. In doing so, they construct their own understandings and connect concepts in ways that are lasting. Our research (McConnell, Parker, & Eberhardt 2013b) showed that learners showed significant growth of science content ideas. This trend was true for learners with a wide range of prior knowledge – learner consistently gained regardless of their starting point.

Just as importantly, participants in our PBL lessons also show changes in how they approach problems. The PBL framework, with its three analytical categories of ideas, was very quickly adopted as a way to solve other types of problems. After only one or two PBL lessons, learners where heard to say "Let's PBL it!" when faced with problems in non-scientific contexts. This suggests that students learn not only the science content but the process by which they can apply their scientific knowledge.

When we think about transformative learning, these critical thinking skills are important in helping learners develop a sense of agency and self-efficacy. The skills to solve local problems, along with a sense that solutions to the problems can come from within rather than from some external source, serves to empower learners and the communities in which they will live.

But in order to make PBL most effective, learners need to see a relevance to their personal experiences. If PBL components are based on texts written for different students in a different place and culture, the problems are merely exercises in finding the right answer. Only when students feel a personal connection to the contexts in which PBL problems are presented will they internalize their learning and transform skills developed in the classroom into skills they can apply in their communities. We hope to support a wider adoption of Problem-Based Learning as a science pedagogy. We also hope to encourage educators and educational leaders to contribute to the development of high-quality PBL lessons that address their local populations, contexts and cultures.

Books in the *PBL in the Science Classroom* series can be purchased at:

http://www.nsta.org/publications/press/pbl.aspx

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Sample Problem

Page 1: The Story

Seeing the Forest for the Trees

Stephen was talking with his friends as they walked to school. "Did you see the people planting more trees at the edge of the forest yesterday? There's another group here talking about deforestation again, and they're trying to talk my father into planting some trees in his fields. My father is not sure he wants to do that. It will mean planting fewer crops next season."

"They spoke with my family, too," said Annette. "I want to see more trees, but it will mean less money for my family. I don't think they'll get many people to help them with the reforestation project."

"Some of us are doing it," said William. "My family did this last year. We planted cashews. In a couple of years, we can start and make sell the nuts and fruit."

Jeannine also spoke up. "My family talked with the forestry service, too. They would rather have farmers plant a variety of native trees and find ways to make money from a natural forest. I think it's all very confusing."

Stephen was curious. He wondered what the best choice for his family might be. His father is not sure what to do, and maybe Stephen can help make a decision.

Your Challenge:

Make a recommendation to Stephen's father about ways to support reforestation while still maintaining a strong local economy. Include at least two possible suggestions, with reasons why each might be a good plan.

Sample Problem

Page 2: More Information

Seeing the Forest for the Trees

Stephen and his friends continued to talk about the reforestation project.

Stephen had questions for William. "When you planted the trees, didn't you lose some farm fields to the trees? How can you afford to lose money for a few years?"

William replied, "Our first trees were planted only a small area. We might add more after we start making money. And we planted some other crops among the cashews – crops we can harvest this year, and that will grow well near the young trees."

"That makes sense, I guess, Stephen said. "But cashews are not native to Kenya. Remember what our teacher taught us? Introducing non-native plants can create new problems. Maybe making money from the native tress in the forest is better. I'm not sure how the natural forest idea Jeannine mentioned would work."

Annette added, "Yes, I wonder about that, too. My family still collects wood for fuel, and the reforestation groups say we should plant more trees for that. But what other ways could farmers survive using the forest?"

Jeannine had questions, too. "William, what kind of crops do you grown near the cashew trees?"

"We're growing peas and sweet potatoes," William said. "Next year, my father wants to plant corn, and maybe some tamarind trees."

"Oh! That's like my uncle's coffee plantation in Kitale!" Stephen said. "He grows macadamia nuts and coffee in the same area. But I'm still not sure what my family should do."

William nodded. "It's a complicated problem. Maybe we should talk to our teacher, or to the forestry workers. I'd like to know more about this.

Your Challenge:

Make a recommendation to Stephen's father about ways to support reforestation while still maintaining a strong local economy. Include at least two possible suggestions, with reasons why each might be a good plan.

Sample Problem

Page 3: Resources

Seeing the Forest for the Trees

- Agroforestry in Kenya: http://www.worldagroforestry.org/country/kenya
- Agriculture for Impact: https://ag4impact.org/sid/ecological-intensification/diversification/multiple-cropping/
- Benefits of Coffee-Banana Intercropping: https://www.sciencedirect.com/science/article/pii/S0308521X10001617
- Matchmaking for Coffee: https://phys.org/news/2016-11-matchmaking-coffee-intercropping-macadamia-trees.html