

# Leveraging Project-Based Learning to Challenge and Extend Conceptual Understanding of Mathematics Skills and Strategies



# Summary

There is little question we are moving toward an education environment and workplace highlighted by teams performing high-paced, information-based tasks and projects. As educators, it is our responsibility to prepare students for the evolving, knowledge-based economy where STEM-based information industries replace traditional jobs and industries (Molnar, 1997).

Inquiry-Based Learning (IBL) offers educators a unique instructional tool for the rapidly changing learning demands of today's classroom. Through inquiry, students work to build the habits of mind that prepare them to compete with their peers locally and globally. There is a growing body of research detailing the success of IBL in all content areas in providing students the tools and thought processes they need to develop inquiring minds with the power to solve creatively, actively, and intelligently even the toughest problems in classrooms and beyond.

The development of inquiring mindsets will serve students well as they function as contributors in the knowledge economy. However, research also demonstrates that students generally do not have schema and experience with inquiry to be successful in an inquiry-based environment (de Jong, 2006)

## Inquiry-Based Learning

In its rawest form, IBL is a very basic learning strategy, and has been around in some form or another throughout history. For a more contemporary model of IBL, we can start with John Dewey, who coined the term Instructional-Based Learning and promoted IBL as an instructional design theory. Specifically, Dewey noted that inquiry was a foundational element for all learners (Dewey, 1956). Through this research, Dewey laid the groundwork for future instructional models based on IBL, several key types of which are detailed later in this paper. Branching from the main tenets of constructivism, IBL results in student-centered learning that transforms students from passive receivers to active participants in the learning process (Creedy et al., 1992).

According to Blumenfeld et al. (1991), Inquiry-Based Learning manifests itself through researching and responding to open-ended questions that are generated by the learners themselves. IBL provides students with: authentic learning opportunities that motivate students to learn new content, a schema for adding new knowledge to existing knowledge, and an opportunity to actively apply their new knowledge to solve a problem (Edelson, Gordin, & Pea, 1999). However, students frequently struggle to succeed with IBL for a variety of reasons, often stemming from their lack of understanding of the inquiry process itself (de Jong, 2006). Instead of understanding that research has a pattern and that results should challenge hypotheses, students often come up with an answer to a problem and then build an experiment to specifically prove their beliefs. This leads directly into a discussion of the models of IBL, as they all approach this learning strategy slightly differently, and helps support Project-Based Learning as the best solution for the Number Worlds classroom.

## The Ways in which Inquiry-Based Learning Is Delivered

While there is general agreement on the basic elements of Inquiry-Based Learning, there are several widely accepted models of instruction based on IBL. All of the models support student-centered learning environments with the teacher serving as the facilitator once inquiry has begun; however, how students get to the inquiry target and how that target is determined vary from model to model. All models have validity in the classroom, meaning they are all viable approaches to IBL depending on the needs of the student, teacher, and content at hand. The following table provides a comparison of the key decision points when choosing one of the four types of IBL outlined in this paper.

	<b>Project-Based Learning</b>	<b>Problem-Based Learning</b>	<b>Case-Based Learning</b>	<b>I-SEARCH</b>
<b>Content</b>	Cross-Curricular	Single Content Area	Single Content Area	Cross-Curricular
<b>Length</b>	Weeks/Months	Single Lesson or Unit of Instruction	Single Lesson	Single Lesson or Center
<b>Topic</b>	Narrow Topic Choice	Narrow Topic Choice	Narrow Topic Choice	Open Topic Choice
<b>Collaboration</b>	Collaborative	Collaborative or Independent	Collaborative or Independent	Collaborative with Independent Products
<b>Process</b>	Generalized Process	Structured Process	Generalized Process	Structured Process
<b>Products</b>	Various Products	Written or Oral Product	Written or Oral Product	Written and Oral Product
<b>Tasks</b>	Authentic Settings/ Tasks	Ill-Structured, Often Fictitious Situations	Case Studies Set Context	Authentic Activities Related to a Theme

### Project-Based Learning

In Number Worlds, students participate in Inquiry-Based Learning through the completion of cumulative projects. Project-Based Learning (PBL) often incorporates the Constructionism and Learning by Design aspects of IBL. PBL differentiates itself from other IBL models through its sustained, cooperative investigation, which takes place in a structured approach that requires multiple learning sessions to complete a project (Han & Bhattacharya, 2001). By offering structure through multiple questions, activities, and product deliverables, Project-Based Learning encourages students to be engaged in productive, guided inquiry learning over a period of time. While students have some meaningful choice and are expected to complete investigative research, they are completing guided activities that begin to build habits of mind, but do not offer the case history of case-based learning or the introspective responses required in I-Search.

Project-Based Learning follows a generalized process that begins with background information and an essential question. Students work through the process, assimilate learning, and present their findings and products. Key steps in the process include (Cameron & Craig, 2014):

1. Provide Setting and Establish Background
2. Outline Essential Question
3. Research and Write
4. Build Products
5. Present Findings and Products
6. Evaluate Performance and Reflect on Process

Throughout a project, which can last several weeks or even months, the teacher is extensively involved with every aspect of the process. More often than not, this is the type of IBL that is used with younger learners due to its structure and the increased role of the teacher in the learning process. By leading learners through projects, educators can ensure that activities are purposeful and authentic, while students learn to become disciplined investigators (Levstik & Barton, 2001).

IBL is very often marked by cooperative or collaborative learning groups or teams. This is true of Project-Based Learning, and the participation of the teacher as a guide for students makes Project-Based Learning a good choice for primary classrooms. Learners who are inexperienced working in teams or groups will gain experience with and learn how to interact with their peers and manage conflict in a team setting (Grant, 2002).

## Problem-Based Learning

The main distinction for Problem-Based Learning as a model of Inquiry-Based Learning is the focus on a real-world, ill-structured problem as the centerpiece of the inquiry process. In Problem-Based Learning, students are separated into groups, presented with an ill-structured, real-world problem, and given the opportunity to explore, negotiate, and define a solution for the problem (Hmelo-Silver & Barrows, 2008). Students are required to build knowledge, filling gaps in current knowledge, to successfully solve the problem at hand.

Since the introduction of this instructional approach in medical schools in the late 1960s and 1970s, Problem-Based Learning has steadily made its way into mainstream education. Problem-Based Learning expands upon the idea that instruction should be built around a larger task or problem that is placed in an authentic setting. Students are given responsibility for and ownership of resolving the task, encouraging contextualized learning (McComas, 2014). The problem should be challenging, set in a structure that allows for investigation, and require reflection and discussion for full resolution of the issues at hand (Savery & Duffy, 1995).

For an introduction to the major principles of Problem-Based Learning, we can look to Howard Barrows, who is recognized as the founder of this model of instruction. Barrows suggests six dimensions of learning within Problem-Based Learning, which are paraphrased below (Barrows & Kelson, 1993).

1. Problem solving with ill-formed problem offering many possible solutions
2. Goal of functional knowledge with cognitive flexibility
3. Self-directed learning
4. Collaboration
5. Student ownership of active, engaged learning
6. A habit of reflection and self-appraisal in all learning experiences

## Case-Based Learning

Case-Based Learning (CBL) is a student-centered, inquiry-focused learning model that has a clear structure to inquiry. CBL is a systems approach to inquiry, with a strong technology focus. Case-Based Learning involves the building of large, organized, searchable indices of cases to give learners access to a history of experience and the processing tools required to access the indices (Kolodner & Guzdial, 2000). Over time, students build the strategies and the knowledge base needed to efficiently and effectively use past experience and existing knowledge to suggest solutions for current problems or questions. CBL requires a strong reflective learning component for evaluating and expanding case knowledge (Kolodner & Guzdial, 2000).

Proponents of Problem-Based Learning take issue with the strong structure and repetitive nature of CBL. While the focus of Problem-Based Learning is on unstructured inquiry, CBL attempts to build a reusable strategy and approach to solving problems (Savery & Duffy, 1995). CBL puts the learner in a certain place and time and asks them to evaluate and offer alternatives for how a result could be changed, but following a narrow set of guidelines, for the most part. This structure lends itself to larger inquiry, but tends to allow less freedom in response and student choice in the topic being addressed than what is needed in a K-8 classroom.

## I-Search

I-Search, developed by Ken Macrorie in the late 1980's, is a form of Instructional-Based Learning that provides more background and support than many of the other IBL models presented in this synthesis. Case-Based Learning, Project-Based Learning, and Problem-Based Learning all provide students with a relatively narrow direction for their inquiry. Projects that are true to the I-Search instructional model, such as those described by Zorfass and Copel (1995), put an even greater choice of topic in the hands of students while offering a more structured process than other IBL models. I-Search still asks teachers to take on the role of a coach or facilitator for much of the research time, but also requires the teacher to provide a solid, motivating central theme on which students base their research. The structure and the individualized nature of the I-Search approach lends itself to younger student populations and shorter-term activities.

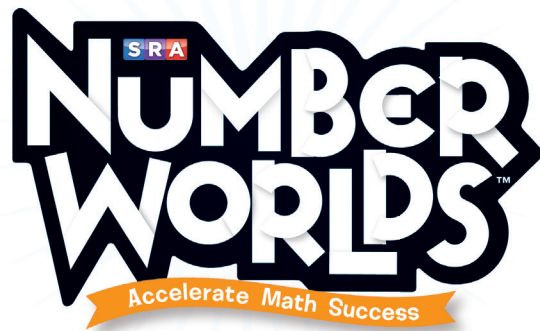
## Why Project-Based Learning in Number Worlds?

Number Worlds has built-in Project-Based Learning lessons for a variety of reasons.

- The role of the teacher as an expert guide in Project-Based Learning is a perfect fit for the teacher-led curriculum present in the program.
- Project-Based learning is an ideal vehicle for students to demonstrate application and transference of mathematics knowledge, skills, and strategies in real-world scenarios, very much in the spirit of the Common Core State Standards.
- Offering a structured approach to Project-Based Learning provides students with a schema for completing projects that will support learning across different content areas as students progress in their education.
- Project-Based Learning activities focus on extending standards, while giving students experience working in group settings.
- The variety of products and artifacts students develop as part of the Project-Based Learning activities in the program give teachers alternative methods of assessing student mastery of mathematics knowledge, skills, and strategies.

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