Technology-Supported Inquiry-Based Learning
A Synthesis for Leveraging Technology to Meet the Needs of Today’s Students

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Abstract

As educators, we are entering an era punctuated by a high-paced, information-heavy learning environment and workplace. Students need to be prepared for the new, knowledge-based economy where science-based information industries replace traditional jobs and industries (Molnar, 1997). Inquiry-Based Learning (IBL) is well-placed to support educators reaching out to today’s learner. Through inquiry, students build the habits of mind that prepare them to compete with their peers locally and globally. Unfortunately, students often lack the schema and experience with inquiry to allow them to successfully participate in and learn through IBL (de Jong, 2006). There is an increasingly powerful collection of research supporting the use of technology to support IBL and give students the tools and thought processes they need to transition to inquiring minds with the power to creatively, actively, and intelligently problem solve even the toughest problems.
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Educators incorporating new technologies in the classroom is nothing new. The latest and the greatest technologies have constantly entered into the consciousness of educators and students. There continues to be concerns that teachers are unprepared to truly incorporate technology effectively in the classroom, especially in rural and urban K-12 environments (Lawless & Pellegrino, 2007). However, when professional development focused on sound pedagogy presents itself around new technologies, whether it is the pencil instead of the quill or using videotaped lessons instead of live lectures or interactive whiteboards as opposed to chalkboards, educators have recognized their value and have adopted the technologies in schools. The goal of this synthesis was to look at

1. the features of inquiry-based learning (IBL) as a theory of classroom education,
2. the major models of instruction informed by IBL,
3. the promise and pitfalls for using technology to support IBL in classrooms,
4. and some of the technologies now being leveraged in classrooms for IBL activities.

Research reviewed included a variety of sources, both for and against the effort to increase the role of technology in classrooms. However, the majority of recent research, which forms the core of this synthesis, indicated that now is the time to integrate technology in the classroom for a variety of reasons, and that student futures and the future of the United States as a whole depend on providing students a strong foundation in the use and availability of technology tools for productivity, not just entertainment.

It is generally accepted that we are at a crossroads in education like we have never seen before. While change is constant, we are standing at the convergence of three major factors to a degree we haven’t in the past. Educators are working in a world with an

1. Unpredictable Future: We are in a situation where we are preparing students for a future we can’t predict. This is nothing new, but the rate of change is unprecedented.
2. Networked Students: Students are connected everywhere with everything they do. They are prepared to find people to answer their questions, if not teachers, then someone else.
3. New Information Landscape: We have no idea what will be new tomorrow, so we have to create content and craft learning experiences that can support learning for today, but adapt for tomorrow’s success (Warlick, 2008).

We have to prepare kids to live in the future, not in the past. As Andrew Molnar stated more than ten years ago, “New, science-based, information industries are emerging in which knowledge and human capital are as important as industrial plants” (Molnar, 1997, p. 63). It is incumbent upon educators to figure out what being a learner or an instructor means in this new tech-heavy society, and what they can do to prepare kids for the new information-abundant classrooms and careers of today and the world of tomorrow.

1. What Is Inquiry-Based Learning?

At its heart, inquiry-based learning (IBL) is one of the most basic approaches to learning, and has been around in some form or another throughout history. As a modern theory of learning, Dewey bears some credit for putting a name to IBL and acting as an early advocate. Dewey suggested that inquiry was an important goal for all learners (Dewey, 1956). In this way, Dewey set the wheels in motion for later work toward instructional models based on IBL, some of which will be described below. Branching from the main tenets of constructivism, IBL suggests student-centered learning that transforms the student from a receiver to an active participant in the learning process (Creedy et al., 1992).

According to Blumenfeld et al. (1991), in IBL, 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 solving a problem (Edelson, Gordin, & Pea, 1999). However, as will be discussed at length later in this synthesis, students often struggle to succeed in IBL for a variety of reasons, but very 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 idea slightly differently, and then, also, into how technology can support IBL for learners.
2. What are the Models of Inquiry-Based Learning?

While there is general agreement on the basic elements of Inquiry-based learning (IBL), there are several widely accepted models of instruction based on IBL. All of the models support student-centered learning environments with the teacher as the facilitator once inquiry has begun; however, how students get to the inquiry target and how that target is determined will 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.

**Project-Based Learning**

The main difference between Project-Based Learning (PBL) and the main definition of IBL is the focus on an ill-structured problem as the centerpiece to the inquiry process. In PBL, students are separated into groups, presented with an ill-structured 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 resolve the problem at hand. This instructional approach was first used heavily in schools of medicine, but has steadily made its way into education at-large since its inception in the 1970’s. PBL expands upon the idea that instruction should be built around a larger task or problem placed in an authentic setting where students are given responsibility and ownership of resolving the task. The problem should be challenging, set in a structure that allows for investigation, and isn’t fully resolved without reflection and discussion of the issues at hand (Savery & Duffy, 1995).

For the best introduction to the major principles of PBL, however, we should look to Howard Barrows as the generally accepted founder of the model of instruction. Barrows suggests six dimensions of learning within PBL, paraphrased below (Burrows & 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. Taking ownership with active, engaged learning
6. Building a habit of reflection and self appraisal in all learning experiences
Case-Based Learning

Case-Based Learning (CBL) is most definitely a student-centered, inquiry-focused learning model, although one with a clear structure to inquiry. In actuality, CBL is a systems approach to inquiry, with a strong technology focus from its initial development. The idea is to build large, organized, searchable indices of cases to give learners access to a history of experience and the processing tools to access the indices to complete focused learning tasks (Kolodner & Guzdial, 2000). Over time, students build the strategies and the knowledge base 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). Those who believe in Problem-Based Learning (PBL) would take issue with the strong structure and repetitive nature of CBL. For the proponent of PBL, the focus is on unstructured inquiry, while CBL attempts to build up a reusable strategy and approach to solving problems (Savery & Duffy, 1995). At its heart, CBL has great potential when delivered through computers with their large, fast, and structured database and processing units.

Constructionism, Learning by Design, and Project-Based Learning

Constructionism, learning by design, and project-based learning are often tied together throughout the different literature discussing aspects of IBL. Where project-based learning really differentiates itself from other IBL models is through its sustained, cooperative investigation, which takes place in a structured project approach that requires multiple learning sessions to complete (Han & Bhattacharya, 2001). By offering structure to students with 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 will build some habits of mind, but do not offer the case history of case-based learning or the introspective responses required in I-Search. More often than not, this is the form of IBL that is most present with younger learners due to its structure and the increased role of the teacher in the learning process.

I-Search

I-Search, developed by Ken Macrorie in the late 1980’s, is another form of IBL. While it is definitely inquiry based and student centered, I-Search provides more background and support
than many of the other IBL models presented in this synthesis. Case-based learning, Learning by Design/Project-Based Learning, and Problem-Based Learning all provide students with a relatively narrow direction for their inquiry. True I-Search projects, as described by Zorfass and Copel (1995), puts even greater choice of topic in the hands of students, but, at the same time, offers a more structured process than at least Problem-Based Learning. I-Search still asks teachers to take on the role of a coach or facilitator for much of the research time, but does require the teacher to provide a solid, motivating central theme for students to base their research on. The structure and the individualized nature of the I-Search approach lends itself to younger student populations and for shorter-term activities than some of the other IBL approaches.

3. Why Technology-Supported Inquiry-Based Learning?

It is insufficient to just say that there are many new, exciting technology tools available and adopted by students; educators have to evaluate if these tools actually provide any benefit to the classroom. There is clearly an ongoing debate as to whether instruction should be changed to fit technologies, whether technology tools should drive instruction, or whether good instruction is good instruction and it should just be ported to technology platforms. Since the explosion of computers on the education scene, porting quality instruction to technology delivery has been the focus of research. Unfortunately, this has been with mostly mixed or unsuccessful results, as evidenced by a recent government-funded study into math and reading software programs and academic achievement (Campuzano, Dynarski, Agodini, & Rall, 2009). While this report is discouraging at first glance, upon closer inspection, it is clear why the technology products in the study failed to show success. The programs are generally older products that looked to just transfer technology from print to a tech-based delivery, without making the best possible use of the delivery mediums. Another possible criticism of this research report concerns the poor fidelity to the instructional model for the implementations in the study. It is well-known that researched-based educational materials are notoriously difficult to scale from research to full implementation. There is nothing different about technology from print in this area. This was proven more than fifteen years ago in a two-year research study that showed that, when implemented with fidelity, a technology-based instructional sequence can have great potential for student success (Van Dusen & Worthen, 1995).

What teachers have long done well is adapt to their environment and their students’ needs to build lesson plans that will lead to student success with whatever tools necessary. However,
the farther from teacher comfort zones technology takes us, the harder it is for teachers to transform good instructional methods into new delivery methods (Lawless & Pellegrino, 2007). At the same time, instructors will catch up with the growth of technology. And as their comfort-level with technology grows, so will their understanding of how best to transition to the new available tool sets to foster student success. The concept of the convergences of technological, pedagogical, and content knowledge contexts (TPACK) in the classroom is one that should hit home with any teacher or trainer. As pedagogy catches up with technology and content knowledge moves to a new delivery system, teachers will also demonstrate their ability to move with the times to make sure good instruction wins the battle of implementing technology appropriately in the classroom (Mishra & Koehler, 2009).

Inquiry-based learning (IBL) is a strong candidate for technology-supported lessons for a variety of reason. De Jong (2006) suggests that instead of understanding that research has a pattern and results should challenge hypotheses, students often come up with an answer to an inquiry problem, and then build an experiment to specifically prove their beliefs. While this challenge gives pause to the use of IBL in the classroom, de Jong suggests that technology itself can provide the supports students need in order to master the inquiry process. Additionally, as Edelson, Gordin, and Pea (1999) noted, Blumenfeld, et al. (1991) suggested six key ways that technology supports IBL:

- Enhancing interest and motivation.
- Providing access to information.
- Allowing active, customizable representations.
- Structuring the process with tactical and strategic support.
- Diagnosing and correcting errors.
- Managing complexity and aiding production.

Over time, additional technology support opportunities have been identified, including the tools needed to manage extended inquiry learning activities and understanding and addressing the practical context for technology implementation and learning (Bruce & Bishop, 2002).

4. What Are Some of the Technologies Being Used to Support Inquiry-Based Learning?

The previous section of this paper sought to establish a narrative supporting the use of technology in Inquiry-Based Learning (IBL) environments. This section will provide examples of some of the technologies used to support IBL.
Web-Supported IBL

Bruce and Bishop (2002) built a community of learners designed to create active, living inquiry-based learning experiences shared on the Web. At first, the site was built to allow one person to lead a group through inquiry activities, but, over time, their Web design allowed for a more customizable, open-ended, democratic approach to building and completing inquiry-based activities. In this way, the Web supports teachers, students, and other communities of learners to complete inquiry activities.

Simulated Environment Encouraging IBL

Simulations requiring the building of a case library or supporting investigation of problems have great appeal to educators as a form of inquiry and appeal to students as a branch of serious games. An example of this is the virtual observatory found in a research project by the name of Astronomy Village® (Taasoobshirazi, Zuiker, Anderson, & Hickey, 2006). By placing students in control of a virtual observatory, and building off the inquiry process employed by NASA scientists, Taasoobshirazi et al. were able to increase student engagement and science knowledge through a simulated observatory. This research points to the need to evaluate simulations further, but supports the use in the short term.

Augmented Reality IBL

One could justifiably argue that augmented reality is really a form of simulated learning environment; however, it also has very clear requirements that are not true of all simulations. Rosenbaum, Klopfer, and Perry (2007) argue that augmented reality provides learners authentic learning experiences that include very close approximation to the jobs of real scientists, including a real possibility of failure. Environmental Detectives, the curriculum delivered during the research study, used technology to support and enhance the inquiry students were completing by using geo-positioning tools and data tracking and reporting to mimic scientific inquiry. They further studied augmented reality through a game called Outbreak @ The Institute, where students worked to stop an outbreak of diseases in their learning community. In the end, Rosenbaum, et al. (2007) suggest that augmented reality can be powerful, but increases in power when partnered with other forms of simulation to support IBL.

Mobile Learning in a Social Studies IBL Environment

Much of IBL research, theory, and practice are built to support science learning. In a study completed by Shih, Chuang, and Hwang (2010), used situated learning combining the real
world and a virtual world to challenge students in social studies-related IBL learning activities. While Rosenbaum, Klopfer, and Perry (2007) used handheld devices, they used them in very controlled settings. Shih et al. took mobile learning a step further by focusing on field learning in less-controlled environments. This approach suits social studies very well, but certainly not to the exclusion of other content areas.

5. Conclusion

There is compelling, and growing, evidence suggesting technology-supported Inquiry-Based Learning (IBL) results in strong, motivating lessons for students in many situations. Developing the habits of mind that allow learners to be successful inquiry learners is positively enhanced by leveraging technology during the inquiry process. While there are similarities between the different models of IBL, both in approaching instruction and using technology to support lessons, it is also important to remember the context, content, and instructional goals when selecting how deeply to integrate technology into instruction. Less important for this synthesis are the exact technologies used by educators and learners (interactive whiteboards, mobile devices, and so on), but the idea that technology can truly support learners if built around the models of instruction developed under the umbrella of IBL. New technologies are quickly being tied to the existing theory, often to great effect. While research continues, technology-supported IBL seems to have a bright future in learning environments around the world.

Areas for Further Research

Out of this synthesis report, there are two important areas for further research around using technology in the classroom to support IBL activities.

1. How can technology-supported IBL be implemented across the curriculum not just tied to science content? Science has long been the focus of these IBL lessons, but there is an opportunity to begin reaching out to content introduced in other disciplines.

2. Is there a predominate technology used in IBL classrooms? Simulations and mobile-based augmented reality learning seem to have the edge at the moment.
References


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