Inquiry-Based Learning: A Review of the Research Literature

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Paper prepared for the Alberta Ministry of Education
June 2013

Introduction

A growing body of research suggests that models of education designed to meet the needs of the industrial past are inadequate for the myriad challenges and opportunities facing 21st century students (Alberta Education, 2010; Barron & Darling-Hammond, 2008; Friesen & Jardine, 2009; Perkins, 2009). New educational environments require different ways of designing learning experiences for students as well as new approaches to teaching and assessment. The call for educational reform away from passive transmission-based learning and the imparting of discrete skills and processes is not new. Institutions of education around the world are reconsidering some of their most deeply-held assumptions about how they conceptualize learning and to what end education should be directed.

This shift in thinking has been prominent in Alberta. Subject-specific programs of study and the Ministry of Education's *Inspiring Education* (2010) document to guide education in Alberta to 2030 call for a vision of education that will prepare young people for the shifting economic, technological, and socio-political realities of the 21st century. Through fostering intellectual engagement, an entrepreneurial spirit, and the dispositions of ethical citizenship, the vision for education outlined in the *Inspiring Education* document advocates that students develop competencies through a process of inquiry and discovery. Students would collaborate to create new knowledge while also learning how to "think critically and creatively, and how to make discoveries—through inquiry, reflection, exploration, experimentation, and trial and error" (Alberta Education, 2010, p. 19).

At the heart of the vision for education articulated in the *Inspiring Education* document is an emphasis on engaging students in genuine knowledge creation and authentic inquiry. This orientation towards learning is part of a long historical tradition in the West. In particular it draws inspiration from Socrates' questioning method in Ancient Greece and from work on inquiry by the educational thinker John Dewey in the early part of the 20th century. Newly emerging insights and empirical findings in the learning sciences suggest that traditional approaches to education that emphasize the ability to recall disconnected facts and follow prescribed sets of rules and operations should be replaced by "learning that enables critical thinking, flexible problem solving, and the transfer of skills and use of knowledge in new situations" (Darling-Hammond, 2008, p. 2). Within this frame, rather than learning about a field of knowledge (i.e., facts and definitions) or learning elements and pieces of a field (i.e., procedures and rules), Perkins (2009) argues that students should be given opportunities to "play the whole game" (p. 25) where they can experience junior versions of how knowledge is created and communicated within specific disciplines.

Contemporary educational researchers promote a myriad of conceptual models and approaches falling under the banner of inquiry-based learning and genuine knowledge creation. Although these approaches possess similarities, they rely on differing definitions of and pedagogical orientations to engaging students in this kind of work. To better inform the choice of practices and orientations to realize the vision for education articulated in the Inspiring Education document we offer a review of the literature on inquiry-based learning. Drawing on the theory and research in the field, we provide insight into the efficacy of particular approaches to inquiry in terms of their impact on student learning, achievement, and engagement. We draw on this same body of literature, along with our own analysis, to outline the strengths and weaknesses of particular orientations to inquiry.

Inquiry-based learning in Alberta

Within the curricular landscape of education, the term *inquiry* has become a central part of mission statements, general outcomes, and program strands in jurisdictions across Canada and the United States. In Alberta most of the major subject-specific curriculum documents contain the term *inquiry* and it holds a central place in both the science and social studies programs of study. For example, the Alberta social studies program states that social studies is "an issues focused and inquiry-based interdisciplinary subject" (Alberta Education, 2007, p. 1) where students "construct meaning in the context of their lived experience through active inquiry and engagement with their school and community" (p. 5). Similarly, one of the core foundations of the Alberta science program (Alberta Education, 2006) involves helping students "develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively and for making informed decisions" (p. 3). Although the term *inquiry* is less prominent in the language arts program, the math program explicitly calls for students to use organizational processes and tools to manage and plan for inquiry (Alberta Education, 2007). In contrast to traditional transmission-based approaches to education where the teacher is the primary holder of expert knowledge and the students are positioned as passive receptors of this information, programs of study in Alberta emphasize active, student-centered, and discipline-based inquiry.

The Ministry of Education recently solidified its commitment to inquiry-based learning by releasing *Inspiring Education* (Alberta Education, 2010), which sets out a long-term vision for education in the province as well as a broad policy framework to 2030. Based on extended feedback from the public and organized around the notion that we need to prepare kids for *their* future and not *our* past, *Inspiring Education* calls for education to be transformed around several key principles. These principles include the three E's of 21st century education:

> *Engaged Thinker*: who thinks critically and makes discoveries; who uses technology to learn, innovate, communicate, and discover; who works with multiple perspectives and disciplines to identify problems and find the best solutions; who communicates these ideas to others; and who, as a life-long learner, adapts to change with an attitude of optimism and hope for the future.
>
> *Ethical Citizen:* who builds relationships based on humility, fairness and open-mindedness; who demonstrates respect, empathy and compassion; and who through teamwork, collaboration and communication contributes fully to the community and the world.
>
> *Entrepreneurial Spirit:* who creates opportunities and achieves goals through hard work, perseverance and discipline; who strives for excellence and earns success; who explores ideas and challenges the status quo; who is competitive, adaptable and resilient; and who has the confidence to take risks and make bold decisions in the face of adversity. (pp. 5-6)

As education in Alberta is organized around the three E's of 21st century learning, a shift will occur from disseminating information and recalling facts toward developing particular competencies. Teachers will cultivate the natural curiosities of students and plant the seeds of life-long learning. Students will be invited to collaborate in order to create new knowledge while also learning how to "think critically and creatively, and how to make discoveries—through inquiry, reflection, exploration, experimentation, and trial and error" (Alberta Education, 2010, p. 19). In moving away from an education system focused on delivering content to one emphasizing a process of inquiry and discovery, students will continue to study core subjects such as language arts and mathematics. However, these subjects will involve an interdisciplinary exploration of topics that integrates a wider range of subjects, including the arts.

To support student innovation and discovery, *Inspiring Education* calls for Alberta educators to integrate powerful technology seamlessly into the learning process. It will not be enough simply to introduce new technologies into the classroom to support a single flow of information where, for example, students use the Internet primarily to retrieve information or watch a video. Rather, *Inspiring Education* promotes transformative uses of technology to prepare young people to flourish in a knowledge-based society. This includes using digital networking platforms to allow students to interact with experts in various fields as well as to collaborate with their peers to create, share, and exchange knowledge and ideas. Students will use a range of applications to communicate their findings in imaginative ways to audiences beyond the school.

This emphasis on knowledge creation and elaborated communication will require new approaches to assessment. Rather than focusing on students' ability to recall content or follow basic procedures, these new forms of assessment will require more sophisticated performances of deep understanding. This will include asking students to solve real-world problems and participate in tasks reflective of work engaged by professionals in particular disciplines. While traditional forms of summative assessment often demand one right solution or response, these more sophisticated performances of key competencies will require qualitative evaluation of student work. Formative feedback loops that provide ongoing descriptive feedback will help students enhance works in progress. This renewed focus on formative assessment will help teachers modify their teaching to help students produce sophisticated and high-quality summative performances of understanding.

Review Methods

To support the vision of education outlined in *Inspiring Education*, this article offers a review of the theory and research documenting the nature and efficacy of approaches to education that seek to engage students in inquiry-based learning, authentic intellectual work, and knowledge creation. We identify a wide range of definitional understandings of what it means to engage students in inquiry-based learning and knowledge creation. In relation to each approach we provide a synthesis and summary of the results of the most contemporary empirical research on the impact of specific approaches on student learning.

Selection Criteria

We examined a range of sources, including research articles and reports, conceptual articles, and books. These are our selection criteria:

- Robust research that included both qualitative and qualitative methodologies.
- Reports, articles, and books written by academics and/or professional organizations known nationally and/or internationally within the scholarly community.
- Literature published internationally, nationally, and provincially.
- Literature published within the past ten years was prioritized.

Search Procedure

From the end of March to May 2013 we searched published academic and professional scholarship using search words that included *authentic intellectual work*, *inquiry-based learning*, *project-based learning*, *problem-based learning*, and *design-based learning*. We used the following search strategies:

- Manual searches of relevant journals, published research reports, and books.
- Electronic searches on the following databases: Academic Search Complete, CBCA Education, ERIC, Google Scholar, Education Research Complete, ProQuest Dissertations and Theses, and WorldCat.
- Internet searches using Google search engine.

To augment these data sources, we scoured the reference lists of relevant articles and books for additional research that aligned with our search criteria.

Analysis

We used a shared drop box to gather resources and create a reference list of strategic literature. To verify and validate key concepts and information that we brought forward during our review of the literature, we posted the first draft of this article in a Google doc. This enabled both authors to undertake multiple readings and co-readings of this document to provide ongoing critical feedback and commentary. The authors met bi-monthly staring at the beginning of March 2013 to verify and validate the emerging synthesis of the research presented in this review of the literature.

Placing Inquiry-based Education in a Historical Context

It is important to appreciate the place of inquiry in a historical context both in terms of the long Western tradition of knowledge creation and inquiry and in terms of the ways traditional approaches to education have hindered efforts to organize education towards these ends. Forces in the world today are simultaneously challenging traditional notions of education and pushing jurisdictions of education around the world to change how they think about and organize education.

Recovering the Ancestry of Inquiry-Based Learning

Socrates. The vision for education outlined in Alberta Education's (2010) *Inspiring Education* emphasizing inquiry-based learning has a long ancestry in the

West. This spirit of inquiry has a strong historical antecedent in Ancient Greece and the questioning method employed by Socrates when engaging in dialogue with his interlocutors. Starting with the notion that the only thing he knew was he knew nothing, Socrates would engage in a systematic and disciplined questioning process to discover basic truths about the inner workings of the natural world and ethical questions related to such enduring concerns as the nature of justice. By posing such seemingly simple questions as *What is justice?* Socrates showed that many commonly-held assumptions were flawed and even illogical. Socratic inquiry cannot be seen as teaching in any traditional sense involving transmitting knowledge from someone who is more knowledgeable to those who possess less knowledge. The teacher here is not the 'sage on the stage' with the student positioned as a passive receptor of information. However, neither is a teacher engaged in Socratic dialogue a 'guide on the side.' Ross (2003) wrote that "in the Socratic method, the classroom experience is a shared dialogue between teacher and students in which both are responsible for pushing the dialogue forward through questioning" (p. 1). In this understanding of inquiry, both the teacher and the student ask probing questions meant to clarify the basic assumptions underpinning a truth claim or the logical consequences of a particular thought.

Understanding the Socratic tradition helps us recover several elements that seem to be missing in how some people understand inquiry-based learning. The Socratic tradition does not involve giving students free rein over the topic they wish to explore with minimal guidance from the teacher. Rather, the Socratic method creates a space where teacher and student are in dialogue to pursue answers to questions that are worth thinking about deeply. Just as *Inspiring Education* focuses on ethical citizenship, Socrates did not seek knowledge for its own sake. For Socrates the unexamined life was not worth living. The good life involved seeking knowledge as a means to living more ethically and consciously in the world. Inquiry was not done sporadically or as a mechanical step-by-step formal method; it was a way of living ethically in the world.

The Middle Ages and the Renaissance. While this spirit of inquiry within the Western tradition may have emerged in Ancient Greece, the term itself can be traced back to the middle of the 13th century through the Latin word inquīrere, which literally means "to seek for." The spirit of seeking answers to the mysteries of the universe based not on established tradition or superstition but on observation, experimentation, and empirical verification, gained momentum during the early 1500's in Northern Italy. Key Renaissance figures such as Galileo Galilei and Leonardo da Vinci were emblematic of a quest for knowledge that spread to the rest of Europe in the late 16th century spurred on through the creation of new technologies, eg. microscope, telescope, printing press, etc. This spirit of inquiry and scientific discovery took hold on a wider scale during the European Enlightenment beginning in the 18th century.

Dewey. In the modern era, these historical threads of inquiry found a home in the work of John Dewey in the early part of the 20th century. As one of the key leaders of the progressive movement in education, Dewey, who had worked as a science teacher, encouraged K–12 teachers to use inquiry as the primary teaching strategy in their science classrooms. Modeled on the scientific method, the particular process of inquiry Dewey (1910) advocated involved "sensing perplexing situations, clarifying the problem, formulating a tentative hypothesis, testing the hypothesis, revising with rigorous tests, and acting on the solution” (Barrow, 2006, p. 266). Dewey was critical of transmission-based pedagogies that emphasized acquiring facts at the expense of fostering modes of thinking and attitudes of the mind related to the ways scientific knowledge is created.

As Dewey’s thinking on education evolved, he broadened the scope of topics and subjects in which to engage students with inquiry. Dewey (1938) encouraged students to formulate problems related to their own experiences and augment their emerging understandings with their personal knowledge. Dewey believed that the teacher should not simply stand in front of the class and transmit information to be passively absorbed by students. Instead, students must be actively involved in the learning process and given a degree of control over what they are learning. The teacher's role should be that of facilitator and guide. It is important to emphasize that this process did not involve anything-goes, free-for-all exploration; it was to be guided by empirical approaches to knowledge creation.

From a curricular perspective, Dewey, like Socrates, believed that active inquiry should be used not only to gain knowledge and particular dispositions, but also to learn how to live. Dewey (1944) felt that the purpose of education was to help students realize their full potential, to strengthen democracy, and to promote the common good. *Inspiring Education* contains similar language of ethical citizenship; learning not only prepares the young to make their way as individuals in the world, but it also helps them to become advocates for positive social change. Much of the higher purpose and democratic spirit of Dewey’s vision for education animates Alberta Education’s vision for education towards 2030.

Traditional Approaches to Education

The factory model. Although Dewey’s pioneering work was realized in some experimental schools and in exemplary classrooms, on a systemic level his inquiry approach to education ran counter to prevailing views about education that sought to prepare young people for an industrial society. As outlined by Friesen and Jardine (2009), for young people to take their place in industrial enterprises or within highly stratified bureaucratic organizations, an education system was created that emphasized following prescribed sets of rules and regurgitating content. Inspired by the factory room floor, curriculum was conceptualized as a mass assembly line delivering “those not-further-divisible ‘bits’ out of which any knowledge was assembled” (p. 12). Underlying this model of education is a series of assumptions about the nature of knowledge and knowing, the purpose of education, and the role of the teacher in the classroom. Sawyer (2006) summarized these assumptions as follows:

- Knowledge is a collection of *facts* about the world and *procedures* for how to solve problems.
- The goal of schooling is to get these facts and procedures into the student’s head.
- Teachers know these facts and procedures and their job is to transmit them to students.
- Simpler facts and procedures should be learned first.

- The way to determine the success of schooling is to test the students to see how many facts and procedures they have acquired. (p. 1)

Within this framework, learning is understood to be a linear process of either getting a pre-given body of content into the students' heads or breaking down any complex task into its basic parts and sequencing these in a way that can be assimilated into the mind of the learner.

Elementis and aboutis. Perkins (2009) argued that this approach to teaching any complex idea or skill, from historical inquiry to mathematical thinking, meant that most students experienced learning in one of two ways:

1. *Elements first*. Ramp into complexity gradually by learning elements now and putting them together later.

2. *Learning about*. Learn about something to start with, rather than learning to do it. (pp. 3-4)

Perkins uses the metaphor of baseball to argue that the experience of most students in school is one where they either learn isolated skills like throwing the ball or they learn about baseball by studying statistics or the history of the game.

In what Perkins called *elementis*, students learn the elements of a discipline in isolation, usually in the form of a prescribed set of rules and operations. For example, in math students learn addition, then subtraction, followed by multiplication and division. Although students are promised that eventually they will be able to put these operations together to solve meaningful problems, often they are never given this opportunity. Similarly, students study grammar with the "idea that the knowledge will later coalesce into comprehensive, compelling, and of course correct written and oral communications" (p. 4). However, students are not given the opportunity to produce powerful pieces of writing intended for a real audience. Divorced from the context in which a subject like math or writing lives in the world, students gain an incomplete and fragmented understanding of these disciplines. Students often leave school unable to perform tasks representative of the work undertaken by professionals in the field.

History and science are most often taught using what Perkins (2009) termed *aboutis*, where students learn about a topic or concept rather than learning how to take part in the process of creating that knowledge. For example, in history students are generally presented with an authoritative authorless series of facts about an era in the form of a long list of names, dates, and developments. Students rarely have an opportunity to take part in actual historical inquiry to learn how historians construct knowledge about the past. This also occurs in science where students learn about, for example, Newton's laws or the steps involved in mitosis. However, Perkins notes, "a huge body of research on science understanding demonstrates that learners show very limited understanding, bedevilled by a range of misconceptions about what the ideas really mean" (p. 6).

These assumptions have become so deeply ingrained in how we think about education that ongoing attempts at educational reform often fail to question the efficacy of organizing learning around *elementis* and *aboutis*. This can be seen in the flipped classroom movement that is often held up as a paradigm shift that will reinvent education. First popularized by Salmon Khan (2013), in the flipped classroom students do not spend class time passively listening to a teacher lecture. This part of instruction is assigned for homework through a video posted on-line (e.g., on YouTube or Vimeo). Students spend class time asking questions and receiving one-on-one feedback and support for content, exercises, or problems they learned at home. Although this model of education has much to offer and may be preferable to many current practices where students spend a great deal of their time in school listening to teachers talk, the flipped classroom leaves intact the core assumptions of *elementis* and *aboutis* that underpin traditional models of education.

Three Developments that Challenge Traditional Approaches to Learning

While an educational focus on content delivery and discrete skills may have been appropriate for the early part of the 20th century, we need new models of education that reflect the modern economy, the rise of new technologies and digital networks, and new advances in the learning sciences.

Moving from an industrial to a knowledge-based economy

From an economic perspective, Darling-Hammond (2008) notes that in the early part of the 20th century 95% of jobs in the U.S. were low-skill manual labour requiring the ability to follow basic procedures designed by external authorities. In the early part of the 21st century these jobs make up only 10% of the total U.S. economy. Darling-Hammond (2008) writes:

> Most of today’s jobs require specialized knowledge and skills, including the capacity to design and manage one’s own work, communicate effectively and collaborate with others; research ideas; collect, synthesize, and analyze information; develop new products; apply many bodies of knowledge to novel problems that arise (p. 1).

In the past, when most jobs required manual labour, only a small elite needed to possess abilities like these. Today the vast majority of the population needs these competencies to flourish in an economy where there is “greater dependence on knowledge, information and high skill levels, and the increasing need for ready access to all of these by the business and public sectors” (OECD, 2005, p. 15).

The need for knowledge creators who possess high skill levels reflects an economy driven by continual technological innovation. Many jobs that will be in demand in the next two decades have not yet been created. This happened in the last decade when the introduction of smart phones and tablets along with the proliferation of social networking sites like Twitter led to a range of new jobs that did not exist as recently as 2003. These jobs include social media managers and app developers. The continually-evolving nature of the 21st century economy will require people who are highly adaptable to change; what they know will be less important than what they are able to do with that knowledge in different contexts. This knowledge-based economy requires educational institutions to move beyond traditional approaches to education that demand students work on “constrained tasks that emphasize memorization and elicit responses that merely demonstrate recall or application of simple algorithms" (Darling-Hammond, 2008, p. 12).

The rise of new technologies and digital networks

The rise of digital networks has led to an increase in the amount, level of specialization, and diversity of information now available to the general public. Anyone with an Internet connection can access a vast store of information on almost any subject. Top universities such as Harvard and MIT now post on-line lectures by leading scholars for the general public to access. In this environment it no longer makes sense for a teacher or a textbook to be the sole holder of knowledge. Digital networks provide opportunities to break down the walls of the school and provide students with new possibilities for gathering information and accessing experts.

However, as *Inspiring Education* notes, digital networks have evolved in way where they do not just support a single flow of information from expert to novice. When teachers simply graft new technologies onto traditional approaches to education, students might use the Internet only retrieve information or watch videos. As Friesen and Lock (2010) outline in detail, technological advancements allow students to work collaboratively with their peers to create, share, refine, and exchange knowledge and ideas. They write:

> Web 1.0 was dominated by browsers containing static screensfull of information, with the user working in isolation. The second generation of the Internet, Web 2.0 is different because it "it is more interactive, allowing users to add and change context easily, to collaborate and communicate instantaneously in order to share, develop, and distributed information, new applications, and new ideas" (Scrhum & Levin, 2009, 183). With applications such as wikis, blogs, voice threads, RSS feeds, social networking (e.g., MySpace, Facebook), and Google Apps, users can work online with multiple users within a collaborative space. (p. 11)

Within this new landscape digital technologies will play an integral role in supporting learning and knowledge-building activities (WNCP, 2011). Students will be able to "engage collaboratively in idea improvement, problem solving, elaborated forms of communication, consulting authoritative sources and knowledge advancement as they undertake real problems, issues and questions" (p. 4). Emerging technologies provide students with elaborated forms of communication such as publishing and movie-making technologies. In the past these technologies were expensive and only available to a small professional elite but they are now available to a much wider population.

Advances in the learning sciences

When universal education was introduced in the early part of the 20th century, it was assumed that learning about a field of study or breaking a field into discrete elements was the most effective way to organize education. However, these beliefs were never based on empirical evidence. New findings in the learning sciences are challenging these assumptions. There is a growing consensus around the nature of knowledge and knowing, the purpose of education, and how teachers can best promote learning.

Knowledge has traditionally been seen as a collection of facts, a body of content, or a list of processes or procedures to master. However, knowledge is now "understood as organized in living, developing fields, changing and adapting in the presence of new circumstances, new evidence and new discoveries" (WNCP, 2011, p. 3). Knowledge is not dead or inert. Instead, a subject of study is a "living place, a living field of relations" (Jardine, Friesen, & Clifford, 2008, p. xi). Those who understand knowledge as situated in a dynamic always-evolving living field cannot study facts or procedures outside the field that created them. Research has shown that people are limited in their ability to remember ideas and knowledge when they learn in decontextualized environments (Davis, Sumara & Luce-Kapler, 2000, 2008). As a result, isolated facts or procedures that are learned as repetitive drills have little meaning and are soon discarded.

This view of knowledge suggests that students learn best when the subjects are meaningful to them. Student tasks must have "an authenticity, [and a sense] that the work being done in classrooms is 'real work' that reflects the living realities of the discipline being taught" (WNCP, 2011). When students and teachers pose guiding questions, problems, or tasks that professionals in the field would recognize as important, they can work and learn from experts towards responses and performances of learning that are meaningful, sophisticated, and powerful. This view of the nature and purpose of learning is supported by a growing body of literature urging educators to design curricula, teaching, and learning experiences where students have the opportunity to "learn their way around a discipline" (Bransford, Brown & Cocking, 2000, p. 139) by engaging in authentic intellectual tasks and opportunities for genuine knowledge creation (Darling-Hammond, 2008; Jardine, Friesen & Clifford, 2008; OECD, 2008; Perkins, 2008; Sawyer, 2006). Educators advocating for this approach argue that each discipline (e.g., science, mathematics, history) has its own particular ways of generating knowledge, verifying what counts as quality work, and communicating. The job of educators thus becomes to apprentice young people into these practices.

In the past it was thought that students could not work within a living discipline until they had learned all the facts, definitions, and procedures about the field. Only once they reached the university level might they have opportunities to engage in historical inquiry, mathematical thinking, or genuine scientific exploration. Today, learning the way around a discipline is no longer for the few who move on in their studies; it is also open to the young. For example, educators traditionally believed that students needed to have a basic foundation of historical knowledge before they could take part in genuine historical inquiry. Because of this belief, studying history for most students involved passively and uncritically absorbing other people's facts about the past. In the present, students can work within the discipline of history from an early age where they are given access to primary sources through various technologies, to understand how historians make sense of the past. This includes working with primary sources, and using methods of historical analysis and argumentation (National Center For History in Schools, 1996). Rather than learning *about* history, students are actually given the opportunity to *do* history. Perkins (2008) calls this approach to education "playing the whole game" (p. 25) where students are apprenticed into developmentally appropriate junior versions of the ways professionals in a field engage, create knowledge, and communicate in their discipline.

This shift in thinking about the nature and purpose of education calls for a redefinition of commonly-used terms in educational discourse. For instance, rigour is most often understood as imparting more sophisticated information to students. However, for Rosenstock (2011), principal of High Tech High, a school devoted to authentic discipline-based inquiry, rigour involves "being in the company of a passionate adult who is rigorously pursing inquiry in the area of their subject matter and is inviting students along as peers in that discourse" (2011). The key distinction is between learning about a field of inquiry and taking on the ways of knowing of the field of inquiry. Rosenstock wants kids "behaving like an actress, scientist, documentary filmmaker, like a journalist. Not just studying it but being like it" (2011).

Findings in the learning sciences, including neurology and cognitive science, support an inquiry-based vision for education in the 21st century (Bransford, Brown & Cocking, 2000; OECD, 2008; Sawyer, 2006; Davis, et al., 2008; WNCP, 2011). Deep understanding comes from being immersed in a subject for a long period of time. Superficial coverage of many topics does not help students develop competencies because there is not enough time to learn anything in depth. Curriculum that is 'a mile wide and an inch deep' does not allow learners to see connections among the things they are learning. There must be a "sufficient number of cases of in-depth study to allow students to grasp the defining concepts in specific domains within a discipline" (Bransford, Brown, & Cocking, 2000, p. 20).

This body of research also contends that for learning to occur people must not be passive recipients. Rather, the learner must be actively involved in the learning process. This is because "when we are simply exposed to events and information (as opposed to acting on them), our brains and bodies are not much affected" (WNCP, 2011, p. 4). Long-term changes in neuronal structures and brain activity occur when people are actively involved in shaping their learning experiences (OECD, 2007; Davis, et al., 2000, 2008). Deep conceptual understanding involves actively adapting and testing ideas, concepts, and processes within new contexts. Learning reflects the capacity of more sophisticated, flexible, and creative action within novel circumstances. Emerging insights from the learning sciences suggest that

> predictable activities can actually 'dumb you down,' whereas participation in unfamiliar structures that demand adaptation —this is, places where learning is required —literally, can make you smarter (Davis, Sumara & Luce-Kapler, 2000, p. 76).

As Davis (2008) and colleagues outline, this does not mean there is no place for some rote memorization. For example, skills such as decoding text and counting "must become automatic and transparent before they can be used in the development of more complex competencies" (p. 28). However, rote memorization if pursued exclusively can lead to a form of learning that allows students to pass a test but not gain the ability to use this knowledge in the development of more sophisticated understandings or apply what they learned within realistic contexts. This phenomenon seems to occur when learning takes place in decontextualized environments where what is learned is isolated from the greater set of relations to which a skill or task is a part. Insights from the learning sciences suggests that learning occurs when students are given threshold experiences just beyond their abilities whereby they are asked to apply what they have learned in realistic situations. As we will see providing rigorous feedback and scaffolding must be an integral part of this process.

These insights into the circumstances in which learning occurs aligns with the work of Sawyer (2006) who, supported by findings in the cognitive sciences, makes a key distinction between approaches to education that promote deep learning versus traditional practices that Papert (1993) calls "instructionism" (p. 137). Here is a summary of the requirements for fostering deep learning versus instructionism:

Learning Knowledge Deeply (Findings from Cognitive Science)	**Traditional Practices** (Instructionism)
Deep learning requires that learners relate new ideas and concepts to previous knowledge and experience.	Learners treat course material as unrelated to what they already know.
Deep learning requires that learners integrate their knowledge into interrelated conceptual systems.	Learners treat course material as disconnected bits of knowledge.
Deep learning requires that learners look for patterns and underlying principles.	Learners memorize facts and carry out procedures without understanding how or why.
Deep learning requires that learners evaluate new ideas and relate them to conclusions.	Learners have difficulty making sense of new ideas that are different from what they encountered in the textbook.
Deep learning requires that learners understand the process of dialogue through which knowledge is created and can examine the logic of an argument critically.	Learners treat facts and procedures as static knowledge, handed down from an all-knowing authority.
Deep learning requires that learners reflect on their own understanding and their own process of learning.	Learners memorize without reflecting on the purpose or on their own learning strategies.

(Sawyer, 2006, p. 4)

Researchers assert that discipline-based approaches to inquiry learning, if designed well, support students in deep learning (Bradford, Brown, & Cocking, 2000; Barron & Darling-Hammond, 2008; Sawyer, 2006). In the last section of this article we document the design structures that teachers need to integrate to ensure that deep learning occurs.

Research on Inquiry-based Learning

Within the contemporary field of education there, a range of inquiry approaches to education move away from passive transmission-based pedagogy. Students undertake real problems, issues, and questions, consult with experts and authoritative sources, work collaboratively to improve ideas and products, and use elaborated forms of communication beyond a research paper (i.e., a podcast explanation, complex display board, or mini- documentary). These approaches to education include: authentic intellectual work (Newmann, Bryk, & Nagaoka, 2001), discipline-based inquiry (Galileo Educational Network Association, 2008), project-based learning (Thomas, 2000; Thomas, Mergendoller, & Michaelson, 1999), problem-based learning (Barrows, 1996); design-based learning (Hmelo, Holton, & Kolodner, 2000), and challenge-based learning (Johnson & Adams, 2011). There is an accompanying corpus of research evaluating the effectiveness of these approaches to inquiry. In this section we examine the various ways inquiry-based learning is defined and the accompanying research evaluating the impact on learning of specific approaches to inquiry.

Authentic pedagogy, authentic intellectual work, and interactive learning

A number of major studies provide compelling evidence that approaches to inquiry that include *authentic pedagogy and assessments* (Newmann, Marks, & Gamoran, 1996), *authentic intellectual work* (Newmann, Bryk, & Nagaoka, 2001), and *interactive instruction* (Smith, Lee, & Newmann, 2001) dramatically improve academic achievement.

Newmann et al. (1996) conducted a large study evaluating elementary, middle, and high schools that had implemented authentic pedagogy and authentic academic performance approaches in their mathematics and social studies classrooms. They sought to determine to what extent student achievement improved in schools with high levels of authentic pedagogy involving higher-order thinking, deep-knowledge approaches, and connections to the world beyond the classroom. The research team observed 504 lessons, analyzed 234 assessment tasks, and systematically sampled student work. The researchers found that environments with high levels of authentic pedagogy led to higher academic achievement among all students. They concluded that differences between high- and low-performing students greatly decreased when students who were normally low-achieving were offered authentic pedagogy and assessments.

In another study examining 2,128 students in 23 schools in Chicago, Newmann et al. (2001) found that students instructed in mathematics and writing organized around more authentic work made higher-than-normal gains on standardized tests. They defined authentic intellectual work as follows:

> Authentic intellectual work involves original application of knowledge and skills, rather than just routine use of facts and procedures. It also entails disciplined inquiry into the details of a particular problem and results in a product or presentation that has meaning or value beyond success in school. We summarize these distinctive characteristics of authentic intellectual work as construction of knowledge, through the use of disciplined inquiry, to

> produce discourse, products, or performances that have value beyond school. (pp. 14-15)

To determine the effectiveness of this approach on learning, Newmann et al. (2001) examined the level of authentic intellectual work in writing and mathematics assignments in Grades 3, 6, and 8 classrooms. After examining the quality of the assignments against the quality of student work, they correlated this data with students' scores on standardized tests

In another large study, Smith et al. (2001) focused on the impact of forms of instruction they deemed interactive on learning in reading and mathematics. They characterized interactive instruction as follows:

> In classrooms that emphasize interactive instruction, students discuss ideas and answers by talking, and sometimes arguing, with each other and with the teacher. Students work on applications or interpretations of the material to develop new or deeper understandings of a given topic. Such assignments may take several days to complete. Students in interactive classrooms are often encouraged to choose the questions or topics they wish to study within an instructional unit designed by the teacher. Different students may be working on different tasks during the same class period. (p. 12)

After examining test scores from over 100,000 students in Grades 2 to 8 along with surveys from more than 5,000 teachers in 384 Chicago elementary schools, they found strong empirical evidence that interactive teaching methods were associated with greater learning and deeper understanding among elementary students in reading and mathematics.

Discipline-based inquiry

In a similar vein to authentic intellectual work, the Galileo Educational Network Association (2008) created a Disciplined-Based Inquiry Rubric that outlines inquiry as a process involving a number of core characteristics:

- The inquiry study is authentic in that it emanates from a question, problem, issue, or exploration that is significant to the disciplines and connects students to the world beyond the school.
- Students are given opportunities to create products or culminating work that contributes to the building of new knowledge.
- Assignments or activities foster deep knowledge and understanding.
- Ongoing formative assessment loops are woven into the design of the inquiry study and involve detailed descriptive feedback.
- The study requires students to observe and interact with exemplars and expertise, including professionals in the field, drawn from the disciplinary field under study.
- Students are given the opportunity to communicate their ideas and insights in powerful ways through a myriad of media.
- Students' final products of communication through public presentations and exhibitions

As part of an Alberta Initiative for School Improvement (AISI) project, over the course of a three-year study Friesen (2010) found that engaging students in disciplinary-based inquiry had a significant positive impact on student achievement on standardized provincial examinations. Designed and implemented by 26 elementary and secondary schools with 12,800 students in a school district in Alberta, Friesen (2010) specifically found that the aggregate achievement scores of students in schools designated as *high inquiry schools* significantly exceeded provincial norms on provincial achievement tests. These findings make a strong argument that disciplinary-based inquiry does not detract from traditional forms of assessment but actually increases achievement on traditional forms of standardized assessment.

Project-based learning

Barron and Darling-Hammond (2008) reviewed three approaches to inquiry-based learning: project-based learning, problem-based learning, and design-based instruction. In this section we discuss project-based learning, with overviews of the other two methods in the sections that follow.

Project-based learning (PBL) organizes learning around the creation of a presentation or a product that is usually shown to an audience. This could include the creation of an original play, a video, or an aquarium design judged by local architects (Barron & Darling-Hammond, 2008, p. 40). According to Thomas (2000), PBL projects involve:

> complex tasks, based on challenging questions or problems, that involve students in design, problem-solving, decision making, or investigative activities; give students the opportunity to work relatively autonomously over extended periods of time; and culminate in realistic products or presentations. (p. 1)

Responding to the question “what must a project have in order to be considered an instance of PBL?” (p. 3), Thomas argues that the following criteria need to be in place. He elaborates on each in his review of the literature.

1. PBL projects are focused on questions or problems that “drive” students to encounter (and struggle with) the central concepts and principles of a discipline.
2. Projects involve students in a constructive investigation.
3. Projects are student-driven to some significant degree.
4. Projects are realistic, not school-like. (pp. 3-4)

Moursund’s (1999) review of the literature identified authentic content, authentic assessment, teacher facilitation but not direction, and explicit educational goals as essential elements of problem-based learning.

There have been a number of studies verifying the impact of project-based approaches on student learning. Conforming to the four criteria outlined by Thomas (2000), studies have found an approach called *expeditionary learning* (EL) to have significant impact on student achievement. As outlined in a report by the New American Schools Development Corp (1997), nine of 10 schools that implemented expeditionary learning models demonstrated significant improvement among their students in standardized tests reflecting academic achievement. In Dubuque, Iowa, two elementary schools that implemented the EL program over two years showed gains on the Iowa Test of Basic Skills from "well below average" to the district average, while a third school went from "well below average" to "well above the district average."

In another study examining Grades 4 and 5 students working on a nine-week project to define and find solutions related to housing shortages, Shepherd (1998) found that the project-learning students scored significantly higher on a critical-thinking test in comparison to a control group who did not take part in the inquiry project. The project-learning students also demonstrated greater confidence in their learning. In another study in England, Boaler (1997) examined the impact of inquiry-based learning through a longitudinal study that followed students over three years in two schools with similar student achievement and income levels. Although the study found similar gains in learning on basic mathematics procedures, a greater number of the students involved in project-learning passed the National Exam in year three than those in the traditional school. These students also developed more flexible and useful mathematical knowledge.

According to Barrow (2006) the National Research council (1996, 2000) defined scientific inquiry as a process where students:

1. identify questions and concepts that guide investigations (students formulate a testable hypothesis and an appropriate design to be used);

2. design and conduct scientific investigations (using major concepts, proper equipment, safety precautions, use of technologies, etc., where students must use evidence, apply logic, and construct an argument for their proposed explanations);

3. use appropriate technologies and mathematics to improve investigations and communications;

4. formulate and revise scientific explanations and models using logic and evidence (the students' inquiry should result in an explanation or a model);

5. recognize and analyze alternative explanations and models (reviewing current scientific understanding and evidence to determine which explanation of the model is best); and

6. communicate and defend a scientific argument (students should refine their skills by presenting written and oral presentations that involve responding appropriately to critical comments from peers). Accomplishing these six abilities requires K–12 teachers of science to provide multi-investigation opportunities for students. (Barrow, 2006, p. 268)

According to Barrow (2006) "when students practice inquiry, it helps them develop their critical thinking abilities and scientific reasoning, while developing a deeper understanding of science" (p. 269). The National Research Council (2000) supports the findings of Barrow.

Problem-based learning

Of all the approaches to inquiry, problem-based learning is the most researched. Originating from a model of learning developed by Barrows (1992) for medical students, problem-based learning helps students hone their diagnostic skills through work on ill-structured problems. The problem-based learning model has recently been adapted for a range of subjects including social studies, science, and mathematics (Stepien & Gallagher, 1993). Although a number of approaches to learning have adopted this title, Barrows (1996) argued that its core characteristics include a student-centered approach to learning, and learning that occurs in small groups under the guidance of a tutor who acts as a facilitator or guide. Additionally, students engage with authentic problems before they have received any preparation or study, and may have to find information on their own to solve the problem. Other authors argue that assessment and evaluation is most concerned with how the students applied their knowledge to solve the problem, rather than assessing one correct answer (Segers, Dochy, & De Corte, 1999).

According to Barron and Darling-Hammond (2008), problem-based learning involves students working in small groups to "explore meaningful problems, identifying what they need to know in order to solve the problem, and coming up with strategies for solutions" (p. 43). Unlike many textbook word problems commonly found in math, these problems are realistic in that they are ill-structured, offering the possibility of multiple solutions and methods to solve the problem. Dan Meyer (2010), a prominent advocate of this approach, used a problem from a textbook that asked students to find the surface area and volume of a water tank. He highlighted the difference between traditional approaches to mathematical problem solving and authentic problem-based approaches to mathematics. In the first instance students were presented a drawing of a water tank, all the dimensions they needed to solve the problem were provided, and solving the problem required a series of sequential steps. In contrast, as shown in a video Meyer (2010) posted online**,** a more authentic approach to this problem demonstrated an actual water tank being filled up with a garden hose. In this instance students were not provided with any of the dimensions of the water tank. Students had to decide what information was needed to solve the problem and how they could find the answers. Students were encouraged to discuss possible solutions with their peers and work with the teacher in a dialogical environment where the teacher recorded possible hypotheses on the board.

Overall, the impact of problem-based learning has been positive. In a study by the Cognition and Technology Group at Vanderbilt (1992) examining over 700 students from 11 school districts, students were given three "Jasper adventure projects" over the course of three weeks. Two of the projects asked students to plan a trip while the other asked students to create a business plan. The researchers measured the impact of these projects on learning by giving students a series of tasks after they had finished the three-week unit. They focused on five key areas that included: basic math concepts, word problems, planning capabilities, attitudes, and teacher feedback. The researchers reported the largest gains in planning capabilities, word problem performance, and attitudes towards mathematics. Students who had been exposed to the Jasper problems showed positive gains in all of the areas in relation to their peers in a control group who did not engage in the projects. Students involved in the Jasper projects also had a more positive attitude towards their learning. Boaler (1997) also found that problem-based learning increased student engagement in a study that found students' experiences with a project approach to mathematics led to less anxiety towards mathematics, a greater willingness to see mathematics as relevant to everyday life, and increased willingness to approach mathematical challenges with a positive attitude.

In another study, Gallagher, Stepien, and Rosenthal (1992) created a problem-based course for high achieving high school students in mathematics and science. In this case problem-based instruction emphasizes presenting students with ill structured problems around the meaning and impact of contemporary scientific issues (i.e., the effect of electromagnetic fields on childhood leukemia, the health care system). Results from the study showed significant changes in students' ability to problem solve as reflected in a much stronger ability among students in the problem-based class to describe a process for finding a solution to an ill-defined problem that they had never encountered. This conclusion was reached through comparing gains made in relation to a pretest and posttest for the 78 students involved in the problem-based course. The researchers then compared these results to a comparison group that did not participate in the problem-based learning course.

In a meta-study, Dochy, Segers, Van den Bossche, and Gijbels (2003) examined 43 peer-reviewed empirical studies on problem-based learning undertaken in classrooms. They found that problem-based learning has a strong positive effect on students' skills. This was shown through both a vote count, as well as by the combined effect size. The one area where there was a tendency towards a negative result was related to the effect of problem-based learning on student knowledge. However, they noted that this result was greatly influenced by two studies. For knowledge-related outcomes their results suggest that the impact on learning increases when students engage in problem-based learning for a second time.

In a study Barron et al, (1998) also investigated sixth-grade students, presenting one class with a problem-solving planning activity prior to beginning their projects, while in another class students were not offered the framing problem-solving task. Their results indicated that students in the problem-solving classroom conditions were better able to apply the targeted math concepts and had higher achievement than those without these conditions in place.

Overall, the results of studies examining the efficacy of problem-based learning have been mixed. However, Barron and Darling-Hammond (2008) documented a number of studies that suggest this approach is effective "in supporting flexible problem solving, reasoning skills, and generating accurate hypotheses and coherent explanations" (p. 45). For example, a quasi-experimental study by Hmelo (1998) found that students that engaged in problem-based learning generated more accurate hypotheses and more coherent explanations. Similarly, Williams, Hemstreet, Liu, and Smith (1998) found that this approach fostered greater gains in conceptual understanding in science.

Design-based learning

In design-based learning students are asked to design and create an artefact that requires them to apply knowledge and principles drawn from a particular discipline (Barron & Darling-Hammond, 2008). Often found in the domains of technology, art, engineering, and architecture, students are asked to generate ideas, create prototypes, and test their creations. Examples of this kind of work include the FIRST Robotics Competition (2009) where students build a remote-controlled robot from a standard kit of 100 parts. Professional engineers work alongside the students, explaining the function of the various parts and providing feedback on the emerging designs. Due to the complexity of this kind of work, students are generally encouraged to work in small groups and take on specialist roles.

There have been few studies using control groups examining the effectiveness of design-based practices on student learning. However, Hmelo, Holton, and Kolodner (2000) found Grade 6 students who designed a set of artificial lungs and built a partially-working model of the respiratory system made great gains in viewing the respiratory system more systemically. Overall, the students gained a deeper understanding of the structures and functions of the system than a control group.

Challenged-based learning

The Apple Education-sponsored Challenged Based Learning model (Johnson & Adams, 2011) offers a step-by-step approach to inquiry. According to their website Challenged Based Learning (2013) provides "an engaging multidisciplinary approach to teaching and learning that encourages learners to leverage the technology they use in their daily lives to solve real-world problems" (p. 1). Students work collaboratively with their peers and use social networking platforms to connect with experts in their communities and around the world. Within this model of inquiry students identify a problem or challenge in the world, take action, and then share their experiences with a wider audience.

Although there is no peer-reviewed research of the impact of this approach to inquiry on learning, Johnson and Adams (2011) undertook two field-based studies on the efficacy of this approach. Here is a summary of their findings, which relied largely on student and teacher surveys:

- *CBL builds 21st Century Skills.* Ninety percent of teachers reported that 12 key skill areas improved significantly, including Leadership, Creativity, Media Literacy, Problem Solving, Critical Thinking, Flexibility, and Adaptability. Seventy percent of teachers reported some improvement in every area of the 21st Century Skills.

- *CBL engages students in learning.* Over three-quarters of students, across every age group, felt that they had learned more than what was required of them, were part of solving a big problem, and worked harder than they normally do.

- *Teachers find CBL effective in engaging students and helping them master the material — and a good use of their limited time.* Over 90% of teachers, across every grade level, felt that CBL was a good use of their limited time and would use it again. Over three-quarters of teachers, again across every grade level, felt that their students mastered the expected material and that their overall engagement increased.

- *While broadly applicable across the range of learning environments, CBL is ideally suited to teaching in a technologically rich environment.* CBL works in a variety of settings, from those with shared access to computers and the Internet, to those with 24/7 Internet access via a combination of school and home-based devices, to fully one-to-one 24/7 classrooms. The study found that today's teachers and students already have the computer and Internet skills needed to engage with CBL effectively. (p. 2)

Inquiry-based teaching

In synthesis of two meta-analysis of "inquiry-based teaching" Hattie (2009, p. 208) found that this approach resulted in improved student performance in a number of areas. Noting that much of the research on inquiry-based teaching has happened in science, Hattie defines this approach as follows:

> Inquiry-based teaching is the art of developing challenging situations in which students are asked to observe and question phenomena; pose explanations of what they observe; devise and conduct experiments in which data are collected to support or contradict their theories; analyze data; draw conclusions from experimental data; design and build models; or any combination of these. (p. 208)

Of note inquiry-based teaching increased the amount of time students spent in labs, decreased teacher-led discussions in classrooms, and also improved critical thinking (as cited in Hattie, Brederman, 1983). Although Shymansky, Hedges, and Woodsworth (1990) found that this approach helped students gain greater competencies in scientific process, the effects were less great on content. Overall, these studies suggest that inquiry-based teaching has positive effects; however, Hattie does not rank these effects on learning as dramatic. One of the drawbacks to Hattie's analysis is that the research he is drawing from is twenty-five to thirty years old. Further, it is not clear if the way this approach was taken up in the classroom was more akin to minimally guided discovery learning, which has limited impact on student achievement.

Other Approaches

The literature related to inquiry-based learning beyond the approaches outlined above reveals a number of orientations involving a step-by-step process to engage students in inquiry. This includes work in Australia such as the Integrating Socially Model of inquiry (Hamston & Murdoch, 1996) and the TELSTAR model of inquiry (Department of Education, Queensland, 1994a). Common to all these orientations is a universal schematic that could be applied to a range of subject areas where students identify a problem or topic, gather information, evaluate the findings, and list possible actions and implications of their research. For example, the following steps are included in the TELSTAR model of inquiry (DEQ, 1994b):

- What is the topic?
- Why should we study this topic?
- How do we feel about this topic?

- Who else feels strongly about this topic?
- What do we want to find out?
- How might we sort our information
- What conclusions can we draw?
- How do we feel about this topic now?
- How could the investigation be improved? (p. 7)

These frameworks from the 1990's have been augmented by more recent work that offers a schematic template to guide inquiry, including Alberta Learning's *Focus on Inquiry* (2004). There is limited peer-reviewed research examining the effectiveness of these approaches, which differ from the approaches we have been examining above in that they are universal and not necessarily situated in a particular discipline.

Making inquiry-based learning count

Not just doing for the sake of doing

Not all the research on specific approaches to inquiry learning has been positive. It is important to respond to detractors of these approaches to learning that often portray inquiry as unstructured, leading to what Barron called "doing for the sake of doing" (as cited in Barron & Darling-Hammond, 2008, p. 12). In this vein, several researchers found that direct instruction is preferable to inquiry (Kirschner, Sweller, & Clark, 2006; Klahr & Nigam, 2004). Kirschner et al. (2006) found that approaches to instruction including project-based learning, inquiry learning, and discovery learning that rely on "minimally guided instruction" are ineffective and inefficient ways to teach. They defined minimally-guided instruction as an approach in which "learners, rather than being presented with essential information, must discover or construct essential information for themselves" (p. 1). In response to this study, Hmelo-Silver, Duncan, and Chinn (2007) argued that the methodology Kirschner et al. used was flawed because they conflated the unguided nature of discovery learning with project-based learning and inquiry-based learning, which are much more structured. In making this assertion Hmelo-Silver et al. acknowledged the shortcomings of minimally-guided instruction that can occur in discovery learning. By contrast, they presented a large body of research that suggests that both project-based learning and inquiry-based learning are powerful and effective models for fostering deep understanding among students.

Klahr and Nigam (2004) claimed that direct instruction, understood as a traditional lecture-based approach to learning, is preferable to discovery-based learning in terms of developing students' basic knowledge of a domain. They examined two groups of Grade 6 students who were asked to design experiments to evaluate the variables associated with the speed of a ball travelling down a ramp. Klahr and Nigam were interested in the students' understanding of experimental design and ability to control for "confounding variables" (p. 11). In one class students were given direct instruction on the importance of not confounding variables in experiments while in the other students were simply asked to design the experiment on their own. Darling-Hammond (2008) disputed the findings of this study: "[A]lthough the researchers' conclusions suggested that the direct instruction approach yielded better learning, they failed to acknowledge that this approach included both a great deal of experimentation and some direct instruction" (p. 16).

These studies do not prove that inquiry-based approaches are not effective but they do support the conclusion that inquiry requires certain instructional supports. Roth (2006) (as cited in Darling-Hammond, 2008) found that deeper understanding of engineering principles does not come from asking students to build a bridge or a tower. Barron et al. (1998) cited an unpublished doctoral dissertation by Petrosino (1998) along with a study by Lamon et al. (1996) who found that although student engagement levels increased when students built rockets, they showed no parallel growth in learning about the principles of flight. A later iteration of the same project introduced a new task where students had to determine the variables related to how far a rocket would travel. In this case, Lamon et al. found a dramatic increase in students' conceptual knowledge of the principles of flight.

How teachers can maximize the effectiveness of inquiry-based learning

Discipline-based approaches to inquiry should not be confused with forms of inquiry calling for minimally-guided instruction (Kirschner, Sweller, & Clark, 2006), where students are given little guidance or support in their learning. As Friesen (2012) notes, inquiry involves a spirit of investigation always linked to a particular topic or field of study. Consequently, inquiry moves away from a purely teacher- or student-centered approach to a form of learning that takes its cue from what the field of study requires of those coming to know it. As they pose guiding questions, problems, or tasks that professionals in the field would recognize as important, students and teachers work and learn from experts to develop responses and performances of learning that are meaningful, sophisticated, and powerful.

Scaffolding. To support students in this process Darling-Hammond (2008) and Barron et al. (1998) argued that scaffolding activities, frequent opportunities for formative assessment, as well as powerful guiding questions are vitally important for ensuring inquiry-based projects to lead to deep understanding. Although there is widespread disagreement in the field as to what constitutes a scaffolding activity, in general it involves tools, strategies, and guides to support students in gaining levels of achievement that would not be otherwise possible. Simons and Klein (2006) argued that an effective scaffold involves bracketing out elements of a task initially beyond the learner's capability in a way that allows the learner to concentrate upon and complete only those elements that are within their range of competence. Similarly, Pea (2004) argued that scaffolds involve a range of instructional measures including "constraining efforts, focusing attention on relevant features to increase the likelihood of the learner's effective action, and modeling advanced solutions or approaches" (p. 446). Research suggests that scaffolding activities positively impact problem solving (Cho & Jonassen, 2002), reflection (Davis & Linn, 2000), research assistance (Brinkerhoff & Glazewski, 2004), concept integration (Davis & Linn, 2000), and knowledge acquisition (Roehler & Cantlon, 1997).

Formative assessment. Along with scaffolding, a large body of research concludes that the learning gains engendered by formative assessment were amongst the largest ever reported among any educational interventions (Bransford, Brown, & Cocking, 2000; Darling-Hammond, 2008; Hattie, 2009; Heritage, 2010). This same body of research found that these learning gains are most dramatic with low-achieving students. Formative assessment must be embedded in the cycle of learning so that students receive ongoing descriptive feedback to improve the quality of their work and understanding. Heritage's (2010) review of the literature asserted that feedback designed to improve learning is most effective "when it is focused on the task and provides the student with suggestions, hints, or cues, rather than offered in the form of praise or comments about performance" (p. 5). Students should be provided opportunities for self-assessment based on clear assessment criteria. Teachers can then use the knowledge gained from this process to adjust their teaching to foster the desired competencies.

Powerful, critical, and essential questions. Barron et al. (1998) noted that well-designed inquiry projects should be organized around powerful driving questions that make clear connections between activities "and the underlying conceptual knowledge that one might hope to foster" (p. 274). Guiding questions help focus the inquiry around enabling constraints. A powerful inquiry question should be significant to the discipline and connect students to the world beyond the school while also honouring the outcomes within the program of study.

Teachers have a number of sources of support in designing inquiry projects. Scott and Abbott (2012) outlined a growing body of literature that promotes purposeful inquiry strategies and frameworks that enrich content understanding and promote the apprehension of disciplinary means and processes (Case 2005; den Heyer 2009; Wiggins & McTighe, 2005). Key to these approaches is a shift away from predominantly information-transmission pedagogies to inquiry oriented around critical questions (Case, 2005) and essential questions (Wiggins & McTighe, 2005).

These inquiry strategies all seek to foster subject-matter understanding and impart disciplinary means and processes. However, they differ in their approach and pedagogical focus. Critical questions allow students to structure their inquiry to demonstrate their understanding of ideas, concepts, and content in the curriculum. For Case and Wright (1997), an inquiry question becomes a critical question if it requires students to make a reasoned judgment among options, use criteria to make that judgment, and connect to outcomes in the core of the curriculum. Examples of critical questions aligned to the Alberta Grade 8 social studies program of study include:

- What is the best location for a successful trading city in Renaissance Europe?
- Rank selected Italian city-states in order of their influence in shaping a Renaissance worldview (Alberta Education, 2012).

Wiggins and McTighe (2005) promoted subject-matter understanding through essential questions that guide units around big ideas that emerge from the content. A question is an essential question if it lies "at the heart of a subject or curriculum (as opposed to being either trivial or leading), and [promotes] inquiry and uncoverage of a subject" (p. 342). Examples of essential questions include:

- To what extent do we need checks and balances on government power?
- What are the common factors in the rise and fall of powerful nations?
- Is the scientific method more like a tollway without any exits or an

interstate highway with many exits?

- How is thinking algebraically different from thinking arithmetically?

School jurisdictions in Alberta have invested significant time, money, and professional development support for teachers to integrate these inquiry models into their practice. For example, the critical thinking framework developed by Case (2005) forms the central organizing framework of the online support resources for curriculum and instruction for the social studies program. Similarly, school districts throughout Alberta continue to provide ongoing professional development opportunities to aid teachers wishing to adopt Wiggins and McTighe's (2005) *Understanding by Design* and essential question framework into their teaching.

Throughline questioning. A final approach to inquiry that has yet to gain traction in Alberta is a throughline questioning method refined by den Heyer (2009) at the University of Alberta. Throughline questions are the "questions the content of our courses should help students address" (p. 31). This approach is rooted in a pedagogic strategy developed by Harvard Project Zero (Active Learning Practice for Schools Project Zero, 2001) and is similar to Wiggins and McTighe's (2005) essential questions. Den Heyer's (2005, 2009) throughline approach uses questions as a key pedagogic organizer, but departs from the essential questions approach by structuring the inquiry around particular issues of concern in the communities in which students live.

By encouraging students and teachers to respond to questions that call for ethical engagement, den Heyer's (2009) throughline notion seeks to interconnect program goals, objectives, and specific outcomes for lessons, units, and courses by asking relevant and provocative questions about issues of concern that meaningfully connect students with the world in which they live. Further, the throughline approach helps students and teachers better understand how current conditions came to be. They explore the ways in which current sense-making practices constrain individual and collective agency to imagine and shape the future. Examples of throughline questions relevant to inquiry-based learning in Alberta generated by Abbott (Scott & Abbott 2012) include:

- In what ways do current conceptions of teaching and learning separate the classroom from the world?
- How can our teaching help students better understand the world they live in and better appreciate their capacities for being agents of change?

Conclusion

A diverse and wide body of research suggests that inquiry-based approaches to learning positively impact students' ability to understand core concepts and procedures. Inquiry also creates a more engaging learning environment. As outlined by the Galileo Educational Network (2008) rubric to guide inquiry and supported by a large body of research, a constellation of processes need to be in place to maximize the impact of inquiry-based education. These elements include scaffolding activities, formative feedback loops, and the adoption of powerful questioning strategies to guide the learning process.

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