Implementing inquiry-based learning

"The meaning of 'knowing' has shifted from being able to remember and repeat information to being able to find and use it." (National Research Council, 2007)

Popular discourse on education as well as recent findings in the learning sciences tell a similar story. The model of education typical of 20th century classrooms was effective for that era of human history, but the 'knowledge society' we live in requires new thinking and approaches to teaching and learning. This new approach means that "former conceptions of knowledge, minds and learning no longer serve a world where *what* we know is less important that *what we are able to do with* knowledge in different contexts." (Friesen, 2009)

Inquiry-based learning is an approach to teaching and learning that aims to increase intellectual engagement and foster deep understanding in students through a hands-on, minds-on approach towards the curriculum. Inquiry-based learning honours the complex, interconnected nature of knowledge construction, striving to provide opportunities for students to collaboratively build, test and reflect on their learning. As an entry point, Inquiry-based approach generally involves students:

- tackling real-world questions, issues and controversies
- pursuing curiosities and interests within a meaningful topic
- developing questioning, research and communication skills
- identifying and testing hypotheses within a collaborative setting
- solving problems or creating solutions
- collaborating within and beyond the classroom
- developing deep understanding of content knowledge
- participating in the public creation and improvement of ideas and knowledge
- becoming confident and independent learners

Inquiry-learning is a umbrella term that covers a number of other approaches to teaching and learning. Subsets of inquiry-based learning include:

- *problem-based learning:* learning that starts with an ill-structured problem or case-study
- *project-based learning*: students create a project or presentation as a demonstration of their understanding
- *design-based learning*: learning through the working design of a solution to a complex problem

As contrasted with more traditional forms of teaching and learning, inquiry-based practices emphasize the *process of learning* and nurtures *deep understanding* in students in addition to the intended acquisition of content knowledge and skills. Inquiry-based learning draws upon a constructivist learning theories, the notion that understanding is built through the active development of conceptual mental frameworks by the learner. This approach is supported and enhanced by a broad research base which has identified three key implications for effective instructional practices:

1. Students come to the classroom with preconceptions about the world. This means teaching practices must draw out and work with students preexisting understandings and make student 'thinking' visible and central to the learning.

2. Competence in an area of study requires factual knowledge organized around conceptual frameworks to facilitate knowledge retrieval and application. Classroom activities should be designed to develop understanding through in-depth study of curriculum topics.

3. Meta-cognition (thinking about thinking) helps students take control of their learning. Opportunities for students to define learning goals and monitor their own understanding need to be embedded into classroom tasks.

If we are to make use of these important findings from the learning sciences, an inquiry-based approach to teaching and learning becomes a highly structured and thoughtfully designed endeavour. As contrasted with 'minimal-guided' inquiry which has been shown to be marginally effective as a teaching technique, (Hattie) classroom tasks that are worthy of students time and attention, relevant, connected to the world and organized around the 'big ideas' of a subject can develop understanding and intellectual interest and engagement with students. For inquiry-based learning to be an effective approach requires significant intellectual investment on the part of teachers to design learning tasks that are connected to the disciplines, to their students' lives, and to the world, while focused toward clear and achievable learning targets.

Playing the "Whole Game"

Another way to consider inquiry based learning is the notion of "playing the whole game," an idea by David Perkins, professor at the Harvard Graduate School of Education. Perkins begins with the belief that teachers have historically approached the complexity of teaching in one of two ways:

Students learn isolated skills and knowledge, starting with the simple building blocks of a particular topic and then building to more complex ideas. While this approach appeals to common sense (think of the efficiency of a automobile assembly line), the problem with this approach is the removal of any context to the learning, making deep understanding of the content less likely. Perkins calls this approach *elementitis*, where learning is structured exclusively around disconnected skills and fragmented pieces of information.

Students learn about a particular topic. This approach is frequently utilized in history and science where students are taught about other people's ideas but rarely if ever given the opportunity to produce and refine their own ideas. Learning is equated with consuming knowledge or information, without developing the critical thinking or creative, knowledge-building skills necessary to transfer knowledge to novel situations.

The solution that Perkins offers to the typical classroom experience is what he calls *learning by wholes*, structuring learning around opportunities to experience or engage in the topic as it would exist outside of school. Perkins uses the metaphor of a baseball game, where the experience of most students involves either learning isolated skills (i.e., only ever throwing a ball) or learning about the game (i.e., studying baseball statistics or the history of baseball) without ever getting out onto the field and participating in an actual game. In a classroom setting, this means providing opportunities for students to experience the 'whole game' of mathematical thinking or scientific problem solving or historical analysis of primary source artifacts.

It is important to note that focusing on the elements of a topic, or learning about a topic are not necessarily bad approaches to teaching and learning. Rather, they are important tools for teachers to use in a classroom environment. However, the issue arises when learning is focused solely on *elementitis* or *aboutitis*, the usual practice in most classrooms. With an inquiry-based, or whole-game approach, authenticity and relevant learning tasks provide the necessary context and engagement into which other teaching practices such as learning the elements or background about a topic can be embedded in a more productive way.

As a framework for designing inquiry and moving our teacher's understanding of inquiry forward, for 8 years the Calgary Science School has been using and revising the Inquiry Rubric developed in partnership with the Galileo Educational Network. In an attempt to make the concept of inquiry-based teaching and learning more concrete, this rubric breaks inquiry down into 8 categories:

1. *Authenticity*
2. *Deep Understanding*
3. *Assessment*
4. *Appropriate Use of Technology*
5. *Student Success*
6. *Connecting with Experts*
7. *Performances of Understanding*
8. *Ethical Citizenship*

The purpose of this document is to provide examples, resources, rubrics and guiding questions for the development of inquiry-based teaching leading to student engagement and deep understanding.

Needs a focus on imagination, creation, creativity, production, participation,

Examining the Inquiry Rubric

Authenticity:

	Beginning	Developing	Accomplished
Authenticity	The inquiry study originates with and only meets programs of study expectations.	The inquiry study originates with the program of studies but provides some opportunities to extend beyond curriculum expectations.	The inquiry study originates with a generative topic, problem, or exploration that engages the students emotionally and intellectually while rooted in the program of studies.
	The task/s would not likely be tackled outside a school setting.	Other adults outside the school are intrigued by the task/s and can find ways to contribute to it.	An adult at work or in the community might actually tackle the question, problem or exploration posed by the task/s. It is deeply connected to life and work beyond the school.
	Students are required to follow clearly defined approaches to teacher- generated criteria.	Students are offered a menu of approaches in order to meet specific learning outcomes.	The study is structured around methods of inquiry and ways of thinking that are central to the disciplines that underpin the topic, problem or exploration.

Authenticity includes tasks, activity or work that is associated with a result or outcome that has clear meaning and value to the student. (Schlechty, 3)

The starting point of inquiry-based learning is an authentic learning task where students are engaged in work that is worthy of their time and attention, is personally relevant to them and deeply connected to the world in which they live. The development of authentic learning tasks for students means situating learning in rich *places* (think: topics, *topos*, topographies) where curriculum outcomes are brought to life with real world connections and stories. Harvard's *Teaching For Understanding* (TfU) project uses the term *generative topics* as the starting point. Effective topics are generative in the sense that "they often have a bottomless quality which leads to deeper questions" and consist of four elements:

> *Central to a domain or discipline*. This involves an approach to curriculum that engages students in developing understanding around the questions, controversies, and modes of inquiry central to a topic.
>
> *Accessible and interesting to students.* The selection of a generative topic considers student experience, interests, learning modes or intelligences, cultural background, and resources.
>
> *Interest to the teacher.* For teachers to introduce students to the elaborate interconnected webs of information central to a discipline requires the teachers to have an understanding of the subject matter and ways of inquiry within that topic. Teachers interest passion and curiosity about a topic will increase the teachers investment and provide a model of engagement for students.
>
> *Connectable.* Powerful generative topics are connectable in two ways: (1) to students previous understanding about the subject and (2) to other ideas and concepts within and across disciplines.

As we begin to structure inquiry-based teaching and learning, authenticity can appear in one of two ways:

1. Authentic to the real world. This means creating learning opportunities that are linked to relevant current events or real-world connections designed to increase student engagement and interest in the topic. In this way a particular classroom task is designed around work or question or problem or an

exploration that actually exists in the world. As an example, grade 6 students engaged in a mathematical inquiry built around the question," are there enough trees in Canada's boreal forest to be considered the lungs of the earth?" This example used a real world context as the hook or entry point for student engagement into the mathematical study.

An example of a framework that aligns with real-world authenticity is Apple's challenge-based learning. Challenge-based learning centers around students collaboratively engaging in a real world problem or issue leading to the design of a solution or action that they can then implement in their local community. Information on Challenge Based Learning can be found here.

Examples of real-world authenticity:

On his widely read math blog, Dan Meyer shares a number of 'real-world' mathematical problems rooted in the use of multimedia and pop culture to engage students in mathematical thinking.

As the task for this grade four humanities project, students planned and designed a sustainable community located in a particular geographic region with Alberta. Students researched the resources, geographical features, and environmental challenges faced by a particular region and designed small community based on basic principles of sustainable development,.

As part of a grade 9 study of government, grade 9 humanities students hosted a forum for candidates in a local municipal election. Students hosted the real world forum, taking in questions for candidates from other schools, as well as broadcasting the event publicly across the Internet.

2. Authentic to the discipline at hand. A second way to consider authenticity is to create learning tasks that align with the ways of thinking or modes of inquiry central to the topic. As Larry Rosenstock, CEO from High Tech High Charter Schools explains, "I want kids behaving like an actress, scientist, documentary filmmaker, like a journalist. Not just studying it but being like it." Seen this way, the purpose of authenticity is to create opportunities for students to take on ways of thinking and adopt standards of evidence that are central to a particular discipline. For example, a rich inquiry-based approach to mathematics would allow students to identify patterns, develop mathematical hypotheses, test mathematical conjectures, and create proofs while working with problems or sets of data that are not necessarily tied to real world contexts.

Examples of discipline based authenticity:
The Galileo Educational Network website provides a significant number of 'worthy and robust' math problems and puzzles for both elementary and secondary students. These problems are designed to open up foundational concepts in mathematics and create possibilities for students problem solving and mathematical thinking. This video is an example of a student podcast solving one of the math problems.

During a grade 5 study of wetlands students took on the ways of data collection utilized by scientists in the field. After becoming experts in particular elements of water quality, students were allowed to develop hypotheses about various water samples taken from a nearby wetland and then use water probes to test and compare the five water samples collected.

In order to demonstrate their understanding of simple machines, grade 8 students used a virtual physics simulator create and test digital 'Rube Goldberg' machines. The software allowed students limitless freedom to exercise their creativity and imagination in integrating the different

elements of the curriculum.

Guiding Questions for Authenticity:

Where does this topic live in the world?
What are some of the current questions that experts are wrestling with in this area?
What will students find relevant about this topic?
Why would someone care about this topic?
What are the ways that experts in this field do their work?
What counts as evidence or proof within this topic?
How might students access or create authentic sources of data on this topic?
Where will students have the opportunity to solve problems, create solutions, test ideas, recognize patterns, innovate, build or design?

Technology and Authenticity:

What technologies are used by people in this discipline?
Are there particular tools, technologies, types of data, sources of information, etc that experts in this areas utilize?
What tools might allow students to collect data in ways similar to experts?

Deep Understanding

	Beginning	Developing	Accomplished
Deep Understanding	The inquiry study provides for the acquisition of known factual information.	The inquiry study facilitates the acquisition and application of a broader understanding.	The inquiry study leads students to build deep knowledge structured around clearly stated 'big ideas' or controversies central to the topic.
	The inquiry study encourages an uncritical approach to memorizing and repeating facts or applying pre-determined algorithms. Students may lack understanding of what they are memorizing and why.	With support, students can be critical or skeptical about what they thinking, know, hear, read and take to be disciplinary content.	The inquiry study embeds healthy critical and skeptical thinking habits of mind including: ☐ evidence (how do we know what we know?) ☐ viewpoint (who is speaking?) ☐ pattern and connection (what causes what?) ☐ supposition (how might things have been different?) ☐ why it matters (who cares?)
	Overarching learning goals are absent or integrated once during the study.	Students are given multiple opportunities to develop improved understanding of the overarching learning goals for the task or study.	Students are given multiple and varied opportunities to develop improved understanding of learning goals that are connected to larger learning goals for the term or year.

"Effective teaching structures material to be learned so as to help students fit it into a conceptual map, integrating carefully designed direct teaching with hands-on inquiries that actively engage students." (Linda Darling-Hammond)

"Expert knowledge is not simply a list of facts/formulas, rather it is organized around core concepts or 'big ideas'". (National Research Council)

Structuring rich, inquiry-based teaching and learning around authentic tasks, questions and problems provides great opportunity for student interest and intellectual engagement. To make this engagement productive, it is crucial to consider the connection between the topic or task at hand and the intended learning goals of the study. As Linda Darling-Hammond reminds us, "authenticity affords opportunities for learning, but does not guarantee it." While designing learning around real world problems, issues, or tasks can lead to student interest, it does not necessarily translate into productive understanding and knowledge transfer. The challenge for educators is to make use of the engagement that is made possible through authentic, hands-on learning in ways that develop deep understanding of the subject at hand.

Conceptual Frameworks. One of the important considerations for teachers when planning for inquiry-based learning is to consider how the knowledge and skills central to a particular task fit into a conceptual framework about a topic of study. Building such a conceptual framework requires laying out the 'big ideas' of a topic, and then considering the organization and structure of knowledge and skills around those ideas. Research shows that a knowledge base which is flexible and usable requires organization around key guiding principles within a topic. One of the best ways for teachers to begin the planning of a inquiry task is to work through a concept mapping exercise themselves. Working ideally in collaboration, teachers would map out the different concepts and skills that students as a way to consider the framework of understanding they hope to develop with students. A concept map will help to guide and narrow the study, as one of the potential pitfalls of an inquiry approach is that a study becomes large and overwhelming. As a guiding question for the development of a conceptual framework, a teacher might ask:

What is the one concept students need to know in order to really understand a particular topic?

Learning Goals. With that in mind, it's important to consider that educational research consistently points to the crucial importance of clear and manageable learning goals for students. One of teacher practices

that has the greatest impact on student learning and achievement is to provide students with a explicit understanding of what they are to be learning and how to move forward. This is applicable across all teaching approaches, including inquiry-based learning. (Hattie)

As teachers are in the planning stage of a learning task, they should consider what learning goals will be at the heart of the study, and how these goals might be explicitly stated and publicly visible. Developing learning goals should also consider how 'phantom skills' (skills that are often alluded to but not explicitly taught) will be addressed through the task. Doing the work of uncovering the deep learning goals for a particular task requires significant intellectual work by teachers, work that is most effectively done in collaborative discussions during the planning of a learning task or study. As well, to be effective, students should have ready access to the learning goals and the different elements of a task or project should be closely tied to improving student understanding of those goals. To assist with the development of learning goals teachers might ask themselves:

What do you want your students to get better at through this task?

Addressing Preconceptions and Misconceptions. One of the key ways to foster deep understanding is to unearth and address students' pre-conceived ideas about a particular topic. In a comprehensive research analysis on learning, the National Research Council repeatedly mentions that if students' initial understanding is not engaged, they may fail to grasp concepts or may revert to preconceptions after the classroom task is completed. For example, in history education, students often rely on stereotypes or oversimplifications, viewing history as a struggle between simple concepts of good and bad. As teachers are designing work for deep understanding, it is important to consider the common misconceptions of students with the topic at hand, and plan learning that will allow students to draw out and work with those preconceptions.

Throughline Questions. One approach to the creation of learning goals is to develop throughline questions which run through an entire unit, or course or year study. Throughline questions are thoughtfully designed overarching questions that help frame and guide the task. When designing throughline questions, teachers can begin by asking themselves: what do you want students to understand by the end of your class? As an example, in Social Studies, teachers might consider developing throughline questions that connect to three S's, asking provocative and relevant questions that encourage connection between *Self*, the *Subject* matter and the *Society* in which they live. You can get more information on throughline questions in social studies here.

Deliberate Practice. There is a great deal of research highlighting the importance of repeated exposure to content in order to develop real learning in students. For example Hattie claimed that three to four exposures to an idea is necessary for students to learn a concept. This does not have to equate to 'drill and practice' worksheets that involve repetitive questions to answer. Rather, within an inquiry-based approach deliberate practice "can also involve specific skills and complex performances." (Hattie) Once learning goals have been established, the challenge is to design the learning task to provide students with multiple and varied ways to practice and improve on the key learning goals. As part of his 'whole game' framework, David Perkins calls this 'working on the hard parts', and suggests that teachers should design both learning exercises and *etudes* that address common misconceptions or troublesome knowledge in a particular area.

Questions for Deep Understanding:

Through this study I want my students to understand that.....

Through this study I want my students to appreciate …..

What is worth knowing about this topic?
What do you want students to get better at through this task?
How will the goals of this task connect to broader goals for the term or year?
What learning activities will you plan that are directed toward building deep understanding of the key learning outcomes?
What habits of critical thinking will your students practice during the task?
What common misconceptions or persistent trouble spots do students have about this topic?
What will make this topic/question hard for learners (specific to the topic)?
Why are these spots difficult? How will you address them?

Assessment

	Beginning	Developing	Accomplished
Assessment	All assessment is done at the end of the study.	Ongoing assessment is conducted on an informal basis and evaluation is conducted at logical midpoints in the process. Assessment is used in a limited way in guiding teacher's instructional planning.	Ongoing assessment is woven into the design of the inquiry study providing timely, descriptive feedback and utilizes a range of methods, including peer and self- evaluation. Assessment guides student learning and teacher's instructional planning.
	The study provides no opportunities for students to reflect on their learning. There are few criteria to guide the students' learning. There is little or no evidence of goal setting.	The study provides opportunities for students to reflect on their learning using clear criteria established by the teacher. Teachers help students set learning goals, establish next steps and develop effective learning strategies.	The study provides opportunities for students to reflect on their learning using clear criteria that they have helped to set. The students use these reflections to set learning goals, establish next steps and develop effective learning strategies.
	Assessment is mainly focused on surface knowledge or the presentation of the knowledge.	Assessment is focused on assessing student understanding of concept concepts.	Assessment is used to improve and refine student understanding of the foundational concepts or ways of thinking central to the topic.

Research has repeatedly shown that the assessment practices used by teachers have a significant impact on student achievement and engagement, including substantial learning gains resulting from providing students with frequent feedback about their learning. Strong assessment practices must be woven into the continual practices of an effective learning environment, and this is especially true in an inquiry-based approach - as it is the assessment that both defines the tasks and evaluates what should be learned.

As we have already seen, having clear learning goals and conceptual frameworks are important elements of designing an inquiry-based task. Considering assessment, the challenge is to create opportunities for students to receive targeted feedback on those learning goals that is directed at students getting better at the intended learning and that provides explicit suggestions for improvement. Linda Darling Hammond suggests three critical elements for assessing meaningful learning:

- design intellectually ambitious performance assessments that define the tasks students will undertake and apply the concepts and skills in authentic and disciplined ways
- guide student efforts through evaluative tools such as clear task guidelines, rubrics and exemplars of strong work
- frequently use formative assessments to improve student learning and guide teachers' instructional practices throughout the process.

According to Darling-Hammond, "time should be built into projects or problems for students to reflect deeply on the work they are doing and how it relates to larger concepts specified in the learning goal, including deep questioning about process and understanding." While building formative feedback structures into a inquiry task does involve additional time, research has shown time for self and peer assessment results in larger gains, even if whole class time is taken away from discussing content.

There are a number of different forms of assessment for inquiry-based teaching and learning. Exemplary inquiry-based teaching uses a combination of formative assessment practices in order to gain a complete picture of student understanding. These include: (Darling-Hammond)

- rubrics to provide specified levels of progress and excellence
- solution reviews where students show work in progress to peers, teachers and other community members

- whole-class discussion can be used to vet and refine ideas and explanations
- an additional short-term performance task to assess the application of understanding to a new situation or context
- written (or digital) journals used to keep an ongoing record of experiences and reflections and struggles
- multi-media forms of expression
- portfolios collect work over time to demonstrate progress and improvement
- weekly written responses to a simple set of questions throughout a process
- self-assessments where student evaluate their own work according to criteria using a rubric or focused questions

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Guiding Questions for Assessment:

Are the learning goals for the task clear and visible?
How will the design of the study intervene to increase student understanding?
Where are the places you will check for student understanding throughout the task?
What will you collect and/or observe as evidence of student understanding?
Does this count as evidence of deep understanding of the key learning outcomes?
Are their clear and direct connections between the key learning goals and the assessment criteria?
How might you involve parents in the assessment practices?

Technology and Assessment:

How might technologies be used to make the learning goals clear and visible to students?
What technologies might be used to increase formative assessment?
What tools would allow for increased peer-feedback?
What tools would allow student work to be shared with experts or parents to increase feedback?

Appropriate Use of Technology

	Beginning	Developing	Accomplished
Appropriate Use of Technology	Technology is used for the sake of using technology, not because it will enhance the inquiry. The task is built around the technology used.	Technology has relevance to the inquiry. Students have choice into which technology is utilized.	Technology is used in a purposeful manner rooted in disciplined ways of thinking and doing. The nature of the work determines the appropriate technology being used.
	The major focus is on developing skill and fluency with software applications.	The study uses technology to conduct research, share information, make decisions, solve problems, create meaning, test theories and communicate, mainly inside the classroom.	The study requires students to conduct research, share information, make decisions, solve problems, create meaning, test theories and communicate with various audiences inside and outside the classroom.
	The ongoing inquiry study is not available online.	Students have ongoing, online access to the study as it develops.	Students, parents and the larger community have ongoing, online access to the study as it develops.

The role that digital technologies can play in supporting inquiry-based learning is complex due to the wide array of possible hardware, software, peripherals and web tools available to teachers. Technology allows both teachers and students access to current information, powerful collaboration tools, the ability to model and simulate ideas, and the ability to communicate learning in a wide variety of ways to a global audience. When thoughtfully designed into an inquiry-based study, technology can help immerse students in engaging and rigorous knowledge-building environments.

That being said, what is most critical is that teachers should always begin with a clear understanding of the deep learning outcomes and before considering what technologies (if any) might support and amplify the student learning. For example, if a teacher is working with students on determining patterns from large sets of numbers, excel may be the appropriate tool to use so that students can sort and resort data, manipulate sets individually or as wholes, and to test their conjectures regarding perceived patterns in ways that a calculator may not.

Physical Barriers

Ineffective Technology Integration	Effective Technology Integration
Learning limited to classroom space; learning is limited by lack of access to physical equipment and supplies	Collaboration, sharing of ideas, building knowledge is not limited to the classroom – students continue to work and learn at home, on field studies; technology permits access to learning resources in lieu of specific equipment or supplies (e.g. the use of simulations versus the purchase of expensive scientific equipment with limited function)

Temporal Barriers

Ineffective Technology Integration	Effective Technology Integration

Learning happens only during class time; homework replicates work done in class; no opportunity for collaborative knowledge building	Technology permits anytime, anywhere learning; other invested parties have ongoing access to the knowledge-building endeavour (parents, experts, other students, teachers, administrators, etc.)

Possible applications for digital technologies:

Locate current information
Technology allows both teachers and students immediate access to current information, statistics and data on a given topic. As this is one of the most regular activities students use technology for, both in and out of school, developing critical information literacy skills is of the utmost importance. Technology also allows students to access multiple viewpoints and perspectives on a issue, something not always covered by textbooks or pre-made resources. Information can be accessed a range of ways including: web searches; online databases (Gapminder), virtual museums and galleries (Google Art Project); GIS tools (Databasin, GPS devies, geocaching); mapping tools (Google Earth); survey creators (Google Forms, Survey Monkey)

Tinker with ideas
With technology, students can test ideas, hypotheses and solutions. This can be done with a number of tools include calculators and spreadsheets (for testing mathematical ideas and patterns, Excel, Numbers, Google Docs); peripherals (digital cameras, science probes); and simulation software (Geometer's Sketchpad, Geogebra, Algodoo, Google SketchUp, Netlogo)

Organize and synthesize concepts
Students in an inquiry-based study will often be tasked with making sense of complex and interconnected ideas. Technology can assist students organize and synthesize their understanding through a number of tools including: mindmapping software (Inspiration, cMap, Mindmeister); drawing tools (Paint, SMARTboards); infographics (informationisbeautiful.net); multimedia digital posters (Glogster)

Communicate understanding
One of the most transformation attributes of digital technology is how it allows students to represent their understanding in a number of different ways. Through the use of emerging technologies student have access to relative simple yet incredibly powerful multi-media authoring tools for text, image, audio and video production. Tools for powerful communication include text (Word, Pages, Google Docs, InDesign); image manipulation and remixing (Photoshop, Gimp, Aviary); audio production (Garageband, Audacity, Aviary) Graphic Design (Illustrator, Fireworks); Screen Capture (Gawker, Quicktime, SmartRecorder) video production (iMovie, Movie Maker, Animoto; Animations (Flash, cameras); presentation tools (Powerpoint, Keynote, Prezi, Pecha Kucha).

Collaborate and share with others
Technology allows learners the opportunity to produce work, receive feedback and communicate with online collaborators ranging from students in their class or school to experts and others around the world, including sharing the progress and process of the study with parents. Technology can also create audiences for student work that extend beyond the walls of the classroom. There is a wide range of collaboration tools including: collaborative cloud tools (Google Docs, iCloud, Dropbox, Voicethread); knowledge building communities (Knowledge Forum); video conferencing (Skype, Facetime), website development (iWeb, Posterous, Dreamweaver, Weebly, Google Sites); blogs (Edublogs, Wordpress, Apple); wikis (Wikispaces, PBwiki); online broadcasting (Ustream, Livestream);

Programming

One of the lesser utilized yet incredibly rich applications of technology is programming. Programming requires that students visualize complex ideas, solve problems, consider elements of design and develop logical thinking skills. A number of programming tools exist for educational contexts including: Logo, Scratch, Squeak and Makerbots.

Participate in learning communities

Technology not only allows learners access to information but also to networks of people. Social media sites such as Facebook and Twitter allow teachers and students to develop their own learning networks. Other online learning communities include Classroom 2.0, the Global Education Collective, the Future of Education and the Flat Classroom Project.

Connecting with Experts

	Beginning	Developing	Accomplished
Connecting with Experts	Students hear or read about relevant information only from the teacher, or resources provided by the teacher.	The task involves speakers or interviews with experts outside the classroom. (e.g. one-shot visits, presentations by experts)	The task provides opportunities for students to collaborate with relevant experts in a variety of situations. Students use experts (or expert work) as mentors (or examples) for their own work.
	The task is designed by the teacher(s) in isolation (without expert input).	The task is designed by the teacher in consultation with an expert regarding the topic of inquiry (which may include reading a relevant book or accessing current data on the topic).	The task is designed and implemented by the teacher in collaboration with an expert who provides ongoing feedback to teachers and students. (Feedback may occur in the form of rubric criteria based on expert work).
	The study requires students to communicate what they are learning with a presentation to teacher audience (i.e. handing in as an assignment).	The study requires students to communicate what they are learning in a presentation to the classroom audience.	The study requires students to communicate what they are learning with a variety of audiences through presentation or exhibition.

Performances of Learning

	Beginning	Developing	Accomplished
Performances of Learning	Students work in isolation with few opportunities to discuss their work with others.	The study provides opportunities for students to share ideas with others. Discussion is often related to the task (i.e digitalstory) rather than the foundational concepts.	The study creates a knowledge-building environment where students support, challenge, and improve each other's ideas with the goal of deepening the collective understanding of the foundational concepts.
	The task dictates the form of expression that the students use. Students have little opportunity to reflect on how the selected medium enhances their message or understanding.	Students have limited opportunities to choose forms of expression and to reflect on what media would best communicate their message or understanding.	The task provides opportunities for students to choose forms of expression appropriate to the task and to reflect on their choices.
	The task requires students to repeat and reproduce surface knowledge and skills.	The task invites students to demonstrate understanding of foundational knowledge and skills through challenging performance tasks	The task deepens foundational knowledge and skills by inviting students to apply understanding in novel situations, problems or cases that increase in complexity.

Inquiry and Knowledge Building

As we have addressed above, one of the hallmarks of a strong inquiry-based study is that it places great emphasis on the foundational concepts and ideas of a topic. In addition to emphasizing deep understanding of concepts, inquiry-based approaches provide opportunities for students to engage in, wrestle with and ultimately improve their own ideas and the ideas of their peers. Framing inquiry-based learning this ways begins to move a classroom into a knowledge-building space, where ideas are treated as objects and made public to be refined, revised and connected to other ideas by the learning community. According to Scardamalia and Breiter, (2002) “knowledge building results in the creation or modification of public knowledge—knowledge that lives ‘in the world’ and is available to be worked on and used by other people.”

The hallmarks of rich knowledge-building classrooms include elements such as:

- *Real ideas and authentic problems.* In the classroom as a Knowledge building community, learners are concerned with understanding, based on their real problems in the real world.
- *Improvable ideas.* Students' ideas are regarded as improvable objects.
- *Idea diversity.* In the classroom, the diversity of ideas raised by students is necessary.
- *Rise above.* Through a sustained improvement of ideas and understanding, students create higher level concepts.
- *Democratizing knowledge.* All individuals are invited to contribute to the knowledge advancement in the classroom.
- *Knowledge building discourse.* Students are engaged in discourse to share with each other, and to improve the knowledge advancement in the classroom.

Framed this way, a knowledge building classroom strives to move learning along a spectrum from shallow constructivism to deep constructivism:

Shallow Constructivism

students are engaged in activities and tasks that are not directly linked to the explicit improving of foundational ideas. Students can describe what they are doing (the activity) but show little understanding of the underlying concepts or ideas.

Deep Constructivism

making a collective inquiry into a specific topic, and coming to a deeper understanding through interactive questioning, dialogue, and continuing improvement of ideas.
Inquiry and Performances of Understanding

Another hallmark of inquiry-based learning is that students demonstrate and deepen their understanding through approachable yet challenging performances of understanding. Underpinning this belief is the notion that student understanding comes about through extending, synthesizing, justifying, explaining, applying or utilizing what they know in new ways and situations. As David Perkins writes, “to gauge a persons understanding at a given time, ask the person to do something that puts the understanding to work - explaining, solviing a problem, building an argument, constructing a product. What learners do in response not only shows their level of understanding but very likely advances it.”

We see this clearly in learning that happens outside of school and in most fine arts classes, where student learning is directly tied to performances of understanding. Think of students in music or graphic design classes where there is most likely a clear and direct link between the intended learning goals and the authentic performances or public demonstrations of that learning. Performances in these areas are a key part of the learning process, not something that is done after the learning is over. As well, these performances are often public in nature and open to critique for the purpose of improvement.

In inquiry-based classrooms, teachers strive to create performances of understanding across all subject areas. Such performances of understanding could be open-ended ‘messing about’ used at the beginning of a study, or small tasks throughout a larger inquiry (formative assessment) or larger scale culminating performances at the end of a project or study.

According to the Harvard Graduate School of Education, effective performances of understanding have the following qualities:

Relate directly to learning goals
Develop and apply understanding through practice
Engage multiple learning styles and forms of expression
Promote reflective engagement in challenging, approachable tasks
Publicly demonstrate understanding

“Instead of rehearsing or recreating knowledge produced by others, performances of understanding engage students in creating their own understandings.” (73)

“understanding is the ability to think and act flexibly with what one knows”

Student Success

	Beginning	Developing	Accomplished
Student Success	The teacher tells students how to organize and manage their time and materials.	The teacher sets project management goals and allows students to self-monitor within that framework.	The task provides opportunities for students to set their own project management goals.
	The task provides little opportunity for teamwork.	The task provides few opportunities for students to determine roles, facilitate discussions, and resolve conflict.	The task provides opportunities for students to determine roles, facilitate discussions, and resolve conflict.

Ethical Citizenship

	Beginning	Developing	Accomplished
Ethical Citizenship	The task only requires students to adhere to clear rules of behavior that govern the way they interact with and treat one another	The task requires students to help determine standards of behavior to govern the way they interact with and treat one another.	The task provides opportunities for students to develop a deeper understanding of themselves, each other, and they way they interact with and treat one another.
	The task requires students to learn about people around the world and/or the natural world.	The task requires students to consider the impact of their understandings and actions on people in their local and global communities and/or the natural world.	The task provides opportunities for students to interact with and care about the impact of their understanding and actions on people in their local and global communities and/or the natural world. Students are also offered the opportunities to change the own behaviors or impact the behaviors of others.
	The task does not require students to consider habits of digital citizenship.	The task provides limited opportunity for students to consider habits of digital citizenship.	Digital citizenship habits are embedded into the task, including the critical and ethical use of images, text, information, sounds and video as well as encouraging students to consider their own digital footprint.

Strong Work in Mathematics

Inquiry

- Reasoning:
    - Develops mathematical conjectures;
    - Tests examples and counter-examples;
    - Tries to explain *why* observed patterns are true and under what conditions they hold

- Problem Solving:
    - Develops a plan, modifies it as needed, simplifies if possible;
    - Identifies sub-problems and relates them back to the main problem;
    - Considers strengths and weaknesses of various strategies and how strategies are related

- Modeling / Mathematizing:
    - Describes situations mathematically (i.e. “mathematizes” rather than applies a teacher-given tool);
    - Considers strengths / weaknesses of model (e.g. “Is weight ÷ track area an appropriate way to describe ‘sinkability’?”);
    - Generalizes models of individual situations to models that work in a variety of situations

Knowledge

- Procedural Competence (strategies): Uses established procedures appropriately and accurately; considers reasonableness of answers
- Conceptual Understanding (big ideas): Understands connections between various mathematical topics (e.g. connections between multiplication and division; linear relations and proportionality)

***Mathematical* Work Habits** (Productive Disposition)

- Considers alternative ideas
- Tolerates ambiguity
- Willing to try own ideas before seeking help

Establishing and Supporting *Mathematical* Community

- Contributes to class discussion re: the development of ideas and solving of problems
- Connects contributions to what others have said or done (This goes with....; I agree with....; I disagree with...; I think I see what ... means by ...; Another way of saying that might be….)
- Respects other people and ideas; i.e. works hard to understand other views (asks questions, paraphrases, etc.)

Communication

- Shows work (uses writing, charts, diagrams, models, etc.)
- Organizes complex ideas
- Uses appropriate mathematical terminology and notation

Misconceptions:

1. inquiry is about asking questions
2. inquiry is student-centred learning
3. in an inquiry-classroom, the teacher is the guide on the side as opposed to the sage on the stage
4. in an inquiry classroom, right answers don’t matter
5. inquiry is all about process, content doesn’t matter
6. inquiry is led completely by student interest and questions
7. inquiry is pure constructivism

Resources Used:

How People Learn
Teaching for Understanding
Friesen, S. (2009). *What did you do in school today? Teaching Effectiveness: A Framework and Rubric.* Toronto: Canadian Education Association.
Making Learning Whole, David Perkins
Powerful Learning, Linda Darling Hammond
The Disciplined Mind, Howard Gardner