TEACHER PREPAREDNESS IN INQUIRY-BASED LEARNING

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By

Bryan Johnson

in collaboration with Jorge Cordova

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The graduate project of Bryan Johnson is approved:

______________________________ ____________________
Gregory Knotts, Ph. D. Date

______________________________ ____________________
Vishna Herrity, Ph. D. Date

______________________________ ____________________
Susan Belgrad, Ed. D., Chair Date

California State University, Northridge
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ABSTRACT

TEACHER PREPAREDNESS IN INQUIRY

By

Bryan Johnson

Master of Arts in Education, Elementary Education

This project/resource is intended to provide insight and strategies for pre-service teachers, beginning teachers, and teachers in grades three through five who are interested in implementing Science, Technology, Engineering, and Mathematics (STEM) in their classrooms. Teachers who are unfamiliar or uncomfortable with the Next Generation Science Standards (NGSS) and the Nature of Science (NOS) will find helpful resources and lessons to begin the process of implementing inquiry-based learning (IBL) into their repertoire of lessons. Through the use of planning tools, pre-made lessons, and self-assessment rubrics, teachers will find resources to begin building a strong foundational understanding of inquiry-based learning and student collaboration. This resource begins by explaining what inquiry-based learning consists of and scaffolds to the process of developing innovative lessons tailored to the specific needs and interests of the teacher’s class.

Keywords: inquiry-based learning, Science, Technology, Engineering, and Mathematics (STEM), professional development, Nature of Science (NOS)
CHAPTER 1: INTRODUCTION

The purpose of this Project is to demonstrate the potential outcomes when inquiry-based learning (IBL) structures are used by teachers in the elementary school classroom to meet the Next Generation Science Standards (NGSS). This Project will provide a helpful guide for upper elementary teachers to understand the background knowledge about inquiry–based teaching needed to effectively implement the designing, leading, and assessing STEM-integrated curricular units of study and instruction that address California’s adoption of the Next Generation Science Standards (NGSS).

The NGSS standards take science education into a new level of learning in which the student is required to develop a greater depth of knowledge—not only in science but in the disciplines of engineering and technology. As educators move closer to the full implementation of the NGSS, they are being urged to begin exploring the new science learning framework and embark on meaningful and collaborative discussions of the ways in which they can prepare to effectively meet the Standards (National Research Council, 2012). Many states, in addition to California, have already adopted the Standards and are working on developing the frameworks that will guide their state-wide implementation.

For decades, K-12 teachers have been encouraged to deliver meaningful and authentic science experiences to their students. During the era of No Child Left Behind, many teachers have elected to forego hands-on science activities and promote memorization of science facts without a conceptual basis. However, with the introduction of NGSS, teachers will also be expected to integrate robust aspects of engineering and computer science into their continuing mathematics and science curricula, instruction, and assessment processes. The challenge to
acquire deeper science content knowledge and pedagogy within a context that requires the integration of the “T” and “E” of STEM is already being addressed by some elementary school educators who have set out to establish curriculum models that deliver technology and engineering principles to students in advance of the middle and high school levels. For example, it is expected that the curricular innovations that have been implemented by these teachers will help to shift the focus of teaching from direct instruction to inquiry and active learning.

The theoretical foundation that underlies each of these methods should be considered when teachers are planning to implement the integration of STEM subjects required by NGSS, as inquiry-based learning. This project advances the structures of IBL, which encourage students to become active learners; where their questions guide or drive lessons; and their prior knowledge from experience engages them in problem solving, communication, and collaboration. These processes are currently identified as the next century skills required in careers and the workplace: communication, collaboration, creativity, and critical thinking (P21, 2014).

The guiding structure of this Project is derived from the work of the National Research Council (NRC), the operational arm of the National Academy of Science. The framers of the NGSS relied upon the findings of the NRC to guide them as they constructed the Standards. This project identifies and develops the suggested design process and methodology for science instruction asserted within the NRC’s findings procedures such as the variations of inquiry and the five essential features of inquiry-based learning. Together, the pedagogical content knowledge, information, and strategies that are advanced and disseminated in this project are expected to assist in the ongoing professional development of teachers as well as the preparation of K-12 educators in anticipation of the implementation of the NGSS. It is also likely that the
resources provided in this project will become available to school-district leaders when considering standards-aligned STEM programs or professional development.

The NGSS are organized into three interconnected dimensions: (1) disciplinary core ideas, (2) scientific and engineering practices, and (3) crosscutting concepts. The disciplinary core ideas can be thought of as the concepts that are essential to all science disciplines. They help connect the student to socio-scientific ideas and concerns that should be important to a child. (NGSS, 2013). The scientific and engineering practices are meant to show children how the processes of scientific and engineering knowledge are constructed (NRC, 2012). Examples of this could include creating graphs, models, or arguments, combining information, conducting information, and evaluating solutions to problems, all of which correlate to the fore mentioned activities of a constructivist learner (NGSS, 2013.) The third component of the standards is crosscutting concepts. These are designed to help the students make connections across all disciplines of science, which include biology, chemistry, physics, etc (NRC, 2012). Considering that most educational institutions commonly present each component as a separate concept such as the scientific method in the California State Standards, the real difficulty for teachers will be to develop lessons that will integrate all three components as prescribed by the NGSS (Bybee, 2014).

It should be noted that no component is more important than the other. In fact, Ostlund (2013) says that this is one of several key conceptual shifts in the Standards. Bybee (2014) provides a description of how the new science standards will change from before and what implications they will have on a teacher’s practice. For instance, the previous standards asked teachers to present individual facts that were related to a single discipline and grade. A life science teacher in fourth grade would teach photosynthesis without having to make any
connection to the chemical process that takes place in the leaf. The NGSS not only expects that connections are made to other science subjects, but that connections to disciplines such as language arts, social studies, and mathematics are made (NGSS, 2013). The nature of science (NOS) will also play a guiding role in how students experience science. Previously, science was treated as a body of knowledge that one would use to solve problems, but now it will be seen as practice or a way of knowing, hence engineering and science practices. The emphasis is now on knowing how a scientist or engineer gains knowledge on something that is not known.

**The Project**

It is logical to argue that a concentrated effort by scholars, researchers, and teacher leaders is now needed to improve elementary teachers’ understanding of effective science teaching methods that encourage higher levels of student thinking and understanding of the nature of science (NOS). This Project presents a needed resource that has been developed to increase teacher awareness of the underlying principles of NGSS and the pedagogical content knowledge (PCK) required at the upper elementary-grade levels to effectively lead students to become successful science learners. The project will be structured to address the following questions: How can IBL teaching and learning processes be adapted to meet the expanded STEM-learning goals of the NGSS? What are the developmentally-appropriate structures and variations of IBL that assist teachers in assuring students’ engagement and success in science curricula? What are some examples of NGSS-Based Inquiry Projects that teachers may adapt and implement in their classrooms? And how will the guide be structured so teachers are encouraged to work collaboratively as they become co-designers of effective IBL instructional units of study?
The Project will also help to provide insight for teachers into the methods in which the cooperative learning structures utilized during inquiry-based learning will more clearly reveal the nature of students’ STEM-discipline knowledge, abilities, and dispositions (KSD). The importance of formative assessments integral to IBL will be addressed as it becomes necessary for educators to provide both measures of evaluation regarding STEM achievement, and continuous feedback offered to students that is help them show improvement in their habits of mind and social skills (KSD). The use of authentic and formative assessment helps educators to assure that students have become more engaged, responsible, and accountable for their STEM learning.
CHAPTER TWO: LITERATURE REVIEW

Shortage of STEM-Educated American Students

The United States has seen an increase of workers specializing in the science and technology fields over the past decade. The rate of growth however, falls far behind the explosive growth of competing countries in Europe and Asia (National Science Board, 2010). The National Academics (2007) reports that fewer than one in seven students from the United States earns a degree in science or engineering, while one out of every two students in China and two out of every three students in Singapore graduate with comparable degrees. Additionally, three out of ten students from the United States, who major in physical science, fail to graduate. Less than one-quarter of students who enter college in the U.S. aspire to earn a degree in STEM education. With only five percent of United States workers employed in STEM fields, the responsibility of sustaining fifty percent of our nation’s sustained economic growth is a formidable challenge. The U.S. had regressed from having 40% of the world’s scientists to a current rate of only 15% (Adkins, 2012). Our country’s long-term stability rests on our students becoming educated and working in STEM fields (National Center for Education Statistics, 2009).

The National Science Board (NSB) predicted in 2010 that there will be a shortage of STEM workers in the near future. Over half of the doctorate degrees awarded to students since 2006 within the areas of natural sciences and engineering in the United States were awarded to students of foreign nationalities, most of these students coming from East Asia (National Science Board, 2010). Exposing our students to STEM-integrated curricula at a younger age may be the key to long-term success for American students in continuing to pursue an education in STEM
and possibly a career in STEM. A student will be more likely to achieve these goals through earlier implementation of STEM education at the elementary levels of our curriculum (DeJarnette, 2012)

These findings beg the question, “Why are our home-grown students failing to complete programs in math and science?” The aforementioned studies suggest that many well-intentioned college students arrive at college with plans to complete programs that focus on STEM education. However, the rates in which students fail to complete these programs are alarming. As educators implementing the Common Core State Standards and the Next Generation Science Standards, we must address the completion rates of our students in STEM-based programs if this nation is to stay competitive in a global economy in which our competitors are seeing success on a level that our students critically fail to achieve. The rates at which college students are beginning STEM programs but failing to complete these programs suggests that students who initially believe they will be successful in these programs find themselves unable to persevere through the rigorous demands of STEM education.

Because a dearth of U.S. workers in these fields continue to exist, (National Science Board, 2010) U.S. students must now be encouraged to pursue middle and high school coursework that educates them to become competent STEM learners and problem solvers. The shift from content-based lessons that require students to memorize facts and vocabulary have been pushed aside as a new set of Common Core State Standards have been adopted. In addition to CCSS, the Next Generation Science Standards (NGSS) recently adopted by the state of California, have called for students to work cooperatively as they explore problems rather than memorize vocabulary and facts. The key idea behind discovery or inquiry-based learning (IBL) is intended to provide students with ongoing, active, and in-depth higher-order thinking
processes and experiences in STEM disciplines. This requirement has been missing from each of
the previous national efforts to both educate our students to become competent problem solvers
(NGSS, 2013) and to enter a more knowledge-based workforce. The challenge to teachers is to
succeed in making this important shift from content-based learning to concept-based STEM
learning in meaningful contexts that contribute to students’ self-efficacy within our STEM
classrooms.

**Student Motivation to Achieve in STEM Disciplines**

It has been hypothesized that when integrated-STEM studies are offered at the
elementary age the anxiety synonymous with solving open-ended problems or questions is
reduced (Russel, Hancock, & McCullogn 2007). Offering elementary students academically-
safe situations where they explore different types of open-ended problems and practice using
various a wide variety of technology tools may provide students with the level of comfort
required to alleviate the anxiety and inability that (Truman, 2014), found in the university
subjects. Such elementary-level experiences for students will likely lead to successful STEM
achievement throughout their continued education.

Russell, Hancock, and McCullogh (2007) assert that the best time to have students
develop a connection and interest in STEM fields is in the elementary years of their education.
STEM-enrichment and education plans should be initiated in advance of students’ entry to high
school (George, Stevenson, Thomason, & Beane, 1992). Classes, workshops, and summer
camps that promote hands-on activities, scientific inquiry, and technological-design activities are
known to engage young learners in the STEM disciplines. At Texas A&M University, students
participate in summer camps for the purpose of attracting students into the STEM fields.
Students engage in classes providing instruction in air pollutant measurements, nanoparticles,
and desalination. Other projects in which students receive instruction in include: bridge building, river pollution, programing AutoCAD design, and computer technology (Yilmaz, Ren, Custer, & Coleman, 2013). STEM learning that is project-based excites young students within these programs and the activities they are experiencing provide application of content knowledge that they may not have had the opportunity to put to use in formal instruction contexts. The learning environments that include such activities will spark motivation in students to pursue more advanced math and science coursework and ultimately lead students to a career in STEM (DeJarnette, 2012).

**Early Experiences in STEM**

Russell, Hancock, and McCullogh (2007) suggest that the best time to have students develop a connection and interest in STEM fields is in the elementary years of their education. Therefore, elementary schools should ideally initiate STEM enrichment and education plans that anticipate students’ successful trajectory toward achievement in science, mathematics, promote technology, and engineering as they advance to high school (George, Stevenson, Thomason, & Beane, 1992). In addition to formal “in-school” STEM curricula, classes, workshops, and summer camps that promote hands-on activities, scientific inquiry, and technological-design activities will engage young learners in the STEM disciplines. In optimal STEM activities, students are exposed to rich and meaningful content that they may not have the opportunity to experience in school curricula. Informal education groups such as EIE and REC-VEX robotics have demonstrated that STEM learning that is inquiry and project based excites young learners. Creating classroom settings and lessons that integrate these types of learning environments will spark motivation in students to pursue more advanced mathematics and science coursework and lead students to majors and careers in STEM (DeJarnette, 2012).
Early Inquiry-Based Learning and Student Success

Increasingly, elementary, middle, and secondary schools are offering classes with STEM principles before and after school that focus on scientific inquiry, problem solving, and cooperative learning. While more research is needed there is already a body of strong evidence that the inquiry approach used by these out-of-school facilitators of student learning increases students’ positive attitudes toward science (Loston, Stephen, & Mcgee, 2005). What today’s elementary school teachers are experiencing is a shift to active learning within the disciplines of STEM. Embracing and building upon this strong foundation that assures more success for students in science education will hopefully encourage more teachers to pursue the knowledge, skills, and understanding of how their curriculum and instruction can lead students to majors and careers in STEM fields.

As mentioned earlier, students will acquire an incremental view of their own intellect—adopting a belief that their intelligence is malleable rather than fixed and can be changed through experiences (Dweck, 1999). They will also have opportunities to understand that working on difficult problems or persisting in the creative design work of engineering will enable them to become capable of achieving difficult goals they set for themselves. Research into what motivates our students to participate in STEM-preparation classes and STEM majors in high school and college may help fill these voids with our own homegrown students (Christman, 2012). We have enough understanding to begin this transformation of elementary-school STEM curricula and instruction. The correlation between the theories and research creates a strong basis for introducing integrated STEM learning in the education of our upper elementary and middle-school students. If we want our students to believe they possess intrinsic value and an
ability to succeed, we ought to provide them with the opportunities to form and change their perceptions of individual success as early as possible.

**The Nature of Science**

The core tenants of the Nature of Science (NOS) require students to examine empirical evidence. However, students must acquire the skills to solve multiple-step problems where no one single method is practiced. Additionally, students must understand that proof is impossible, but scientific conclusions are a valuable contribution to the scientific community. Throughout the scientific process students are encouraged to display creativity in their scientific endeavors. While attempting to be as impartial as possible, there is a subjective element to scientific data. Two scientists looking at the same data set or evidence may draw different conclusion based on their prior experiences or historical, cultural, and social influences. Science and technology affect each other, but they are different facets of STEM. Most importantly students examining scientific questions must realize that science and its methods cannot provide answers for all questions (McComas, 2004). This type of thinking and realizations about the scientific process may differ from the methods taught to previous generations of students.

**Student Perceptions of STEM Learning Contexts**

Students create personal perceptions about their role in education at a young age and this is especially important when considering the need for their early engagement in STEM programs. A recent study (Capobianco, Diefes-Dux, Mena, & Weller, 2011) examined students’ perceptions of what an engineer or a practitioner of science looks like. The researchers instructed elementary students to draw pictures of an engineer. This study found that racial and gender stereotypes were already present in the students’ drawings. Student drawings often
stereotypically portrayed males in the role of the engineer and the drawings illustrated individuals who were predominately of White descent. While gender and ethnicity is not the focus of this Guide, it is plausible that gender identification and ethnic stereotypes do play a role in a student’s STEM self-efficacy. Gender studies demonstrate that female students struggle to identify with a STEM field of study, and as young women they may see themselves as not being able to enter a role that they believe was designed for a male (Capobianco, Diefes-Dux, Mena, & Weller, 2011).

Many elementary schools are now offering classes introducing integrated-STEM principles in before and after-school contexts. These programs focus on engineering design, scientific inquiry, problem solving, and cooperative learning. We have begun to see a body of evidence that the inquiry approach used to facilitate student learning in these contexts increases students’ positive attitudes toward science (Loston, Stephen, & Mcgee, 2005). With the implementation of CCSS and anticipation of NGSS, educators in the state of California are experiencing a shift from directed instruction to active learning within the disciplines of STEM. This will hopefully provide a strong foundation for students in science education while also encouraging students to pursue careers in STEM fields. The processes of active learning introduced in elementary school could become extremely beneficial to students because they will be prepared to think scientifically in a thoughtful manner (Sirinterlikci, Zane, & Sirinterlikci, 2009).

**Inquiry-Based Learning Defined**

Bruner 1966, states that theories of learning are descriptive rather than prescriptive. Children’s learning represents an inherited ability to show learning by means that are not
immediately recognizable. Curriculum does not only show the nature of knowledge, but reveals the knowledge of the knower and the process in which knowledge was obtained. We do not teach students in order to create “living libraries.” We would rather have students become independent thinkers. Students should be able to think mathematically for themselves and dissect knowledge much like that of a historian. Students must ideally immerse themselves in the process of knowledge-getting. Knowing is a process not a product. Inquiry-based education that offers a diverse range of strategies in which students are directly engaged in observing and describing the natural world requiring their own explanations based on evidence generated from their study. Additionally, inquiry includes the activities students participate in where they develop accurate knowledge and understanding of scientific ideas and an understanding of how scientists study the natural world (National Research Council, 1996). Inquiry is a student-centered approach to teaching and learning in which students generate a question and conduct an investigation. Inquiry may also be teacher guided. An inquiry assignment is teacher centered when the teacher selects the question. The teacher and the students then agree on an approach to conduct the investigation. A teacher-centered or explicit-inquiry model is facilitated primarily through teacher modeling and directs instruction. The teacher selects the question and carries out the investigation modeling the process to the students in the process (National Research Council, 2000).

Dewey’s definition of inquiry (Won, 2012) on the other hand, suggests that inquiry (not necessarily as the sole work of a scientist, a teacher, or even a student) is focused mostly upon the learner in general. Won has conducted studies in which he has concluded that one of the reasons why the Dewenian theory of inquiry did not withstand the test of time was that education experts interpreted inquiry in a great variety of ways. For the purposes of this Project, we have
adopted the NRC’s definition of inquiry to focus upon the intentions of the NGSS, which have been guided by the NRC’s findings.

Studies show that inquiry-based instruction can have a positive impact on student learning. Cuevas (2005) found that IBL increased student learning, even in students of diverse background. Palisncar (2002) also found that IBL raised student engagement and participation, which included students with special needs. Not only are students positively affected by inquiry learning but so are teachers. When a teacher has the opportunity to experience inquiry, whether it be through a professional development workshop, during pre-teaching courses, or simply while teaching in the classroom, that experience strengthens that teacher’s understanding and ability to apply it (Britner & Finson, 2005; Hanegan, Friden, and Nelson, 2009; van Zee and Roberts, 2003). The assumption of this Project is that students and teachers will be able to develop habits of mind and problem-solving practices that can not only be used in science but in many other subject areas.

The National Research Council’s set of essential features of classroom inquiry and their variations has been used to guide this Project’s development. On one end of the spectrum, it points out that a learner can participate in open-ended inquiry with the direct guidance of the teacher. In this case, the learner is provided with questions, data, steps, procedures for communication, and most importantly, guidance. On the other end of the spectrum, a learner can participate in open inquiry by posing questions, determining what constitutes evidence, collecting said evidence, and formulating his own explanation (NRC, 2000). The difference between this setting and the previous one is that the learner goes through all of the steps independently. In fact, all of the inquiry settings are differentiated by the amount of support that
the teacher provides or as Bell, Smetana, and Binns (2005) points out, the amount of information that is directly provided to the learner varies.

Like the name implies, the key to guided inquiry requires the teacher to act as guide through the entire inquiry process. IBL begins with a broad concept-based question that the teacher provides, such as “How do organisms’ features help with survival?” As the students discuss, the teacher hones in on key points and asks additional questions that are meant to help the students design an inquiry topic. Throughout the entire process the class is encouraged to report their findings so that they in turn can reflect on their study. The key component here is that the teacher is asking leading questions that help guide student inquiry and not directly instructing the students on what to do.

If guided inquiry seems to allow for much student autonomy, then open inquiry completely opens the gate for student exploration. In open inquiry, the learner is provided with a maximum amount of autonomy to answer a question on a topic. Morrison (2012) found that teachers’ perceptions about open inquiry are not necessarily optimistic. This might be for the reason that if not managed properly, students can become confused, disengaged, or even lost during the open-inquiry process. But in order for autonomous learning to take place, teachers must accept and encourage it, and students must become self-motivated to learn (Smilktein, 2003; Brooks, 1999). Since the NGSS lends its self to inquiry learning, it will be interesting to see how teachers who are comfortable with “open inquiry” will perform.

**Understanding Inquiry-Based Learning as a Foundation of STEM Integration**

“Inquiry is a process that explores real-world situations and problems by creating investigations that are authentic to the learner” (Burstein & Knotts, 2011, p. 226). Dewey
theorized that students construct knowledge through active questioning, gathering and examining information, then drawing conclusions, and reflecting on what they have learned (Burstein & Knotts, 2011). The roots of inquiry-based learning can be understood with an examination of constructivist practices (Brooks & Brooks, 1999; Bruner, 1966). The framers of the NGSS created the standards with constructivist inquiry practices in mind. Inquiry, in essence, asks the learners to present their own questions, ideas, and conclusions about science just as science and engineers would (NRC, 1996; Tobin & Tippins, 2003). Therefore, in order for educators to know how to interpret and implement the new standards, we will begin by understanding the beginnings of such thoughts.

Constructivist teaching practices places students in an environment where they are able to learn by discovering through the world around them. In this manner they are “constructing” knowledge. Constructivist classrooms encourage students to observe the world around them. Scenarios and environments are created to foster the use of their senses to develop their skills of observation. Students are able to classify their observations and discoveries to provide a basis for understanding the relationships between various objects and phenomenon. Students then communicate their findings by providing written and oral descriptions of the object or phenomenon. Other skills students develop throughout the constructivist process include predicting and inference. Constructivist experiences provide students with a platform to describe their world and immediate environment through the discovery of relationships between their observations and prior-knowledge (Marin, Jean-Sigur, & Schmidt, 2005).

To further understand what a constructivist teacher does, we can look at the work by Jacqueline and Martin Brooks (1999). Among the many characteristics of constructivist learning that support IBL, they suggest that constructivist teachers:
- encourage and accept student autonomy and initiative;
- use cognitive terminology such as “classify,” “analyze,” “predict,” and “create;”
- allow student responses to drive, shift instructional strategies, and alter content;
- encourage students to engage in dialogue, both with the teacher and with one another; and
- provide time for students to construct relationships and create metaphors.

An influential thought leader on the theory of constructivism, Piaget felt that the growth of knowledge came from the experiences that a learner went through (Brooks & Brooks, 1999). By the same token, Dewey felt that if it is recognized that we learn from the natural world, then it would follow that is impossible to truly learn without physically experiencing what is being learned (Simpson, 2005). For example, a person or a child best learns how to play a musical instrument by playing with it, rather than being told about how to play it. It is evident here that both Piaget and Dewey believed that a hands-on approach to teaching would be best. This is because, as Smilkstein has suggested, Piaget thought that children are naturally capable of self-motivating themselves to construct their own knowledge (2003). Dewey’s writing aligns with Piaget’s in that both assert that the role of the teacher is not to teach, but instead to guide and motivate children to learn (Simpson, 2005). When students listen passively and rely on an instructor to dole out information, as they have during the past several years, they do not internalize what has been taught.

One might ask, “Why are we asking such young children to act as scientists do?” Berger (2003) cites studies in which it was learned that children as early as six years of age are able to classify, think logically, process information at varying speeds, and have a developed working memory. In fact, he points out that, “their daily experience advances these children’s cognitive performance in ways that neither maturation nor education could do alone” (Berger, pg 362).
The logical question then is, “How can we as teachers facilitate these experiences in the classroom? Inquiry-based learning might be the key.

**Shift from State Standards to Common Core State Standards**

As a result of this understanding, the new Standards emphasize that the ways of seeing science will have a tremendous impact on the 21st century science classroom. No longer will the focus be on what the teacher is doing, but instead it needs to become focused on what the student does. Students will need to develop cognitive models that help explain natural phenomenon. They will have to use their science and engineering practices to gather data and make connections as they also have to make direct connections to knowledge that was gained in previous classes addressing other disciplines and subjects. Even performance assessments must change. Sparks (2013) argues that, “to assess these sorts of skills, tests likely could not use multiple-choice or short-answer problems… and the tests would have to measure both students' answers and the process by which they arrived at them” (Pg. 5).

As mentioned in Chapter 1, the change to our science curricula is a result of a grave situation that the American educational system is in. According to the National Center for Educational Statistics, the United States ranked 24th in science education (2012). A separate survey found that if given a report card grade, a majority of reviewers felt that the appropriate grade for the current American system would be a “C”. Of the total those respondents, 84% felt that improving science education was needed to compete globally (Achieve, 2012). At the same time though, the respondents gave a glimpse of optimism because within that survey, 54% strongly favored the idea of the new science standards while only nine percent opposed them. The bottom line is that most people agree that change is needed, and that the new NGSS standards might be the key to bring about that change.
In addition, K-12 teachers applaud the idea of teaching the essential skills and concepts that are required, but remain confused about how these skills will be taught and assessed. According to the NGSS website, the intent of the framework is meant to change what is expected of the students, but, “additional work will be needed to create coherent instructional programs that help students achieve these standards” (NRC, 2012). The National Science Education Standards suggests that inquiry-based learning provides a fundamental aspect of such programs. “The diverse ways in which scientists study the natural world and propose explanations is based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (NRC, 1996).

Why Inquiry-Based Learning in STEM?

Many teachers identify inquiry as being an important component in their students’ education. However, many more teachers lack the resources to construct a practical framework to guide implementation of engaged learning strategies such as IBL (Bell, Smentana, and Binns, 2005). Teachers have been required to prepare their students to be successful in answering multiple-choice questions on local, state, and national tests designed to assess a student’s ability to memorize facts and vocabulary. According to the (National Research Council 1996) inquiry is a process that requires active learning. Questioning, data analysis, and critical thinking are integral components of a meaningful inquiry lesson. Inquiry instruction across all disciplines is most authentic when students are able to pose and answer their own question by analyzing data they collect and set out to research independently. Students need substantial scaffolding before they are able to undertake the task of developing scientific questioning and analysis of their data. The shift from rote memorization to giving students the freedom to discover and answer their own
questions will be a dramatic change for many educators of elementary students; a reality that must be readily addressed.

Questioning, investigation, and pattern recognition are key human skills that develop over time and allow us to build the foundation to inquire more deeply about our surroundings and the scientific world-at-large. The NOS lays out the format for inquiry-based learning that does not rely on one set methodology for problem solving. The shift to the NGSS by way of the NOS, encourages teachers to engage students through a complex set of experiences described as problem or project-based learning (PBL). Creativity and imagination are key components of the NOS. Beginning as early as third grade, students will soon receive instruction stating that science is a collaborative rather than an solely individual process that seeks to answer questions through examination of empirical evidence (NGSS, 2013).

IBL conducted in the K-12 years in important because as mentioned earlier, the National Science Board predicted in 2010 that there will be a shortage of STEM workers in the near future. Over half of the doctorate degrees awarded to U.S. students since 2006 within the areas of natural sciences and engineering were awarded to students of foreign nationalities, most of whom migrated from East Asia (National Science Board, 2010). Exposing our students to STEM curricula at a young age may be the key to long-term success for American students continuing to pursue an education and possibly a career in STEM. We can achieve these goals through the implementation of inquiry-based learning in the elementary levels of our curriculum (DeJarnette, 2012). The IBL tasks that are provided in the guide assist teachers in creating lessons that require students to analyze a given problem, collaborate on possible solutions with other students, and design a solution to the problem within the given situational constraints. Teachers need learning opportunities to recognize that the desired result of this process (aligned
with both CCSS and NGSS) is to have students begin to see themselves as problems solvers and believe that they can be successful in a future STEM major or career.

**Depth of Knowledge, Mathematics/Problem Solving**

The content knowledge of elementary teachers is now essential to the improvement of teaching and learning in STEM disciplines. It is often debated that teachers spend a great deal of time in preparation for the content standards rather than the type of content they need to learn to be able to deliver effective lessons. For example, teachers need extended support in gaining expertise with mathematical practices. They require specialized knowledge to engage their students in meaningful activities that focus on key concepts and content specific vocabulary. Helping students to learn conceptually requires teachers to be able to do mathematics and unpack the structure of mathematics to help students understand its unique features (Ball, Thames, & Phelps 2008). Mathematical teaching demands placed on teachers in CCSS now require a deeper level of knowledge that is specialized, but may not necessarily be needed by others. Teachers must learn the rules for classifying mathematical knowledge. In this way, they will be able to ask questions that address the rule being taught. If teachers ask a question that does not fit the rule, the students will answer incorrectly (Holmes, 2012).

Even when teachers know all the rules regarding mathematical instruction, they may not know enough to be able to instruct students in the ways that researchers and educators believe they should. In CCSS teachers’ ability to use what they have learned to correct, refine, and improve instruction are all key components of teaching well. Teachers must be able to observe students’ learning situations and dissect them from moment to moment. Teachers must be able to use this knowledge for the adaptive decision making that helps to improve their practice. Being able to create generalizations for example will help teachers to be able to assist students in
drawing meaningful conclusions from their inquiries and to facilitate a foundation for navigating future situations. Teachers must similarly know how to create an environment where students are able to safely operate experimentally; and where they are encouraged to adapt to situations. The direction from the teacher will help students to be able to frame, guide, and revise tasks. Students will be able to pose and reformulate questions (Ball & Cohen, 1999).

Students working at high level of Depth of knowledge are required to analyze and justify their thinking and methods. Working at this level requires students to be intuitive thinkers. The development of intuitive thinking or problem solving is highly regarded amongst teachers of mathematics and science. Intuitive thinkers may miss steps in the process. Regardless if the answer is correct or otherwise, intuitive students often have to go back and evaluate their process through analytic means. Analytic thinkers tend to have a step-by-step process presented to them in which problems are solved using that given process. Bruner states that the relationship between the inductive and analytical is a complementary one that should not be ignored. Because of this, relationship boundaries for inquiry-based learning are necessary and important (Bruner, 1960). While it is important to allow students to critically analyze and problem solve on their own, working with in a general set of expectations and a framework is essential to facilitating meaningful inquiry experiences that students will be able to reflect upon in the future.

**Inquiry or Standards based assessment?**

Today’s students must acquire the ability to think critically, and communicate their thinking in collaborative contexts in order to find their role in the 21st century world (National Research Council, 2000). The ability to question, hypothesize, design investigations, and develop conclusions with consideration for evidence, is promoted in an instructional environment where students build problem-solving skills. Unfortunately our standards-based assessments in science
and mathematics have evaluated students at the lowest depth of knowledge level. A study of mathematics and language arts test questions conducted in Ohio, found that between the years 2003-2004, 87% of all the items assessed were at level one of complexity. This number decreased slightly to 86% in the 2005-2006. Many of the questions were centered on a basic recall of facts (Boyd, 2008).

Teachers implementing the CCSS are being presented with increasing demands for advancing the instruction of students toward authentic science processes and rationales while still preparing them with knowledge of facts, vocabulary, and concepts (Nowicki, Sullivan-Watts, Shim, Young, & Pockalny, 2012). Coming prepared with the background knowledge to teach science to a diverse population of students requires K-5 multiple subject teachers to be competent in each of the earth, physical and life sciences. Additionally, K-5 teachers must be able to guide students through a variety of authentic experiences that facilitate students’ building their own understanding of natural phenomena. These become necessary, daily challenges for teachers seeking to promote students’ depth of knowledge in science as they require teachers to effectively engage students in considering and testing their scientific misconceptions and generating their own questions and solutions to human problems (engineering). Teachers are also challenged to provide meaningful feedback to students that accepts and the scaffolds their unique responses and ideas to deeper understanding and higher order thinking (National Research Council, 2000).

Developing inquiry science pedagogy for example, requires teachers to provide students with a strong foundation for problem-solving and critical-reasoning abilities (Varelas, Pappas, Kane, & Arsenault, 2008). Many elementary school teachers however, have acquired limited understanding of the subject matter in which they are required to teach or in other words, they
having weak pedagogical content knowledge (PCK) in science (Appleton, 2007). The studies conducted by several researchers confirm that a teacher’s DOK will directly affect the quality of the experience a student will have in science learning. Increasing the content knowledge base of teachers will provide positive results in establishing a foundation for student success.

**Minority and Low Socio-Economic Status Student Population Representation in STEM**

Minorities have been generally underrepresented in upper-division STEM classes and careers. According to Rodgers-Chapman (2013), Latinos represent the fastest-growing minority population in schools. Therefore their successful participation in STEM curricula and programs has practical and social ramifications. As more schools become focused on increasing STEM achievement for diverse populations, it is important to develop strategies to increase participation among Latino(a) students who will otherwise continue to be under-represented in STEM majors and careers. (Rodgers-Chapman, 2013).

Students with low socio-economic standing are similarly under-represented in STEM programs. U.S. schools with STEM programs today tend to have higher socio-economic rates than schools that do not have STEM programs. These schools are often located in affluent areas with access to a wider range of monetary and social resources. Rodgers-Chapman (2013) suggests that students coming from low socio-economic backgrounds tend to score better in schools where the ratio of higher socio-economics is greater than 50%. Socio-economic standing therefore is seen to play a vital role in student STEM achievement. Until recently, many of the students participating in the STEM program at my school have not had a first-hand opportunity to experience what a scientist or an engineer does. Their experiences may come from the depictions of STEM workers in television and movies. I have explored our students’ perceptions
of what types of individuals are employed in STEM careers. The outcome of this query provided me with a unique perspective on the Rodgers-Chapman study findings. When I compared the rate of students receiving free and reduced lunch to students’ perceptions about STEM workers I realized that my students are already at a disadvantage due to the fact that they are currently receiving free and reduced lunch at a rate of 92.7%. Clearly, it is important for K-5 educators who serve students from minority and low-SES populations to understand the correlations between poverty and perspectives on career opportunities in STEM.

**Vocabulary Development through Inquiry-Based Learning**

Academic Language continues to be an area of weakness for many children. Science instruction provides students with multiple experiences to unique academic language. Science uses academic story language or narrative that requires students to explicitly name objects, people, and events. This is necessary for a listener or a reader to be able to understand what is happening without support from the any context but the words themselves, similar to skills learned in Language Arts. Additionally, science language provides experiences that other forms of academic language do not. Science language classifies the relationship between characteristics and attributes of objects; it compares categories, and explains why things happen. Science language is rich in vocabulary that is specialized with in the subject matter being taught (Hoing, 2012).

Scientific vocabulary supports Language Arts instruction and English Language Development students (ELL). Results of a study conducted by Santau, Maerten-Rivera, & Huggins found that fourth-grade students participating in their three-year study, student made significant gains. The researchers believed that these positive gains could be attributed to
effective professional developments which lead to effective science instruction. Because teachers’ self-efficacy in inquiry-based learning increased, student learning was promoted. Not only did the professional development focus directly on science inquiry instruction, but it also integrated an English-language development component (Santau, Maerten-Rivera, & Huggins, 2011).

The alignment of results of these two studies would suggest that an additional benefit of inquiry-based instruction is increased student development in vocabulary skills. By using academic vocabulary to analyze their surrounding and justify their conclusions, students demonstrate competency in the language skills that are directly taught during English Language Arts instruction. Students who came from backgrounds with lower SES achieved at a comparable rate to the norm group as a result of effective inquiry-based instruction (Santau, Maerten-Rivera, & Huggins, 2011).
CHAPTER THREE: RATIONAL/METHODS

This resource guide is intended to guide the teacher who is curious about or has never tried to implement inquiry-based learning in the classroom. Inside the teacher will find a variety of lessons and activities that support the growth of inquiry-based learning in the classroom. It looks to address the issue that was pointed out by Elkind (2004), a lack of teacher readiness for curricular and instructional change. This resource guide is not intended to give advanced support to teachers who have already begun the process of inquiry-based learning. However, the material provided is easily adaptable for teachers at all levels of comfort and experience. This guide should be adapted to facilitate instruction for the teacher who chooses to apply the lessons provided. There is no “one size fits all” resource that will engage and reach every student. Therefore, teachers should use their own professional discretion when applying the material provided in this resource guide.

Bridging the gap in STEM educated individuals is a monumental task. Providing a starting point where teachers can begin to integrate inquiry-based lesson into their own classroom at the grassroots level is vital to leading our young students into a future where a STEM career is not only a possibility but an achievable goal. Pre-service teachers who have been introduced to inquiry-based learning in their credentialing program may be seeking additional resources to bring into their classrooms. That is the intention of this resource.

Providing a starting point gives the teacher a place to discover or refresh her knowledge of inquiry-based learning. Providing an outline of the inquiry process will support teachers by supplying teachers with scaffolded experiences to build confidence in the inquiry process. Using the matrix to plan lessons assists the teacher in addressing the various components of
inquiry. Breaking the process down into four components with subcomponents allows the teacher to create and plan meaningful inquiry experiences for their students.

As teachers reflect on their practice, it is essential that they do not become complacent in their lessons. Teachers should use this guide as a starting point to facilitate their own unique IBL experiences for their students and expand their level of competence though the continuous development and implementation of IBL lessons. The NASA 5E lesson format can be adapted for any type of inquiry-based question a student or a teacher researches. The lessons presented in this guide should be expanded up and tailored to meet the needs of specific groups of students. It is our intention that this guide drives increased participation in inquiry-based learning and creates an environment of wonder and discovery for diverse students.

This guide seeks to promote the constructivist qualities teachers should practice while preparing and engaging their students to be successful in IBL. Brooks and Brooks state that the constructivist qualities a teacher should possess are:

1. encourage and accept student autonomy and initiative;
2. use cognitive terminology such as “classify,” “analyze,” “predict,” and “create;”
3. allow student responses to drive, shift instructional strategies, and alter content;
4. encourage students to engage in dialogue, both with the teacher and with one another;
5. provide time for students to construct relationships and create metaphors (Brooks, & Brooks, 1993).

This resource guide was created while reflecting on these principles, in order to further promote these dimensional teaching practices through inquiry-based learning.
Resource Guide Overview

The resource guide has been organized in a developmental order. As participants complete each task, they should notice that both the tools and the lessons become not only more involved but more focused.

Planning for STEM IBL lessons is essential to the success of the lesson. Without taking the steps to understand what obstacles, questions, desired outcomes, and materials are needed for the activity; a teacher can easily become overwhelmed. Knowing as much about the goals, standards, and the topics that will be discussed will greatly increase a teacher’s ability to adjust to last-minute changes that might present themselves. As stated in Chapter 2 and by Morrison (2013), IBL is a dynamic process that may not be familiar to some educators who have either little experience or were not exposed to IBL in their early education or pre-service training. For this reason there are three activities that are designed towards making sure that a teacher is well prepared for a lesson. The first, “Misconceptions about the Nature of Science,” looks to make sure that a teacher is aware of the knowledge, or lack of, that he or she has regarding the Nature of Science. This resource was chosen in response to the increased NGSS emphasis on understanding how a scientist or engineer gains knowledge. “The Inquiry Process” provides an overview of the typical path that an IBL lesson should follow. Although not linear, one would benefit in knowing the general direction in which one is guiding the class. The most involved activity that deals with planning is the “Inquiry Lesson Planning Guide”. It is much a much more involved guide that should be used before every lesson.

Considering that IBL pivots around a person’s ability to develop answerable questions a teacher’s ability to guide a student through the inquiry process and a person’s ability to develop answerable questions, this resource guide makes a point to provide opportunities to develop the
ability to assist in strategic questioning through the activity, “Inquiry-Guided Questioning Activity.” Constructivist theorists such as Dewey, Piaget, Brooks and Brooks, who were mentioned in earlier chapters, would agree that a key to successful inquiry is a teacher who can guide students through their educational endeavors. In an attempt to introduce teachers to the demands of the NGSS standards, this activity also includes the first samples of those standards. The standards may appear daunting at first and so a gradual immersion might be less intimidating.

As a participant progresses through the activities of the resource guide, the fully developed lessons that are included become increasingly integrated. The first of these lessons, which is called, “Race against Friction, “only integrates two components of STEM, whereas the “Plant Growth Chamber Activity” and the “Spud Light” lessons are fully integrated. In contrast to the state standards for Science, the NGSS provides teachers with insight in regards to the integration of science principles and engineering practices. A teacher who is not familiar with integration would have considerable difficulty in designing a lesson that integrates more than a couple subjects. One can chose to utilize the suggestions that are made in each lesson as he or she feels comfortable.

The creators of this resource guide believe firmly in the potential benefits of reflective practice. For this reason, a reflection piece is included for both the teacher and the student. Wagner (2006) makes the case that reflective practice benefits everyone from the student to the principal. Reflective practice is one facet that can greatly increase teacher and student self-efficacy in STEM subjects. The reflective worksheets that are provided should be used throughout the activities to ensure that an accurate measure of your growth as a participant is kept.
Throughout the implementation of the resource guide it is also important to consider the questions that were presented in Chapter 1: How can IBL teaching and learning processes be adapted to meet the expanded STEM-learning goals of the NGSS? What are the developmentally-appropriate structures and variations of IBL that assist teachers in ensuring students’ engagement and success in science curricula? What are some other examples of NGSS-Based Inquiry Projects that teachers may adapt and implement in their classrooms? How does participation in professional developments such as these increase my self-efficacy in teacher STEM related lessons such as IBL?
CHAPTER FOUR: TEACHER INQUIRY RESOURCE GUIDE

Misconceptions about the Nature of Science

Teacher misconceptions about science range from simple misconceptions about what science is to how science is accomplished. Inquiry is not performed through a set of steps contrived to produce a particular outcome. Analyzing the misconceptions we have about science as adults will enable us to dissolve the same misconceptions our students have before and after they enter our classrooms. Taking the time to address misconceptions will prevent the difficult undoing of these same misconceptions in the future (Jain, Lim, & Abdullah, 2013). It is of paramount importance to address pre-service teacher’s misconceptions in the understanding of the Nature of Science. If the misconceptions are not addressed early on, it is likely that these teachers will transfer their beliefs about science to their students. This will result in a counterproductive effort to building a scientifically-literate society of students (Jain, Lim, & Abdullah, 2013).

It is suggested that a metacognitive approach towards these beliefs will increase a teacher’s self-awareness regarding their knowledge of the Nature of Science and its teaching practices. It will also help develop an increased effectiveness in planning for instructional units and stand-alone activities (Sajin, 2000).

This website from the University of Berkley provides teachers with an array of possible misconceptions that teachers have held onto since their childhood science instruction. Teachers can examine their own perceptions of science and reflect on their pedagogical practices in delivering inquiry-based instruction. A focus of this artifact is not to increase an awareness of what we know, but how to increase an awareness of how we know. Teachers should use this
website in planning and preparing for addressing the possible misconceptions they and their students may have regarding the Nature of Science and its individual components.

http://undsci.berkeley.edu/teaching/misconceptions.php
Inquiry-Based Learning Process

Inquiry is a developmental process; therefore inquiry at a young age differs from that of advanced students. The inquiry model will need to be adjusted to accommodate the appropriate level of development for students engaging in an inquiry activity. For example, Figure 4.2 demonstrates a suggested process for inquiry. Students should generate a question to analyze using the inquiry model. However for students who are new to the process, the teacher may pose a question to scaffold the experience. After students have a workable question, they will need to secure resources pertaining to their question. Students should use the questioning principles from step two to assess the validity of their resources. The resources selected may cause students to adjust or rethink the question they are analyzing. Once the resources and the question are solidified, students advance to step three where they will analyze their resources to obtain further background knowledge relating to their topic in question. Finally, students will use their information to generate a possible answer to the question that was posed or generated through their research or teacher.

As part of this exercise, take a moment to observe something in your environment. Follow the process that is laid out in the inquiry model to familiarize your students and yourself with this process.

1. Have students ask question they would like to know more about regarding an object or phenomenon in their environment.

2. As time permits have student participate in research relating to their question. For students that are new to the process, the teacher may pre-select the research for students
to analyze. Students will decide on the types of resources they believe will provide them with answers to the problem.

3. Students will use determine how this information relates to their question. Using the self-questioning provided on the inquiry process model, (fig. 4.2) students will analyze the information, determining how it pertains to their question and will determine if the information is sufficient for answering their question.

4. Students will share their findings with their audience. This includes how their information connects to their question. Students should be encouraged to have open dialogue with one another about their findings. Students may also use multi-media to convey their findings.

It is also important to observe that the inquiry process is not linear. Students may go back to any portion of the process as new discoveries are made. It is essential that students use formative assessment tools that enable them to be self-reflecting and self-regulating throughout the entire inquiry process as they determine for themselves what approach they take to answering a question or solving a problem (Piaget, 1959, & Fox, 2008). An array of options exist for students to self-assess their progress. However, student portfolios can be used to facilitate growth and development, reflection, goal setting, and self-evaluation. Portfolios and e-portfolios can be created and implemented by the classroom teacher as students make progress through the inquiry process. The collaborative nature of IBL lends itself to the use of portfolios. Students can compare their work to rubrics or goals placed before them. This allows students to adhere to the general guidelines of the inquiry process and provides a foundation for what should be included in their portfolio (Belgrad, Burke, & Fogarty, 2008).
Figure 4.2: Inquiry Process Chart. (C. Brunner, 2014)


Note: This model has no starting point but does emphasize reflective practice at all stages.
Partially-Integrated STEM Lesson:

Race against Friction Overview

Race against friction is an inquiry-based assignment that will provide students with a collaborative experience using their background knowledge to predict outcomes. Students will be taught about the basic principles of friction and the application it may have in their lives. Student understanding of the principles of distance, rate, and time combined with discovery and instruction on how friction prevents the sliding of one object against another are essential to success in this activity.

This lesson can be modified to fit a variety of student sophistication. Students with less experience working with inquiry-based problems will find success in being able to make predictions and justify their reasoning, while students with greater levels of sophistication will be able to derive and apply mathematical formulas and principles to support their predictions and findings. Advanced students will be able to find support or grounds for revision of their predictions through the application of Newton’s Laws.

Students practice working in a collaborative setting and are responsible for their part of the task. Every role in this project is vital and students should be encouraged to fulfill their role to the extent of their ability. The nature of science is an environment where students collaborate and share ideas to agree on a possible solution to a given problem. This lesson finds its strength in offering the teacher who has acquired and implemented various approaches to instruction that include inquiry lessons an opportunity to determine that it is appropriate for students to initiate their own investigations.

While this lesson is teacher directed in its initial stage, the students take over and go through what they know about friction and the materials used to create the friction on the ramp. This lesson is best used as a scaffold for having students begin to formulate their own
questions for inquiry. As students become increasingly sophisticated in their ability to answer questions, more freedom can be given as students begin to formulate their own questions. This makes this lesson and ideal step for students who may be ready to become increasingly independent.
Racing against Friction Lesson

Objective

To understand how friction affects the speed of a vehicle.

Target concept: Velocity

Preparation time: 20 minutes

Duration of activity: 40–45 minutes

Student group size: Teams of two to four students

Materials and Tools

- Large sheets of corrugated cardboard
- Masking tape
- Felt fabric
- Wax paper
- Sandpaper
- Construction paper
- Various textbooks
- Small toy cars
- Stopwatches
- Student Sheets
- Scissors

Management

Before the activity begins, cut out strips of felt fabric, wax paper and sandpaper slightly wider than the width of a toy car and approximately 1 ft (30.48 cm) long. Ensure each group has a piece of cardboard approximately 1.5 × 2 ft (45.72 × 60.96 cm) to make their ramp surface.

Read Two-Ton Hockey Pucks on page 98 to the students.
Background Information

Working in space can be tricky. With no gravity or friction to keep things in place, relatively simple tasks can become complicated ordeals. To prepare for the rigors of working in space, astronauts train in many different facilities on Earth. One of these facilities, the Precision Air Bearing Facility at Johnson Space Center in Houston, Texas, is used to simulate the reduced friction found in space.

This lesson will introduce students to the concept of friction being a slowing force.

Procedure

1. Write the word FRICTION on the board. Have students share any information they may know about friction.
2. Explain that the class is going to investigate friction and the effects it has on a moving vehicle.
3. Place students into groups and hand out the Student Sheets.
4. Go over the instructions on the Student Sheets and answer any questions the students may have.
5. Allow time for the students to complete the activity.

Discussion/Wrap-up

Have students share their results, and discuss why the results turned out as they did.

Extensions

Study Isaac Newton’s Laws of Motion.

Race against Friction

Procedure

1. Use the scissors to trim the different strips of material to the same length.
2. Place the strips of material on the piece of cardboard. One end of each strip should be lined up against the edge of one side of the cardboard. (See the above diagram.) Tape the strips in place using the masking tape.

3. Stack the textbooks on top of one another. Place one end of the cardboard on top of the books to form a ramp. The ends of the strips of material should be toward the table. Tape the cardboard into place.

4. Predict which material will allow the car to move down the ramp the quickest. Write your prediction on the Data Sheet, and explain your prediction.

5. Place the toy car at the top edge of the first strip of material. Let the car roll down the ramp to the table. Use the stopwatch to time the amount of time it takes the car to travel from the top of the material strip to the table. Record the time on the Data Sheet.

6. Repeat this process with the first strip of material until you have completed three trials. Record all data.

7. Repeat steps 5 and 6 with the other three strips of material. Record all results.

8. Answer the questions on the following data sheet.
Fully-Integrated Lesson Plan:

Plant Growth Chamber Activity Overview

The following lesson plan is an example of a fully-integrated STEM lesson plan. Plant interdependence is the guiding concept, but along with the lesson, technology is used both by the teacher and the students through an online plant-growth simulator. Engineering practice takes place when the students work collaboratively to solve the question of how one could successfully grow food on the space station. Finally, math is incorporated by including restrictions on the dimensions of the product that the students create. Although one is not explicitly teaching either of subjects, the students should be made aware that they are behaving just as scientists and engineers do when they are solving a problem. This can be done through visual aids such as the inquiry and engineering flow maps that are included in this PD.

The unit begins by engaging student interest in space exploration. Students are able to see real time video of the international space station through NASA’s live feed at http://www.nasa.gov/multimedia/nasatv/iss_ustream.html. Through the use of strategic questioning the students are encouraged to find ways to support plant life in a space station. To do so, a student would need to research what plants need to survive before building a prototype of the plant chamber. At the end of each day of activities both the students and the teachers should take a moment to reflect in their journals or worksheets.

As a participant of this professional development, teachers are encouraged to implement this lesson with their students. In preparation for the lesson, it would be beneficial to take the time to become familiar with the resources that are recommended. Doing so will also ensure that they are developmentally appropriate for your class. A list of potential supplies is included, but if a student requires supplies that are not readily available, alternatives should be provided. It
would also be helpful to review the questioning worksheet on page 52 to prepare for the group discussion that takes place at the beginning of the lesson.

Not all inquiry lessons should integrate all subjects. Lessons usually consist of the integration of only two or three STEM subjects. This lesson can easily include a Language Arts component through the use of narrative readings that have plant life as a subject. On the other hand, one can remove a STEM component to simplify the demands of the activity. The main goal of this activity is to provide an example of what integrated STEM lessons look like.

**Plant Growth Chamber Lesson**

**Objective**

The students will design create a “Plant Growth Chamber” that provides the essential necessities for plant survival. Ex. CO2, H2O, and sunlight.

Groups of 4 arranged by human graph, “How much do you know about plants”

**Formation of Groups**

- Materials manager
- Reporter/Recorder

**Role Assignments:**

- Participation encourager
- Quality Control Manager

Groups will be asked to create a space growth chamber. They will be given supplies, information on plant growth, and a description of the
criteria. (See student handout)

Task

Approximately Five Days
Day 1 – Introduction
Day 2- Exploration and Design
Day 3- Building
Day 4- Evaluate and Adjust
Day 5- Presentation

Problem solving, disagree with the idea not the person, evaluate, support decision making.

Social Skills and or
Habits of Mind

Table talk voice

Level of Voice

California Content Standards-

2. All organisms need energy and matter to live and grow. As a basis for understanding this concept: a. Students know plants are the primary source of matter and energy entering most food chains.
NGSS

Disciplinary Core Ideas

LS1.A: Structure and Function

- Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (4-LS1-1)

Science and Engineering Practices

Engaging in Argument from Evidence

Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).

- Construct an argument with evidence, data, and/or a model. (4-LS1-1)

Use a model to test interactions concerning the functioning of a natural system. (4-LS1-2)

Crosscutting Concepts

Systems and System Models

- A system can be described in terms of its components and their interactions. (4-LS1-1), (4-LS1-2)

Measurement and Data

Apply the area and perimeter formulas for rectangles in real-world and mathematical problems. For example, find the width of a rectangular room given the area of the flooring and the length, by viewing the area
Assessment of Cooperation/Collaboration

Encouraging Energizer

“Fan-tastic” and “Zoom boom to the Moon”

Lesson: 5E Model

Day 1 - 2

Engage

**Teacher:** Show NASA Space Station webcam to grab student attention.

**NASA Space Station Webcam**

http://www.nasa.gov/multimedia/nasatv/iss_ustream.html

**Teacher:** Imagine that you are going to live on the space station for several months. What are the most important things to take?
**Students:** (will provide a list) Guide the group towards food.

**Teacher:** *What if you want to make sure that fresh food is available for example: oranges or tomatoes?*

Allow for student responses.

**Teacher:** You know, being able to provide food is a major challenge. It’s so much of a challenge that NASA is asking for the help of all engineers, including young ones like you, to help design ways of growing fresh food for the astronauts.

Introduce the challenge using NASA’s plant growth chamber challenge.

http://www.nasa.gov/audience/foreducators/plantgrowth/home/index.html

**Explore**

**Teacher:** *This week you will continue to refine your engineering skills and take on this challenge. Engineers can begin by stating the problem.*

Show poster.

Provide the sentence frame. Allow students time to practice with their
partners before calling on responses:

We need to find a way to _______________________.

*Suggestion: Use popsicle sticks to call on non-volunteers*

Teacher: Before we can select a solution, good engineers generate ideas about what can be created.

Allow time for discussion and log ideas on chart paper.

*Teacher: Now that we have an idea, have your team think of problems that may arise. Write them on the provided post-its and post them on the “generate ideas” side of the engineering process. Model: plants need to have sunlight.*

Allow time for discussion… Guide group discussion towards the fact that plants need CO2, water, sunlight.

Review with the class.

*Teacher: Here is some information to help guide your thinking. You can use this information to further understand what NASA needs.*

Provide guide sheet and review the information.
Note: The students will be provided with materials, online resources, and directions on this worksheet. At this moment computers should be made available so that the students can access the online resources.

Teacher: At this point you will select a solution or approach to your problem. Engineers make sure that as much planning is done before construction begins. You can use the “Diagram” sheet that has been provided. This way you can better visualize your concept.

During this phase the teacher will act as a facilitator. Guidance will be provided by asking for explanations of choices. If a group needs to be redirected the teacher can provide some feedback.

Formative assessment will take place by observing drawings with labels and student responses.

Teacher: Once you feel that you are ready to begin the building phase of your project. You can take your materials and begin building. An engineer is always evaluating the progress that is being made. You will use a double entry journal to take a log. Some of the questions that you will want to think about are:

- What do you like about your project? What makes it successful?
- Is the project addressing all the needs that were mentioned on the guide sheet?
- What last minute changes do you want to make? Why?

The students will continue to build their project. Any last minute changes should be supported with good reasons.

Formative assessment will be done by observing the student and reading the journal logs. It is important that the teacher provide feedback in the logs to ensure student learning.
Explain:

Teacher: Once you have completed your projects you will conclude by presenting your solution to the problem. As a group you will have to assess your progress, and assess the progress of your mates. I have provided a rubric, and self-assessment sheets so that you can do so.

Refer to student assessments-Student self-assessment (What I Learned), partner assessment (rate your mate), Teacher assessment (Use Rubric Provided)

Elaborate

Evaluate

Plant Growth Chamber Activity

Task:

You and your team will create a plant growth chamber that can be used by astronauts to grow their favorite foods!

Restrictions:

1. Make sure that the plants get Sunlight, CO2, and Water.

2. The chamber should be 12 inches tall, 16 inches wide, and 12 inches deep so that the astronauts do not use up too much space.
3. The space station is filled with O2 (oxygen) so you must make sure that they get adequate CO2. Hint: humans produce it when they breathe out.

**Materials:**

- cardboard
- construction paper
- rulers
- plastic wrap
- seeds
- hoses
- paper towel rolls
- 2 liter bottles
- tape
- scissors

**Job Assignments:**

**Materials manager**- makes sure that the table has all the materials necessary

**Reporter/Recorder**- Writes a journal entry everyday

**Participation encourager**- Makes sure that everyone is participating fairly

**Quality Control Manager**- Will make sure that all writing, labels, and information is correct

**Resources**

**Youtube: Build a greenhouse**

http://www.youtube.com/watch?v=LFoyZYCC3Kc

**Plant grower simulator**


**Brain Pop**

http://www.brainpop.com/science/cellularlifeandgenetics/photosynthesis/
Fully-Integrated Lesson Plan:

Spud Light Overview

The following lesson plan requires students to integrate multiple components of STEM. Electricity is the guiding concept of this lesson. However, in order to successfully complete this lesson student will need to have a working knowledge of conductors and insulators. Engineering and design principles are addressed as students create a working model of a potato powered light bulb. Students must work collaboratively to determine the best conductors for connecting the potatoes as a source of power. Science, technology, and engineering are the primary components of this lesson students will be addressing.

The lesson begins by giving students a possible scenario they may encounter. Through the use of an image to draw in their attention, students begin to see the amount of light and energy is used to power our world. This visual will drive the question of, “What options are available if the electricity was to stop and the lights went out?” Students will be using this driving question to consider possibilities.

Teachers participating in this professional are encouraged to implement this lesson with their students. In preparation for the lesson, teachers will need to be familiar with conductors and insulators as well as a basic knowledge of how electricity flows in a circuit. A list of necessary materials is provided to ensure proper preparation for the lesson. Teachers, who familiarize themselves with conductors and insulators, will be able to acquire alternative materials if any of the suggested materials are not available at any given time. Student response papers are provided but may be adapted as necessary to accommodate the specific needs you’re your classroom.
This is an exceptional lesson due to its integration of three of the four STEM disciplines. The integration of the Language Arts component through the justification piece will support Common Core and high depth of knowledge responses. As students navigate this experiment they will be able to observe, create, test, and modify their designs, making use of the engineering process laid out by NASA.

**Spud Light**

**Grade Level 4-6**

Science standards

NGSS (4-PS3-4) Apply scientific ideas to test, design, and refine a device that converts energy from one device to another.

Writing Standards

W.4.4 Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience.

W.4.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

Speaking and Listening

SL 4.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups and teacher-led) with divers partners on grade 4 topics and texts, building on others’ ideas and expressing their own clearly.

**Justification:** I selected this lesson because it integrates Science, Technology, and Engineering for the purpose of creating a presentation that will get students interested in electricity and the creation of it. My hope is that this lesson will inspire students to further engage in the study of how things work. Making electricity with household items will encourage students to explore their surroundings and ask questions about the properties of other household items.

**Necessary prior knowledge:** Students will need to have an understanding of the basic properties of conductors and insulators. They will need to be able to determine the difference between the materials provided and make predictions about the items.

**Formation of Groups:**
Groups will be formed at the teacher’s discretion. Suggestions could be to partner knowledgeable students with those who struggle, and integrate students who display mid-range knowledge within those groups.

**Objectives:** Students will be able to:

1. Describe the difference between conductors and insulators
2. Chart information relating to their project
3. Write a justification statement supporting their project
4. Orally defend and discuss the results and findings of their project

**Role Assignments:**

Materials: This student is responsible for the acquisition of materials necessary for the group to successfully complete the task.

Recorder: This student records the findings of the group and records it on the handout.

Reporter: This student is responsible for sharing out the group's findings at the conclusion of the project.

Encourager/Time Keeper: This student is responsible for keeping the group positive. The students will also keep the group focused and provide reminders on time when appropriate.

Spy, Traveler: This person may go from group to group and look at the progress of the other group. This student will then bring information back to the group. This person only leaves the group when the group decides that they are not making progress in the experiment.

**Task:** Students will use the provided materials (insulators and conductors) to create a circuit that will cause a light bulb to illuminate.

**Time Limit:** Approximately 50 minutes a day for 2 days will be the time allowed for this lesson

**Level of Voice:** Classroom Level 2 – Normal Voice Table Talk

**Social Skill:** cooperation, discussion, consensus, think/group/share, disagree with the idea not the person

**Engaging context: (15 minutes)** Students are prompted with scenario: Imagine you are home alone. The electricity shuts off. You cannot find a candle. The flashlight batteries have almost expired. All you have available are some potatoes, a small light bulb and a variety of materials to
connect them. What materials could you use to connect the potatoes to the light bulb to transfer the electricity?

Night satellite image of Earth from geology.com. Students will be shown a visual model of the Earth at night demonstrating the world’s usage of light and energy. Students are prompted to discuss how energy is generated. Naturally students will most likely answer with suggestions like power plants, dams (hydroelectric), solar, and wind. Inquire of students to generate ideas about how that energy is transferred from one place to another.


(Explore, experimenting) (30 minutes) When ready, the materials person will obtain a variety of materials that are conductors and insulators provided by the teacher. Students will be asked to predict which of these items will transfer energy from the potato to the light bulb. Students will be asked to justify their reasons for deciding which of these materials will or will not transfer the electricity. The recorder will note the group’s predictions on the prediction page. Teacher should monitor groups and asked tiered questions to further group progress. The reporter will share out the groups’ findings the culmination of the project.

(Imagine, Explain) (20 minutes) Students will use the handouts to record their findings. Teacher will facilitate conversations with questions such as. What makes ____________ a conductor of electricity? What makes this an insulator? Students will discuss their ideas with in their groups and share out. (Special attention should be paid to why some materials work over others.)

(Extend) (30 minutes) What other materials might use to conduct electricity? Why did you choose these materials? Students will generate ideas for other common items that contain electricity. Students will then partner with members of other groups so discuss their findings. After meeting with other groups students will take their shared experiences and justify their answers in writing.

Evaluate: (10 minutes) The students and teacher will determine what has been learned through the duration of this project.

1. Students will revise their predictions made at the beginning of lesson and determine if what they thought would conduct actually occurred. Students will enter the information on their student handout.

2. Students will evaluate their lesson on the self-assessment rubric.

3. Students will evaluate the participation of their team members through the group evaluation checklist.

STEM integration: This lesson integrates Science, Technology and Engineering. Students will create a power source to illuminate a light bulb. Project will be a single circuit electrical relay.
The Engineering piece occurs from the constraints of having to use household item to transfer electricity. Technology comes from the reality that our control of electricity is a relatively new invention. The scientific knowledge stems from knowledge of how electrical energy is transferred.

Materials List

- 8-10 potatoes for each group
- Zinc plated nails
- Small LED light bulb
- Student work sheets

*Connecting Materials* (materials may be added or taken away at teachers discretion)

- Rubber tubing
- Paper clips
- Copper wire
- Tooth picks

Website illustrating how to set up the project

http://mathinscience.info/teach/k5_science/physics/electric_circuits/potatolight.pdf
Inquiry-Guided Questioning Activity Overview

Considering that IBL relies on a teacher’s and a student’s ability to generate engaging scientific questions. It is important that they continue to develop their ability to strategically guide classroom discussion to facilitate meaningful dialogue and questioning practices. This activity provides exposure to being able to guide student conversations towards developing scientifically oriented questions.

In this activity we ask that you assign a simple homework task for your students:

*Look at various organisms and observe what qualities they possess. For example: it has a hard shell, thorns, lives underground, and has claws.*

In the meantime, take a moment to observe the guidelines on the next page. As part of the planning process, think about the comments that might be made and how you will guide the discussion towards the topic goal:

Why do you think ______________ has developed this quality?
How does __________ use __________ survive?

Set time aside to prompt the class about the observations that were made. Pay attention to types of questions that you ask and the comments that you make as you move through the conversations. You will need to reflect on these after the activity is finished.

This activity has been chosen because without carefully constructed questions on which to build a foundation inquiry-based activity, students may generate questions that are too broad or unanswerable. For example, given the same homework assignment and a lack of guided conversation, a student might construct a question such as, Why do insects have 6 legs? or Does...
As argued in Chapter 2, a teacher’s job is to guide learning and not just to dole out information. The overlying lesson is that a teacher should take the time to understand what the learning goal is and how to scaffold everything from activities to conversation.

*The question that has been provided is taken from NGSS standard 4-LS1-1. Feel free to change the question that is assigned to address the standards in your grade level. Provided below are some standards that can utilize a similar question the one provided.

3-LS3-1. **Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.** [Clarification Statement: Patterns are the similarities and differences in traits shared between offspring and their parents, or among siblings. Emphasis is on organisms other than humans.] [Assessment Boundary: Assessment does not include genetic mechanisms of inheritance and prediction of traits. Assessment is limited to non-human examples.]

4-LS1-1. **Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.** [Clarification Statement: Examples of structures could include thorns, stems, roots, colored petals, heart, stomach, lung, brain, and skin. Each structure has specific functions within its associated system.] [Assessment Boundary: Assessment is limited to macroscopic structures within plant and animal systems.]
5-ESS1-1. Support an argument that the apparent brightness of the sun and stars is due to their relative distances from Earth. [Clarification Statement: Absolute brightness of stars is the result of a variety of factors. Relative distance from Earth is one factor that affects apparent brightness and is the one selected to be addressed by the performance expectation.] [Assessment Boundary: Assessment is limited to relative distances, not sizes, of stars. Assessment does not include other factors that affect apparent brightness (such as stellar masses, age, stage).]
Inquiry Guided Questioning Activity

Scientific questions engage students by having them connect to science concepts. Scientific questions lead students to empirical investigations. Students naturally generate many questions that ask “why” about their surroundings. However, many “why” questions cannot be answered by science. Rather than ask why a particular phenomenon occurs, teachers can direct students to reword their question to ask how a particular phenomenon occurs. Teachers provide essential scaffolding in guiding student’s questions. Meaningful inquires result from questions that primarily originate with students as a result of their own personal investigations about the world and their surroundings.

Teachers should ask questions:

· To actively involve students in the lesson
· To increase motivation or interest
· To evaluate students’ preparation
· To check on completion of work
· To develop critical thinking skills
· To review previous lessons
· To nurture insights
· To assess achievement or master of goals and objectives
· To stimulate independent learning

Questions with higher cognitive demand should make up the largest portion of the question being asked.

Blooms taxonomy depth of knowledge

· Knowledge – recall data or information
· Comprehension – understanding meaning
· Application – use a concept in a new situation
· Analysis – separate concepts into parts; distinguish between facts and inferences
· Synthesis – combine parts to farm new meaning
· Evaluation – make judgements about the value of ideas of products

Resources


Reflective Practice Worksheet Overview

Reflective practice is an important part of our teaching profession (Boden et. al, 2006). It is a “systematic process of collecting, recording, and analyzing our thoughts and observations, as well as those of our students and going on to making changes (Tice, 2004).

Without reflective practice a teacher might come to false conclusions about events that take place during a lesson. A typical comment might look like “The lesson went well” or “It didn’t go as planned”, but the question that lingers after this type of statement is usually always “Why?” or What could I have done differently? In the absence of a log of events and reactions, pinpointing a reason would be difficult or inaccurate. Therefore, as part of this professional development, we ask that you use the worksheet throughout your experience so that it can be used during our group discussions.

The worksheet that is included is meant to be used throughout an IBL unit. It is a one page worksheet that helps a teacher keep a record of the types of questions, comments, and answers that teachers and students make during classroom conversations. In using this worksheet, a teacher can choose to write notes at the end of every lesson, activity, week, or only when something worth noting occurs.

Each section is tailored to fit a typical stopping point during an inquiry based lesson. In the Posing the Problem section you should make observations about the process that was taken to create an inquiry question. You can use this to either observe student questioning abilities or your reactions to their comments. During the Collection of Information phase you will want to take note of student strengths and weaknesses in researching information. You can also document student to student conversations during this time. This section is useful in deciding if mini-lessons are needed to support a successful outcome of the inquiry process. The Whole-
Class Discussion section can be used at the end of each day or during culminating activities such as classroom presentations. Here you can take notes of how students question or support each other in an effort to make sense of what has been learned. At a later time, one can take then a moment to analyze a variety of facets of the lesson with the intent of enriching the next activity.


### Reflective Practice Worksheet

<table>
<thead>
<tr>
<th>Date of Note</th>
<th>Observation notes, drawings, commentary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Posing the Problem</td>
</tr>
<tr>
<td></td>
<td>Collection of Information</td>
</tr>
<tr>
<td></td>
<td>Whole Class Discussion</td>
</tr>
<tr>
<td></td>
<td>Post Reflection/Extension Notes</td>
</tr>
</tbody>
</table>
Inquiry Lesson Planning Guide

Planning a fully integrated inquiry lesson will feel like a daunting task at first, but as mentioned in Chapter 3 this resource guide is designed to ease you into a fully integrated inquiry lesson. Appropriate tools are necessary to ensure successful implementation and outcomes for a lesson. This planning guide, which is taken from the Manitoba Department of Education, is designed to be used during a single subject inquiry lesson or a fully integrated one. It should not be viewed as a scripted lesson plan considering that Inquiry lessons can be dynamic in nature.

The planning guide is broken down into four columns:

- Column 1: Curricular Connections (subject area integration)
- Column 2: Curricular Outcomes
- Column 3: Instruction: Learning, Teaching, and Assessment Strategies (which includes the Inquiry Process or cycle)
- Column 4: Learning Resources/Sources

Column one pertains to which subjects are being explicitly integrated in this lesson. Many times though, one will feel that other subjects are unintentionally being addressed. The curricular outcomes column can be used several ways: it can describe scientific practices that a student will learn, standards that are being addressed, or skills that will be practiced. The end result should be a set of objectives that the lesson will gravitate towards. Column 3 revolves around the inquiry process. A key component of this section is the learning responsibilities section, which takes into account whether the lesson will be teacher driven or student driven as mentioned in Chapter 2. The final and fourth column is set aside to take note of what resources a
teacher will make available to the students. This includes readings, websites, videos, classroom centers, and teacher lessons. This section makes it clear that thinking about what a student will need before a lesson is implemented is important.

As part of the PD, you will be encouraged to fill out each section before implementing a lesson. Not all sections must be filled in the beginning but this guide will help in considering the components of your inquiry lessons. As you use this guide, you can use the guiding questions to help you think about each of the components. Over time you will feel more confident in designing and implementing your lessons.

The Four Column Inquiry Planner

Integrated Theme or Topic: ______________________________

Duration: __________________________________________

<table>
<thead>
<tr>
<th>Goals:</th>
<th>Performance(s) /Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processes:</td>
<td></td>
</tr>
<tr>
<td>Curricular Integration</td>
<td>What do I want my students to know or be able to do?</td>
</tr>
<tr>
<td></td>
<td>Instruction:</td>
</tr>
<tr>
<td>Curricular Integration</td>
<td>o How will I access prior knowledge?</td>
</tr>
<tr>
<td>Curricular Integration</td>
<td>o How will I facilitate student learning?</td>
</tr>
<tr>
<td>Curricular Integration</td>
<td>o How will I/they know what is learned?</td>
</tr>
<tr>
<td>o English Language Arts</td>
<td></td>
</tr>
<tr>
<td>o Math</td>
<td>Activating</td>
</tr>
<tr>
<td>o Science</td>
<td>Teacher Led</td>
</tr>
<tr>
<td>o Technology</td>
<td>Student Led</td>
</tr>
<tr>
<td>o Engineering</td>
<td>Shared</td>
</tr>
<tr>
<td>o Art</td>
<td>Choosing a theme or topic.</td>
</tr>
<tr>
<td>o Social Studies</td>
<td>Identifying Prior-Knowledge.</td>
</tr>
<tr>
<td></td>
<td>Asking Initial Questions.</td>
</tr>
<tr>
<td></td>
<td>Sources: Where will the students gather information?</td>
</tr>
<tr>
<td></td>
<td>Learning Resources, Technology, Print, Multimedia, etc.</td>
</tr>
<tr>
<td>Exploring and selecting sources.</td>
<td></td>
</tr>
<tr>
<td>Planning for inquiry.</td>
<td></td>
</tr>
<tr>
<td>Acquiring Information</td>
<td></td>
</tr>
<tr>
<td>-Gathering, processing, and recording information.</td>
<td></td>
</tr>
<tr>
<td>-Focusing the Inquiry.</td>
<td></td>
</tr>
</tbody>
</table>

| Applying |
| -Planning to express findings. |
| -Creating performance, Demonstrations, Products |

| Culminating Event |

---

The Four Column Inquiry Planner (with guiding questions)
Integrated Theme or Topic:
______________________________

Duration:
___________________________

Goals:
What do I want my students to know or do at the end of this unit?
What do I need to do to facilitate student success?

Performance(s) Expectations
How will my students show what they know or can do?

Processes:
How much autonomy will I provide my students?
1 2 3 4 5 6 7 8 9 10

Curricular Integration:
What subjects are being taught?

Curricular Outcomes
Instruction:
- How will I access prior knowledge?
- How will I facilitate student learning?
- How will I/they know what is learned?

Curricular Outcomes:
Instruction:
- How will I access prior knowledge?
- How will I facilitate student learning?
- How will I/they know what is learned?

Learning Resources,
Technology, Print, Multimedia, etc.

o English Language Arts
o Math
o Science
o Technology
o Engineering
o Art
o Social Studies

What standards will this lesson address?

What scientific skills are being

Inquiry Process
Activating 
- Choosing a theme or topic.
- Identifying Prior-Knowledge.

Teach
- Teacher Led
- Student Led
- Shared

Sources: Where will the students gather information?
What do I want my students to know or be able to do?

- Asking Initial Questions.
- Exploring and selecting sources.
- Planning for inquiry.

**Acquiring Information**
- Gathering, processing, and recording information.
- Focusing the Inquiry.

**Applying**
- Planning to express findings.
- Creating performance, demonstrations, Products

**Culminating Event**
Inquiry Assessment Rubrics

When planning an inquiry-based lesson a teacher should expect certain outcomes not only from their students but the quality and depth of their lesson. While no lesson is perfect, many lessons can be considered strong and very meaningful for the majority of students. A rubric is a useful tool to assist in the planning and evaluation of an inquiry-based lesson. Rubrics serve two general functions:

1. to clearly describe what classifies a beginning level of performance from an advanced performance
2. to communicate to students their strengths and areas that should be a target for growth and improvement.

These rubrics set three to four levels for assessing and communicating student and lesson development. These two rubrics should work in conjunction with each other to facilitate equity for all involved in the lesson. Point totals were not assigned to the various categories because the purposes of these rubrics are to describe a student’s sophistication as clearly as possible. The performance categories chosen should be used by teachers and students to:

1. Develop a profile of a student’s inquiry abilities at a given point in time;
2. Identify strengths and areas for improvement;
3. Clearly describe criteria for progressing to the next higher level of competence; and
4. Track student growth each year, and across grades.

The National Academy of Sciences identifies for main components for scientific inquiry:

Component 1- Making scientific observations and posing testable questions

Component 2- Designing investigations to answer scientific questions
Component 3- Displaying and working with data

Component 4- Communicating evidence-based conclusions
# Student Rubric for Inquiry Learning Assessment

**Name:**

<table>
<thead>
<tr>
<th>Skill</th>
<th>Beginning</th>
<th>Emerging</th>
<th>Aspiring</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Questioning</strong></td>
<td>The teacher thinks of the questions.</td>
<td>I think of questions to ask, with the teacher’s help.</td>
<td>I can independently discover questions about issues or problems about my inquiry topic.</td>
</tr>
<tr>
<td>(recognise decisions, issues and problems when looking at a topic)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Planning</strong></td>
<td>I find it difficult to plan my learning and locate information I need.</td>
<td>I can find some information to plan for my learning inquiry.</td>
<td>I can locate relevant information to help me learn and plan for my inquiry.</td>
</tr>
<tr>
<td>(Identify sources of information likely to build understanding)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gathering</strong></td>
<td>My information needs to be more organised.</td>
<td>I am able to organise some information for my learning</td>
<td>I am able to collect and organise important information for my learning inquiry.</td>
</tr>
<tr>
<td>(Collect and store information for later consideration)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Analysing</strong></td>
<td>I do not organise my information with the aim of making it useful or easy to use.</td>
<td>I am able to organise some of my information with the aim of making it useful for my learning inquiry.</td>
<td>I can clearly organise my information so that it makes sense and I can use if effectively.</td>
</tr>
<tr>
<td>(Reorganise information so that the most valuable becomes readily available to support understanding)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Synthesising</strong></td>
<td>I do not make my own decisions or solution but can tell about other people’s ideas.</td>
<td>I can reorganise and combine the decisions or solutions of others.</td>
<td>I can create an original decision or solution myself.</td>
</tr>
<tr>
<td>(recombine information to develop decisions and solutions)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **Evaluating**  
(Determine whether information gathered is sufficient to support a conclusion) | I make my conclusions quickly without much thought | I look for missing information that I need to know for my learning inquiry. | I test solutions and decisions to see if supporting information is suitable |
|---|---|---|---|
| **Reporting**  
(Translate findings into a persuasive, instructive or effective product) | I use other people’s ideas to support my own answers. | I offer some ideas of my own to support my findings. | I am able to create and present an original product that effectively addresses the original problem or issue. |
## Rubric for Discipline-Based and Inter-Disciplinary Inquiry Studies

<table>
<thead>
<tr>
<th><strong>Authenticity</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beginning</strong></td>
<td>The scope of the study is determined by the mandated curriculum. The assignments, activities, and tasks within the study contain few roles that reflect a single perspective.</td>
</tr>
<tr>
<td><strong>Developing</strong></td>
<td>The scope of the study, while determined primarily by the mandated curriculum, takes into consideration students’ interests and concerns. The assignments, activities, and tasks within the study contain some separate roles that reflect a limited range of perspectives.</td>
</tr>
<tr>
<td><strong>Emerging</strong></td>
<td>The scope of the study emanates from a question, problem, issue or exploration that is significant to the discipline(s), builds connections beyond the school, is mapped to the mandated curriculum and takes into consideration students’ interests and concerns. The assignments, activities, and tasks within the study require a complex array of roles and diverse perspectives.</td>
</tr>
<tr>
<td><strong>Aspiring</strong></td>
<td>The scope of the study emanates from a question, problem, issue or exploration that is significant to the discipline(s) and the community locally, provincially, nationally or globally; is meaningful and relevant to students; and is mapped to the mandated curriculum. The assignments, activities, and tasks within the study require students to engage with diverse ideas creating a dynamic environment in which contrasts, competition, and complementarity of ideas is evident, creating a rich environment for ideas to evolve into new and more refined forms.</td>
</tr>
</tbody>
</table>

### ASSESSMENT SPONSORS DEEP LEARNING AND IMPROVED INSTRUCTION

<table>
<thead>
<tr>
<th><strong>Beginning</strong></th>
<th>Assessment is used to grade student work. Students have a vague sense of the desired goal and limited or no knowledge of how to improve. The assignments, activities and tasks provide no opportunities for students to reflect on their learning.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Developing</strong></td>
<td>Assessment is used to grade student work and to a limited extent to guide teachers’ instructional planning. Students understand the desired goal; have no evidence about their present position in relation to that goal, and no guidance on the way to close the gap between the two. The assignments, activities and tasks provide limited opportunities for students to reflect on their learning.</td>
</tr>
<tr>
<td><strong>Emerging</strong></td>
<td>Assessment is dynamic woven into the design of the study from the onset providing timely, descriptive feedback and utilizing a range of strategies including peer and self-evaluation</td>
</tr>
</tbody>
</table>
to move learning forward. Students understand the desired goal; have some evidence about their present position in relation to that goal, and limited guidance on the way to close the gap between the two. The assignments, activities and tasks provide opportunities for students to reflect on their learning.

| Aspiring | Assessment is dynamic and embedded, guiding students’ learning and teachers’ instruction through which students have multiple opportunities to improve their work based on specific feedback, as well as contribute to the learning of their peers. Students understand the desired goal; have evidence about their present position in relation to that goal, and guidance on the way to close the gap between the two becoming owners of their own learning. The assignments, activities and tasks provide multiple opportunities for students to reflect on their learning. |

<table>
<thead>
<tr>
<th>ADDS VALUE BEYOND THE SCHOOL</th>
<th>The assignments, activities, and tasks students are asked to undertake within the study would not likely be tackled outside a school setting. Assignments, activities, and tasks require students to connect within the classroom community.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>The assignments, activities, and tasks students are asked to undertake somewhat connect to the work of adults outside the school. Assignments, activities, and tasks require students to connect with their community (locally, provincially, nationally and/or globally).</td>
</tr>
<tr>
<td>Developing</td>
<td>The assignments, activities, and tasks students are asked to undertake address a question, exploration, issue or problem, relevant to curriculum outcomes, and are grounded in the life and work beyond the school. Adults outside of the school context are intrigued by the study. Assignments, activities, and tasks require students to engage with their community (locally, provincially, nationally, and/or globally).</td>
</tr>
<tr>
<td>Emerging</td>
<td>The assignments, activities, and tasks students are asked to undertake are recognizable to those working within the discipline(s), i.e., someone working within the discipline(s) or profession might actually tackle a similar question, problem or exploration and it addresses curriculum. Assignments, activities, and tasks require students to contribute knowledge, products or services to their community (locally, provincially, nationally, and/or globally).</td>
</tr>
<tr>
<td>Aspiring</td>
<td>The assignments, activities, and tasks students are asked to undertake are recognizable to those working within the discipline(s), i.e., someone working within the discipline(s) or profession might actually tackle a similar question, problem or exploration and it addresses curriculum. Assignments, activities, and tasks require students to contribute knowledge, products or services to their community (locally, provincially, nationally, and/or globally).</td>
</tr>
<tr>
<td>STUDENTS LEARN WITH DIGITAL TECHNOLOGIES</td>
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<tr>
<td>------------------------------------------</td>
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<tr>
<td><strong>Beginning</strong></td>
<td>Digital technologies are used in perfunctory ways contributing little value to student learning.</td>
</tr>
<tr>
<td><strong>Developing</strong></td>
<td>Digital technologies are used in effective ways contributing to students’ enjoyment of learning.</td>
</tr>
<tr>
<td><strong>Emerging</strong></td>
<td>Digital technologies are used in ways that are appropriate to their use in the discipline(s), the world beyond the school, and add value to student learning.</td>
</tr>
<tr>
<td><strong>Aspiring</strong></td>
<td>Digital technologies are used in ways that mirror their use in the discipline(s), the world beyond the school, and extend, expand, and deepen student learning.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>STUDENTS ENGAGE IN ACTIVE EXPLORATION</th>
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<tbody>
<tr>
<td><strong>Beginning</strong></td>
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<tr>
<td><strong>Developing</strong></td>
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<tr>
<td><strong>Emerging</strong></td>
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<tr>
<td><strong>Aspiring</strong></td>
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<tr>
<th>CONNECTING WITH EXPERTISE</th>
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</thead>
<tbody>
<tr>
<td><strong>Beginning</strong></td>
</tr>
<tr>
<td><strong>Developing</strong></td>
</tr>
<tr>
<td><strong>Emerging</strong></td>
</tr>
</tbody>
</table>
requires adults to collaborate with one another and with students on the design and assessment of the study work.

| Aspiring          | Students engage with experts and professionals beyond the classroom to deepen their understanding and improve their performance and product. The teacher designs opportunities for students to improve their work as a result of connecting with experts/expertise. |

<table>
<thead>
<tr>
<th><strong>ELABORATED FORMS OF COMMUNICATION</strong></th>
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<tbody>
<tr>
<td><strong>Beginning</strong></td>
<td>Students have little or no opportunity to discuss their work with others. Assignments, activities, and tasks require students to communicate what they are learning to a teacher audience (e.g. handing it in as an assignment). Forms of communication meet school requirements but are disconnected from the discipline</td>
</tr>
<tr>
<td><strong>Developing</strong></td>
<td>Students have opportunities to share their ideas with each other. Assignments, activities, and tasks require students to communicate what they are learning with a classroom audience. Forms of communication meet school requirements and somewhat resemble those used in the discipline.</td>
</tr>
<tr>
<td><strong>Emerging</strong></td>
<td>Students have opportunities to share ideas and to negotiate the flow of conversation within small and large group discussions. Assignments, activities, and tasks provide opportunities for students to communicate what they are learning with an audience beyond the classroom. Forms of communication meet school requirements and resemble those used in the discipline.</td>
</tr>
<tr>
<td><strong>Aspiring</strong></td>
<td>Students have opportunities and are expected to engage in idea improvement; mirroring the work of disciplined thinkers in gathering and weighing evidence, and ensuring that explanations cohere with all available evidence. Assignments, activities, and tasks require students to communicate their learning with audiences appropriate to the discipline. Forms of communication meet school requirements and effectively reflect those used in the discipline.</td>
</tr>
</tbody>
</table>

*Inquiry and the National Science Education Standards* (National Academy of Sciences,
CHAPTER FIVE: IMPLICATIONS

Inquiry-based learning provides students with a hands-on approach to solving scientific problems. Students participating in these types of activities identify problems, plan solutions, implement these solutions, and revise their thinking based on results. The solutions are then modified to accommodate the best possible solution for a given scenario. The nature of science is one of constant experiment, evaluation, and modification. Students who begin these practices early in their education have additional background and support to facilitate the transition into becoming increasingly scientifically literate in the future.

Teachers who desire for their students to become scientifically literate will be successful by implementing the principles presented in this resource guide. If teachers are to be successful in the implementation of inquiry-based learning, more study needs to be done. While there are many excellent resources presented in this guide, there is a plethora of resources available. By giving students the foundation to develop their own inquiry questions, students will become confident in solving increasingly complex problems. Inquiry-based learning takes time and patience to build proficiency. This guide provides teachers with ideas and examples from which they can draw to implement and create their own project-based lessons.

Building up teacher morale and confidence is essential for the essential transfer of scientific knowledge skills and dispositions to students. The resources provided in this guide scaffold the professional development process from teachers’ introduction to the practice of inquiry-based education to proficiency in creating inquiry and PBL curricula. While the shift in teaching practices may be a difficult transition for teachers who have been mandated to provide their students with direct instruction lessons, understanding what inquiry is and how it can build a solid STEM KSD foundation for students in grades three through five, is essential in preparing
them to participate in critically important studies, majors and careers in the future. Additionally, pre-service teachers will find needed support for the implementation of project-based learning in their classrooms.

Inquiry-based learning is not a process that can be accomplished in one day. It takes an exceptional amount of time and effort to bring students to the level of independence when creating and completing their own inquiry projects. Teachers will undoubtedly find frustration while bringing their students to an understanding of how an inquiry-based assignment is conducted. Teachers will find challenges in providing students with meaningful foundations in which they can begin to become independent of the instructor. Meeting the rigorous challenges of the NGSS requires that teachers plan and implement lessons in which students become problem-solvers across the STEM curriculum with particular emphasis on the application of scientific principles.

Students’ experience of success in STEM education before they are form a negative learning self-concept is essential in bridging the gap that the U.S. faces in remaining competitive in the twenty-first century. Offering inquiry-based lessons early in a student’s education will assure that the tangible experiences continued into middle, high school and college result in ongoing curiosity and knowledge about the nature of science and importance for future study. The student’s acquisition and ease in applying problem-solving skills will facilitate academic success across the spectrum of STEM subjects and disciplines.

The resource guide has been developed with the understanding that as a teacher’s comfort level increases, so too will the comfort level of the students participating in inquiry lessons. Students will begin to identify that they are able to be independent thinkers. They will be
increasingly willing to take academic risks. Students will take the initiative to explore their own world and devise solutions to problems with increasing degrees of sophistication. Not only will they find success in science, but in all areas that require solutions to complex problems. The processes of active learning may be found to be extremely beneficial to young students because they will become able to think scientifically in an engaging and thoughtful manner (Sirinterlikci, Zane, & Sirinterlikci, 2009). Students with an incremental view of their own intellect will come to believe that their intelligence is malleable and can be changed through experiences (Dweck, 1999). If we want our students to believe they have value and the ability to succeed in life and work, we ought to provide them with the opportunities to form and change their opinions of their perceived success as early as possible.

Clearly, the perspectives advanced in this resource guide call for new and continuing research into what motivates our elementary-level students to participate in STEM preparation classes that advance them into STEM majors in high school and college. In so doing, these students may help populate the voids in the STEM labor workforce as they take their place as our own homegrown students (Christman, 2012). While studies have shown correlation between these theories of STEM curricula and workforce development more research is needed to create a strong basis for the inclusion of inquiry-based STEM education with our diverse elementary students.
REFERENCES


