Teacher Preparedness in Inquiry-Based Learning

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by
Jorge Cordova

in collaboration with
Bryan Johnson

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The thesis of Jorge Cordova is approved:

________________________________________  __________________________
Gregory Knotts, Ph. D.  Date

________________________________________  __________________________
Agustin Mena, M.A.  Date

________________________________________  __________________________
Susan Belgrad, Ed. D., Chair  Date

California State University, Northridge
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Dedication

The work presented here is dedicated to everyone who has chosen to dedicate their lives to the field of Education, to the fourth grade staff at Pacoima Charter School who has supported me, and to Vanessa Flores who has motivated me to reach my life’s goals.
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ABSTRACT

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By

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The purpose of this project/resource guide is to prepare upper-elementary teachers in teaching Inquiry-Based Learning (IBL) in light of STEM education. Many teachers are either unfamiliar or uncomfortable teaching IBL and are therefore unwilling to try out this methodology. Instructional approaches such as this can facilitate implementation and integration of the Next Generation Science Standards (NGSS) and the Common Core State Standards (CCSS). To prepare teachers, this project takes a professional development approach in which teachers are asked to plan and implement activities with their students while reflecting on their experiences throughout the entire process. It is the author’s opinion that by gradually exposing teachers to key aspects of IBL, they will develop a greater sense of self-efficacy and will thus become motivated to use it in their daily instruction. In addition, the project proposes that when teachers’ self-efficacy in STEM-integrated instruction is increased, so too will their students’ achievement and academic self-perception.
CHAPTER ONE: INTRODUCTION

The purpose of this Project is to demonstrate the potential of inquiry-based learning (IBL) structures for teachers in the elementary school classroom who will soon be challenged to prepare their students to meet the Next Generation Science Standards (NGSS). This Project provides a helpful resource and guide for upper-elementary teachers to promote both the understanding and background knowledge needed to effectively design, lead, and assess STEM-integrated curricular units of study that addresses 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, 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.

The NGSS are organized into three interconnected dimensions: (1) disciplinary core ideas (DCI), (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 (NGSS, 2013). The scientific and engineering practices are meant to show children the processes of how scientific and engineering knowledge is
constructed (NRC, 2012). Examples of this could include creating graphs, models, or arguments, combining information, conducting research to identify information, and evaluating solutions to problems. All of these actions correlate to the aforementioned 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, for example, the scientific method and the California State Standards, the real difficulty for teachers will be in developing lessons that will integrate all three components as is 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 new standards. Bybee (2014) provides a description of how the new science standards will change what has gone before and what implications they will have on teachers’ practice. For instance, the previous standards asked teachers to present individual facts that were related to a single discipline and grade level. 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 looks to not only make connections to other science subjects, but also to make connections to disciplines such as language arts, social studies, and mathematics (NGSS, 2013). The nature of science (NOS) will also play a guiding role in how students experience science. Before, science was treated as a body of knowledge that one would use to solve problems, but now it will be seen as a practice or a way of knowing, hence the inclusion of both engineering and scientific processes. The emphasis
is now being placed on knowing how a scientist or engineer gains knowledge on something that is unknown.

For decades, K-12 teachers have been encouraged to deliver meaningful and authentic science experiences to their students. But programs such as FOSS, which promoted hands-on science education, fell short because they also promoted memorizing facts instead of science practices. 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 curricula and instruction. The challenge is for students to acquire deeper science content knowledge. Teachers need to acquire a new pedagogy within a context that requires the integration of the “T” and “E” of STEM, which is currently being addressed by only a few elementary school educators. These teacher leaders need to set out to establish and present curricular models that deliver technology and engineering principles to students in advance of the middle and high school levels. It is hoped that the curricular and instructional innovations that have been implemented by these teachers will help to shift the focus of elementary school STEM teaching from direct instruction to inquiry and active learning.

The theoretical foundation that underlies each of these innovations should be considered when teachers are planning to implement the integration of STEM subjects required by NGSS. This Project advances the structures of IBL, which encourage teachers to create opportunities for student thinking to drive lessons, engage in dialogue with each other, and make connections to their prior knowledge. In essence students need to become active learners; where their questions drive lessons; and their prior knowledge
from real-life experiences 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 since the framers of the NGSS relied upon the findings of the NRC to guide them as they constructed the Standards. The Project identifies and develops the suggested design process and methodology for science instruction asserted within the NRC’s findings the promote procedures such as the variations of inquiry and the essential features of inquiry-based learning: Engaging in scientifically oriented questions, giving priority to evidence, formulating explanations, connecting explanations to scientific knowledge, and communicating and justifying explanations (NRC, 2000). The pedagogical content knowledge, together with the information and strategies that are advanced and disseminated in this Project, are expected to assist in the ongoing professional development of teachers. It is also likely that the NGSS-implementation resources provided in the Project will become available to K-12 teacher-preparation faculty as well as school-district leaders when considering standards-aligned STEM programs.

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 promote higher levels of student thinking and understanding of the nature of science (NOS). This Project present 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 upper-elementary-grade levels to effectively lead students to become successful science learners. The Project is 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? 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 seeks to provide insight for teachers into the ways in which the cooperative learning structures utilized during inquiry-based learning, will more-clearly reveal the nature of students’ STEM-discipline acquisition of knowledge, abilities and dispositions (KSD). The importance of formative assessments integral to IBL is addressed as it has become necessary for educators to provide both summative measures of evaluation regarding STEM achievement, and continuous feedback to students that addresses improvement of their habits of mind and social skills (KSD). The use of authentic, formative assessment is suggested as it assists educators in assuring that students have become more engaged, motivated 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 job 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. 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 American 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 and possibly a career in STEM (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 college students arrive at college well-intentioned and plan 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 they 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, our educators must become able to promote the early STEM-integrated curricula and instruction that promotes student access to achievement at the elementary and secondary levels of schooling and access to and retention in college majors and careers. The rates at which college students are beginning STEM programs but failing to complete these programs suggest 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 and succeed in 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), which were recently adopted by the state of California, have called for students to work cooperatively as they explore problems rather than memorize
vocabulary and facts. 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 key is to prepare students by engaging them in discovery or inquiry-based learning (IBL). Such processes provide students with ongoing, active and in-depth experiences in STEM disciplines. The challenge, therefore, is to assure that teachers can succeed in making this important shift from content-based teaching to concept-based STEM teaching in meaningful contexts that contribute to students’ self-efficacy within our STEM classrooms.

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

In addition to the shortcomings of access to our American STEM workforce, minorities have been generally underrepresented in upper division STEM classes and careers. According to Rodgers-Chapman (2013), Latino(a)s 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 effective strategies to increase participation among Latino(a) students who will otherwise continue to be underrepresented in STEM majors and careers (Rodgers-Chapman, 2013). While there is a growing body of research and scholarly literature related to this problem, it is essential to further develop curricula and instructional strategies that increase the self-efficacy of Hispanic students.
Students with low socio-economic standing are similarly underrepresented 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 often are located in affluent areas with access to a wider range of monetary and social resources. Rodgers-Chapman (2013) suggests that students coming from low-socioeconomic backgrounds tend to score better in schools where the ratio of higher socioeconomics is greater than 50%. Socioeconomic standing therefore is seen to play a vital role in student STEM achievement. 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.

**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 student’s 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. STEM learning that is project-based excites young students as within these programs and activities they are experiencing applications of content knowledge that they may not have the opportunity to put to use in directed instruction contexts. The learning environments that include such activities will spark motivation in students to pursue more advanced math and science coursework and ultimately leads students to a career in STEM (DeJarnette, 2012).

**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 fulfill 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 both 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). 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. The Sirinterlikci, et al. study, demonstrates the change in educational practices leading towards actively learning that supports Dweck’s principles of students being able to reassess their intelligence throughout a variety of experiences. While research into what motivates our students to participate in STEM-preparation classes and STEM majors in high school and college may help inform 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 these theories 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.

**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 models that help explain natural phenomenon, they will have to use their science and engineering practice to gather data and make connections, and they will also have to make direct connections to knowledge that was gained in previous classes that dealt with other disciplines and subjects. Even performance assessments would 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 curriculum 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 felt that the appropriate grade for the current 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, 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 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).

**Depth of Knowledge**

The content knowledge of teachers is essential to the improvement of teaching and learning. 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. Consider Math for example, 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 demands placed on teachers 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 if teachers know all the rules regarding mathematical instruction, they would not know enough to be able to instruct students in the ways that researchers and educators believe they should. However, teachers’ ability to use what they have learned to correct, refine, and improve instruction are all key components of effective teaching. Teachers must be able to observe learning situations and dissect them from moment to moment. They must 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. It is important to know how to create an environment where students are able to operate experimentally; and where they are encouraged to adapt to situations. The direction of 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).

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, 1966). 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 conclusion with consideration for evidence, promotes an 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 the instruction of students in 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 earth, physical and life science. 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 are 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 misconceptions and generating their own questions. Teachers are also challenge to provide meaningful feedback that accepts and scaffolds their students’ unique responses and ideas (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 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 these 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.

“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).
Understanding Inquiry-Based Learning as a Foundation of STEM Integration

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 constructivist practices 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.

Constructivism, as Dewey theorized, is the idea that students construct knowledge through active questioning, gathering and examining information, then drawing conclusions and reflecting on what they have learned (Burstein & Knotts, 2011). Brooks and Brooks (1999) agreed that among the many characteristics of constructivist teaching that support IBL, the key qualities include:

- 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;
- provide time for students to construct relationships and create metaphors (Brooks & Brooks, 1999).

An influential thought leader on the theory of constructivism, Jean Piaget felt that the growth of knowledge came from the experiences that a learner went through. 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 pointed out, Piaget thought that children are naturally capable of self-motivating themselves to construct their own knowledge (Smilkstein, 2003). John 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 discover (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 could ask, “Why do constructivist theorists and the NGSS standards ask such young children to act as scientists do?” Berger (2003) cites studies in which children as young as six-years old 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.

**Opposition to Inquiry-Based Learning**

Unfortunately, the decades-long calls for constructivist teaching practices that include IBL in the United States have been mostly unheeded. Elkind (2004) explains that the failure of its practice and full implementation could be attributed to three reasons: a
lack of teacher, curricular, and societal readiness. It has been documented that in some instances teachers think that they are actually teaching inquiry, but in reality, they are using a direct-instruction approach (Gooding 2009). To further point out the discrepancy, Gooding conducted a study in which it was found that many teachers are resistant to change, especially something like inquiry. Insight into the reluctance to change can be observed when teachers are interviewed. Morrison (2013) found that many teachers teach the way they were taught and so if constructivist or inquiry practices were not taught to them as students, they in turn are less likely to employ them. With this said, it is becoming clear that many teachers have not had the opportunity to understand inquiry-based teaching and its variations through engaging in it.

During the implementation of the No Child Left Behind legislation, the American educational system was compelled to move in the direction of direct instruction and, high-stakes testing where immediate results of student achievement took the place of student-driven exploration and active learning (Dee, Jacob, & Schwartz, 2013). It is now recognized that standardized tests do not show authentic learning; and while direct instruction is an important and necessary mode of teaching, it is most valuable for immediate recall, not for long-term learning. We now understand that authentic learning results from a gradual and extended process of experience, exploration, hypothesis testing and active construction. (Dean, 2006, Smilkstein, 1999; Baxter, Ruzicka, & Blackwell, 2012).

Inquiry-Based Learning Defined
Inquiry-based education is comprised of a diverse set of strategies in which students are directly engaged in observing and describing the natural and human world through explanations based on evidence generated from their work. Additionally, inquiry includes the activities students participate in while they develop knowledge and understanding of scientific ideas and an understanding of how scientists study the natural world (National Research Council, 1996). It is a student-centered approach to teaching and learning in which students generate a question and conduct an investigation. Keep in mind that it may also be teacher guided, for example, when the teacher selects the question. The teacher and the students can then negotiate an approach to conduct the investigation. 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, addresses inquiry (not necessarily as the sole work of a scientist, a teacher, or even a student) as focused mostly on 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 have interpreted inquiry in a great variety of ways. For the purposes of this Project, we have taken the NRC’s definition of inquiry to focus upon the intentions of the NGSS that have been guided by the NRC’s findings.

Studies show that the inquiry-based instruction can have a positive impact on student learning. Cuevas (2005) found that inquiry increased student learning, even in students of diverse background. Palisnecar (2002) also found that inquiry 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 use of 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 become able to develop habits of mind and problem solving practices that can not only be used in science but in many other subjects.

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 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) point out, it is the amount information that is provided to the learner that varies.

Like the name implies, the key to guided inquiry if found in the teacher’s ability to act as a guide through the entire inquiry process. It begins with a broad concept-based question that the teacher provides, like “How do organism’s 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 key questions that help guide student inquiry and not 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 teacher’s perceptions about open inquiry are not necessarily optimistic. This might be for the reason that, if not managed properly, students can become confused, disengaged, and lost during the open-inquiry process. But in order for autonomous learning to take place, teachers must accept and encourage it, and students must be self-motivated to learn (Smilktein, 2003; Brooks, 1999).

**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 their 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.

Those that promote the belief that students should understand the nature of science (NOS) provide opportunities to acquire skills that are useful in more than just science (Ashbrook, 2014). Questioning, investigation, and pattern recognition are key human skills that develop over time and allow us to build the foundation to inquire 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 project-based learning (PBL). Creativity and imagination are regarded as key components of the NOS. Beginning as early as third grade, students will soon be instructed that science is not an individual process but a collaborative process that answers questions that examination of empirical evidence (NGSS, 2013).

Furthermore, exposing our students to STEM curricula at a young age may be the key to long-term success for American students seeking to pursue higher education and possibly a career in STEM. They can achieve these goals through the introduction and implementation of inquiry-based learning in the elementary levels of our curriculum (DeJarnette, 2012). The IBL tasks that are provided in this 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 will 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.

These student-based outcomes are offered to teachers who seek to use this self-help guide toward building their next century teaching and learning PCK. It is anticipated that if successful, the resource guide will promote teacher self-efficacy in aligning to the NGSS in leading student achievement in STEM disciplines while bridging the gap students experience among these disciplines. In this manner, elementary school teachers will assist their diverse students in meeting the increasingly rigorous demands of STEM studies in high school and into post-secondary education.

**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, 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 had the opportunity to experience in school curricula. Informal education organizations such as EiE, LEGO Education and REC-VEX Robotics have demonstrated that STEM learning that is inquiry and project based
excites young learners. If elementary school teachers become successful in creating classroom settings and lessons that integrate these types of learning environments, they 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 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, skill and understanding of how their curriculum and instruction can lead students to majors and careers in STEM fields.

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 come to believe that their intelligence is malleable and can be changed through experiences (Dweck, 1999). The Sirinterlikci, et al. study, demonstrating the change in educational practices leading towards active learning would support Dweck’s hypothesis that students become able to reassess their intelligence through a variety of experiences. Research into what motivates our students to participate
in STEM preparation classes and STEM majors in high school and college may help populate these voids within our own homegrown students (Christman, 2012). The correlation between these theories creates a strong basis for the education of our elementary students in STEM. If we want our students to believe they have value and the ability to succeed we ought to provide them with the opportunities to form and change their opinions of their perceived success as early as possible.

**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 with 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 within 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, and Huggins found that fourth-grade students participating in their three-year study made significant gains. The study findings showed that these positive gains might be attributed to effective professional developments which lead to effective science instruction.
Because teacher’s self-efficacy in inquiry-based learning increased, student learning was promoted. The professional development not only focused directly on science inquiry instruction, but also integrated an English language development component (Santau, Maerten-Rivera, & Huggins, 2011).

These findings of these two studies provide some initial evidence that another benefit of inquiry-based instruction is increased student development in their vocabulary skills. By using academic vocabulary to analyze their surrounding and justify their conclusions, students are showing competency in the language skills that are directly taught during English language arts instruction. Students in the studies who came from lower-SES backgrounds achieved at a comparable rate to a norm group as a result of effective inquiry-based instruction (Santau, Maerten-Rivera, & Huggins, 2011). For the purposes of this resource guide we mention this key point with the intent to point out that even though Vocabulary development will not be explicitly address in the resources, it can be indirectly affected.
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. It is not intended to give advanced support to teachers who have already begun the process of inquiry-based learning. There is no one size fits all resource that will engage and reach every student. Therefore, the teacher should use their own professional discretion when applying the material provided in this resource guide. However, the material provided is easily adaptable for teachers at all levels of comfort and experience.

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 a 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.

Providing a starting point gives the teacher a place to discover or refresh their 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. For example, using the matrix to plan lessons assists the teacher in addressing the various components of inquiry. By breaking the process down into four
components with subcomponents, a teacher is able to create and plan meaningful inquiry experiences for their students.

Teachers should use this guide as a starting point to facilitate their own unique IBL experiences for their students. The 5E’s lesson format can be adapted for any type of inquiry-based question a student or a teacher researches. It is our intention that this guide drives increased participation in inquiry-based learning and creates an environment of wonder and discovery.

This guide seeks to promote the constructivist qualities a teacher should practice while preparing and engaging their students to be successful in IBL. Brooks and Brooks states 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.

**Resource Guide Overview**

As mentioned, the resource guide has been organized a development 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 that an activity should gravitate towards. 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 throughout the activity titled, “Inquiry Guided Questioning Activity”. Constructivist 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 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 subjects, whereas the “Plant Growth Chamber Activity” and the “Spud Light” lessons are fully integrated. In the addition to the standards, the NGSS standards makes suggestions about which standards from other subjects and engineering practices can be integrated. A teacher who is not familiar with integration would have considerable difficulty in designing a lesson that integrates more than a couple subjects. Of course, 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.

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? And 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 multimedia 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).

The Inquiry Process

1. **Pose Real Questions**
   - What do I want to know about this topic?
   - What do I know about my question?
   - How do I know it?
   - What do I need to know?
   - What could an answer be?

2. **Find Resources**
   - What kinds of resources might help?
   - Where do I find them?
   - How do I know the info is valid?
   - Who is responsible for the info?
   - What other info is there?

3. **Interpret Information**
   - How is this relevant to my question?
   - What parts support my answer?
   - How does it relate to what else I know?
   - What parts do not support my answer?
   - Does it raise new questions?

4. **Report Findings**
   - What is my main point?
   - Who is my audience?
   - What else is important?
   - How does it connect?
   - How do I use media to express my message?

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 various levels 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 determined 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 an 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, H20, and sunlight.

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

Formation of Groups

Role Assignments:

Materials manager

Reporter/Recorder

Participation encourager

Quality Control Manager

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.

Processing/Standards Addressed

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 formula as a multiplication equation with an unknown factor.

Rate your mate, Journal Entries in Science Journals,

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 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.

**Explore**

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

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

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.*
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 diverse 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 groups 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 idea 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 hair on a dog keep it warm? 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 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 inquiries 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


Retrieved from

http://beyondpenguins.ehe.osu.edu/.

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.


Julie Tice, Teacher, Trainer, Writer, British Council Lisbon 2004 *Reflective teaching: Exploring our own classroom practice*  
http://www.teachingenglish.org.uk/article/reflective-teaching-exploring-our-own-classroom-practice
## 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></th>
</tr>
</thead>
</table>
| **Performance(s)
/Expectations** |  |

<table>
<thead>
<tr>
<th>Processes:</th>
<th></th>
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</thead>
</table>
| **Curricular Integration**
What subjects are being taught? |  |
| **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** |  |

<table>
<thead>
<tr>
<th>Inquiry Process</th>
<th>Activating</th>
<th>Teacher Led</th>
<th>Student Led</th>
<th>Shared</th>
<th>Sources: Where will the students gather information?</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Choosing a theme or topic.</td>
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<td></td>
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<tr>
<td>- Identifying Prior-Knowledge.</td>
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<tr>
<td>Art</td>
<td>Social Studies</td>
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<tr>
<td>Asking Initial Questions.</td>
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<tr>
<td>- Exploring and selecting sources.</td>
<td></td>
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<tr>
<td>- Planning for inquiry.</td>
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<tr>
<td>Acquiring Information</td>
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<tr>
<td>- Gathering, processing, and recording information.</td>
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<tr>
<td>- Focusing the Inquiry.</td>
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<tr>
<td>Applying</td>
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<tr>
<td>- Planning to express findings.</td>
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<tr>
<td>- Creating performance, Demonstrations, Products</td>
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<tr>
<td>Culminating Event</td>
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</tbody>
</table>
The Four Column Inquiry Planner (with guiding questions)

Integrated Theme or Topic: ________________________________
Duration: ____________________________

<table>
<thead>
<tr>
<th>Goals:</th>
<th>What do I want my students to know or do at the end of this unit?</th>
<th>What do I need to do to facilitate student success?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance(s) Expectations</td>
<td>How will my students show what they know or can do?</td>
<td></td>
</tr>
<tr>
<td>Processes:</td>
<td>How much autonomy will I provide my students?</td>
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<tr>
<td>1 2 3 4 5 6 7 8 9 10</td>
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</tr>
<tr>
<td>Curricular Integration: What subjects are being taught?</td>
<td>Curricular Outcomes Instruction:</td>
<td></td>
</tr>
<tr>
<td>o How will I access prior knowledge?</td>
<td>o How will I facilitate student learning?</td>
<td></td>
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<tr>
<td>o How will I/they know what is learned?</td>
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<tr>
<td>Curricular Outcomes Instruction:</td>
<td>Learning Resources, Technology, Print, Multimedia, etc.</td>
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<td></td>
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<tr>
<td>o How will I/they know what is learned?</td>
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<tr>
<td>Inquiry Process</td>
<td>Sources: Where will the students</td>
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<tr>
<td>Activating Teacher Led Student Led Shared</td>
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<tr>
<td>What standards will this lesson address?</td>
<td>What scientific skills are being practiced?</td>
<td>What do I want my students to know or be able to do?</td>
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<td>----------------------------------------</td>
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<td>--------------------------------------------------</td>
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<tr>
<td>o Choosing a theme or topic.</td>
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<td>Acquiring Information</td>
</tr>
<tr>
<td>o Acquiring Information</td>
<td>o Acquiring Information</td>
<td>o Gathering, processing, and recording information.</td>
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<tr>
<td></td>
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<tr>
<td>Culminating Event</td>
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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> <em>(recognise decisions, issues and problems when looking at a topic)</em></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><strong>Planning</strong> <em>(Identify sources of information likely to build understanding)</em></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><strong>Gathering</strong> <em>(Collect and store information for later consideration)</em></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><strong>Analysing</strong> <em>(Reorganise information so that the most valuable becomes readily)</em></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 it effectively.</td>
</tr>
<tr>
<td></td>
<td>available to support understanding</td>
<td>Synthesising (recombine information to develop decisions and solutions)</td>
<td>Evaluating (Determine whether information gathered is sufficient to support a conclusion)</td>
</tr>
<tr>
<td>---------------------</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 look for missing information that I need to know for my learning inquiry.</td>
</tr>
<tr>
<td><strong>Evaluating</strong></td>
<td>I make my conclusions quickly without much thought</td>
<td>I test solutions and decisions to see if supporting information is suitable</td>
<td>I test solutions and decisions to see if supporting information is suitable</td>
</tr>
<tr>
<td><strong>Reporting</strong></td>
<td>I use other people’s ideas to support my own answers.</td>
<td>I offer some ideas of my own to support my findings.</td>
<td>I am able to create and present an original product that effectively addresses the original problem or issue.</td>
</tr>
</tbody>
</table>
### Rubric for Discipline-Based and Inter-Disciplinary Inquiry Studies

<table>
<thead>
<tr>
<th>Authenticity</th>
<th>Description</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>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beginning</strong></td>
<td>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.</td>
</tr>
<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</td>
</tr>
</tbody>
</table>
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.

Emerging  | 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 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><strong>ADDS VALUE BEYOND THE SCHOOL</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>Beginning</strong></td>
</tr>
<tr>
<td><strong>Developing</strong></td>
</tr>
</tbody>
</table>
| **Emerging** | 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).

| Aspiring | 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). |

<table>
<thead>
<tr>
<th>STUDENTS LEARN WITH DIGITAL TECHNOLOGIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
</tr>
<tr>
<td>Developing</td>
</tr>
<tr>
<td>Emerging</td>
</tr>
<tr>
<td>Aspiring</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>STUDENTS ENGAGE IN ACTIVE EXPLORATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
</tr>
<tr>
<td>Developing</td>
</tr>
<tr>
<td>Emerging</td>
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<tr>
<td>Aspiring</td>
</tr>
</tbody>
</table>
discipline (i.e. field work, labs, interviews, studio work, construction, working with complex problems, etc.) to negotiate a fit between personal ideas and the ideas of others.

<table>
<thead>
<tr>
<th>CONNECTING WITH EXPERTISE</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Beginning</strong></td>
<td>Students hear or read about relevant information from the teacher, or resources provided by the teacher. The teacher designs the task in isolation (without input from external expertise).</td>
</tr>
<tr>
<td><strong>Developing</strong></td>
<td>Students engage with speakers or interviews with experts from outside the classroom. The teacher designs the task in consultation with expertise, either directly or indirectly regarding the topic for study.</td>
</tr>
<tr>
<td><strong>Emerging</strong></td>
<td>Students observe and interact with adults with relevant expertise and experience in a variety of situations. The teacher designs the task in collaboration with expertise, either directly or indirectly. The study requires adults to collaborate with one another and with students on the design and assessment of the study work.</td>
</tr>
<tr>
<td><strong>Aspiring</strong></td>
<td>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.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ELABORATED FORMS OF COMMUNICATION</th>
<th></th>
</tr>
</thead>
<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.</td>
</tr>
</tbody>
</table>
audience. Forms of communication meet school requirements and somewhat resemble those used in the discipline.

| Emerging          | 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. |
| Aspiring          | 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. |

Inquiry and the National Science Education Standards (National Academy of Sciences, 2000):
CHAPTER FIVE: IMPLICATIONS

Inquiry Based Learning is not a novel or recent idea. It is a subset of a well-developed constructivist idea. It is a principle that lies in the belief that children are capable of much more than memorizing fact. The reality is that they are capable of developing their own questions and ways of answering them, just as scientists would. They are able to judge when data is valid and when conclusions are justified. But like any other skill and ability, guidance is needed. Inquiry based learning is not an easy approach to teaching. It requires many of the skills that are presented in the habits of successful teaching. Most notably it requires the willingness to release more control to the students as their abilities develop. Through preparation, practice, and reflection, a teacher can develop the skills and confidence that are needed to do so effectively.

This resource guide looks to better prepare teachers for cooperative learning strategies like Inquiry Based Learning. It is the opinion of this resource guide the success of its recommendations relies on teacher participation throughout the entire professional development, especially for those who have little to no experience with IBL. Teachers who look to boost their student’s science practices should use and adapt the resources that presented to fit the needs of their students. Yet this guide presents a miniscule fraction of the resources that are available to teachers of all grade levels. Programs such as JPL, NASA, and EiE understand the need to develop instructional materials that support engaging a student’s interest in STEM subjects. For this reason, they offer their ideas at little to no cost.

In addition, the resources are a useful venue from which to prepare for the implementation of the NGSS standards. Just like IBL, the standards look to increase a
student’s scientific literacy. Legislators, STEM professionals, and educators are working together to outline what is needed to be successful in college and in their careers. Inquiry can be one of those approaches. Teachers, schools, and districts that are also taking the initiative to discuss how they will approach the standards can begin by exploring this guide simply to get a sample of the broad resources that are out there.

As mentioned in Chapter 2, a teacher’s confidence in their ability to teach STEM subjects affects their student’s feeling of self-efficacy as well. Through their experiences with STEM they will begin to feel that they are capable of “doing science”. This will also have a rippling effect that can result better performance for the rest of their academic careers. Furthermore, their confidence will extend to affect their choices they make when choosing their careers. STEM jobs in fields that they would otherwise not have will become wonderful possibilities.

Further research into IBL is needed though. There exists a limited amount of data that points to which setting of IBL is ideal for lower elementary students. We know that children are capable of completing an inquiry activity but, what is developmentally appropriate at each grade level? Are children who receive IBL instruction from the onset of their academic careers more likely to enter STEM careers? This work would agree given the empirical and theoretical evidence that has been provided. More IBL materials should be created. Cooperative Learning Communities should be created to explore not just IBL but also to explore other types of group learning environments that promote the growth of scientifically capable citizens.
References


