Inquiry Learning and Motivation

By

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Introduction

"Education consists mainly of what we have unlearned."

~ Mark Twain

I was a junior in college and the idea that in another year I would be thrown ceremoniously into the work force to make my way as a scientist in the world brought me nose to nose with the fact that I was utterly unprepared for that impending eventuality. I had zero experience in a lab of the real world or academic variety. All my hands-on experience had come from pre-scripted lab assignments, with clear goals and patently right answers. Sometimes I got it 'right', but more often than not, I found I was wrong. Which, my laboratory professor explained in a pained voice, meant my technique sucked. I was a failure for not knowing how to do a western blot the first time out. This was the extent of my education so far. However, I was aware that serious students were hitting up professors for volunteer hours in their labs, working on real projects (or possibly just washing the glassware), and getting some much needed experience, and even more importantly, reference letters for actual jobs after school. It was time I did the same.

After a seriously long pep talk, I ventured into my favorite professor's office to offer my meager laboratory skills. Dr. Redgrave kindly told me that she had a waiting list of freshmen lined up to work in her lab when they eventually became upper classmen and she couldn't accommodate me. However, there was a new professor down the hall who was just hired and probably didn't have that problem yet. I walked down the hall. Dr. Shoal was dwarfed by a ginormous umbrella plant, a welcome gift from the botanist next door. I sat down and gamely offered to volunteer in his lab. When he said, "This must be my lucky day! I just had a master's student apply too!" I knew I'd hit the jackpot. Then he said something that I'd never heard. Not once in my sixteen years of education. "So, what do you want to work on?"

"Uh…," was my eloquent response.

And then a fire like I'd never known consumed my every waking moment. I read all his papers, I read the papers he cited, and the papers they cited. I became an expert on crustacean hormonal systems and found that sweet spot, that spot where you realize the literature ends and you are poised on cliff staring out over a vast ocean of uncharted territory, the unplumbed depths of original research.

Then I began to plan. I studied techniques and wrote up procedures. Suddenly procedures I'd done blindly and with all the interest of clipping my toenails now made *sense.* I needed them to *explore my questions.* I wrote up twenty pages of procedures to try and sequence crustacean hyperglycemic hormone from *Cancer magister*, the tasty Dungeness crab. It had never been done before.

Then I began to work.

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"So what do you want to work on?" Amazing how such a simple question could elicit such a powerful response. Why did it take sixteen years to be given the opportunity to ask my own questions? What happens when we ask students to generate their own questions? **How I can effectively scaffold inquiry learning in my classroom and how does it affect student motivation?**

During my teaching career so far I have tried to address this question and found limited success. Students are spectacular at generating questions. This year I focused on having students record their questions as they observed the world around them, activities in the classroom, or even YouTube videos that got them thinking. The results were profound. Within weeks we had generated hundreds of questions about the universe around us. The tricky part came in identifying researchable questions and then planning out experiments to test them. Understanding the inquiry process in a clear and actionable way is a challenge for many students. In light of this, a variety of sub-questions present themselves: What does student inquiry look like in the classroom? What skills do students already have? What skills are involved in inquiry? How do we effectively explore our questions? How can I measure the development of inquiry skills? How can I effectively scaffold these skills for students? Does inquiry learning motivate students? This proposal outlines how I plan to explore these questions, and in time, share my findings with other educators interested in a more authentic experience of science in their classrooms too.

Understandings

National Science Education Standards And Inquiry

Despite two decades of increased focus on teaching science through inquiry, it is still the exception rather than the rule in American high school classrooms (Deters, 2005). In 1996 the National Science Education Standards (NSES) published by the National Research Council (NRC) state:

> Schools that implement the *Standards* will have students learning science by actively engaging in inquiries that are interesting and important to them.
>
> Students could not achieve the *Standards* in most of today's schools. Implementation of the *Standards* will require a sustained, long-term commitment to change.

However, in the interim sixteen years only modest progress has been made towards systematic change. In its most recent publication, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, the NRC defines scientific and engineering practices as: "*asking questions and defining problems, planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information."* These practices reflect the process that scientists go through to create an understanding of scientific phenomena, and it is assumed that following these practices provides a more authentic experience for students as researchers and active participants in constructing their own understandings of the world around them.

Origins of Inquiry

Inquiry has its roots in social development theory, constructivism, and open learning. Vygotsky's theories on social development revolve around the role of social interaction in learning and the Zone of Proximal Development; the zone in which optimal learning is achieved, defined as the distance between a student's ability to perform a task with guidance or peer collaboration, and the student's ability to solve the problem independently. Once success is experienced the student is able to seek successive challenges (Vygotsky, 1978). Inquiry learning assumes that knowledge is built in this step-wise fashion and that learning occurs best in group situations. Von Glaserfeld (1989), a prominent constructivist wrote:

> Students may not have the same particular goals that scientists try to attain. But unless we assume that they share, with the inventors and developers of the conceptual models we call science, the goal of constructing a relatively reliable and coherent model of their individual experiential worlds, we cannot lead them to expand their understanding.

> Memorizing facts and training in rote procedures cannot achieve this. (p. 133)

Open learning theorists propose learning without the constraints of a "right answer," or explicit objectives, and instead emphasize following a path of inquiry, where students manipulate information and actively seek to create meaning from a set of given materials or circumstances. Both John Dewey and Martin Wagenschein were strong proponents of open learning as a means to understanding over rote memorization of knowledge. In his 1916 *Democracy and Education* Dewey discusses how, in a school environment learning often occurs out of context:

> There is a strong temptation to assume that presenting subject matter in its perfected form provides a royal road to learning. What is more natural than to suppose that the immature can be saved time and energy, and be protected from needless error by commencing where competent inquirers have left off? The outcome is written large in the history of education. Pupils begin their study of science with texts in which the subject is organized into topics according to the order of the specialist. Technical concepts, with their definitions, are introduced at the outset. Laws are introduced at a very early stage, with at best a few indications of the way in which they were arrived at. The pupils learn a "science" instead of learning the scientific way of treating the familiar material of ordinary experience. (Chapter 17)

Benchmarks for Scientific Literacy, released in 1993 by the American Association for the Advancement of Science, takes further steps to distinguish between inquiry and the current practice in most high school science classes:

> More complex than popular conceptions would have it. It is, for instance, a more subtle and demanding process than the naïve idea of making a great many careful observations and then organizing them. It is far more flexible than the rigid sequence of steps commonly depicted in textbooks describing the scientific method. It is much more than just doing experiments, and it is not confined to laboratories. If students themselves participate in scientific investigations that progressively approximate good science, then the picture they will come away with will likely be reasonably accurate. But that will require recasting typical school laboratory work. The usual high school science "experiment" is unlike the real thing. The question to be investigated is decided by the teacher, not the investigators; what apparatus to use, what data to collect and how to organize the data are also decided by the teacher (or the lab manual); time is not made available for repetitions or, when things are not working out, for revising the experiment; the results are not presented to other investigators for criticism; and, to top it off, the correct answer is known ahead of time. (p. 9)

More recently, Hammerman (2006) describes the eight essential elements of inquiry-based science instruction: (1) develops an understanding of basic concepts; (2) develops process and thinking skills; (3) builds understanding of ways that science is linked to technology and society; (4) provides experience necessary to support and develop or modify interpretations of the world; (5) enhances reading and writing; (6) allows for a diversity of strategies or learning; (7) allows for a variety of ways for students to show what they do know; and (8) actively engages students in the learning cycle.

Challenges to Implementing Inquiry in the Classroom

Given the emphasis on inquiry in the NRC released standards and the literature, why have not more teachers and districts implemented inquiry based teaching strategies in their classrooms? The reasons range from external legislative constraints such as the No Child Left Behind (NCLB) Act, to inadequate teacher training, to pedagogical resistance of teachers or administrators. Further complicating successful implementation are underlying issues related to student motivation and engagement.

The NCLB Act passed by Congress in 2001 linked funding to student performance in basic skills. Inquiry skills are very difficult to assess, and standardized tests often revert to assessing basic content knowledge instead of the more complex inquiry based skills stressed in the national standards. In addition, schools receiving title I funds are required to make Adequate Yearly Progress (AYP), meaning that students in a particular grade must receive higher scores than the previous year's students in the same grade (No Child Left Behind, 2002). Schools in jeopardy of not making annual yearly progress may feel significant pressure to teach to the test. This type of pressure often reduces the classroom environment to a 'drill and kill' type of teaching style. This has drastic consequences for student motivation and engagement (Sheldon and Biddle, 1998).

Implementing inquiry in the classroom is challenging. Most teachers are educated through lecture-based classes in university. According to a survey by Abraham (1997) 91% of universities in the United States use direct laboratory instruction in general chemistry. In addition, a survey of high school chemistry teachers found that almost half did not use any type of inquiry based laboratory activities in their classroom (Deters, 2005). Teachers often default to what they feel most comfortable with in a classroom, and it often mirrors their own educational experience. It is difficult to adopt inquiry-based methods of teaching if you have never experienced it yourself.

The planning stage is often the most important and one of the most difficult for the novice teacher. Inquiry-based learning is not something that can be put into action in the classroom quickly. A great deal of thought is required to address how standards will be incorporated, how students' knowledge and performance will be assessed, and how to navigate the open ended nature of student exploration. The teacher's responsibility during inquiry is to support and facilitate student learning (Bell et. al. 2010). The trick is to support student learning without providing too much information - eliminating the need for students to engage in critical thinking - but providing enough to prevent undo frustration. Without prior experience it can be a difficult line to walk.

Novice teachers' first attempts to scaffold inquiry in the classroom can be disastrous (personal experience), and without significant and artful scaffolding, students lack the skills and preexisting cognitive development to participate in open-ended inquiry. The first few times I tried an open inquiry design, a handful of my students would possess the necessary skills to run with the project, and the vast majority floundered, unable to begin. The most challenging aspects for them were coming up with an area to explore without really having any prior experience with the subject matter, and with the inquiry process itself. I had assumed that everyone had already been exposed to science fairs and experiment design beginning in elementary school, which was my experience when I was a child. What was immediately obvious in my classroom was that students did not understand how to a) generate an investigable question, or b) logically create an experiment to test an investigable question once they had thought of one. A common mistake novice teachers make is lacking the vision to see where students' weaknesses lie. Bain (2005) points out that teachers often assume that students will hold the same assumptions and thinking processes as a professional within that discipline. However, students have not yet developed the prerequisite body of understanding to work in this manner and must be adequately guided to ensure success and eventual mastery. Kirschner, Sweller, and Clark reviewed multiple studies that suggest that minimally guided instruction causes student frustration, incomplete concept schema development and cognitive working memory overload, impairing long-term learning and information retrieval (Brown, 1994; Arocha and Patel 1995; Sweller, 2004).

In response, Hmelo-Silver, Duncan, and Chinn, argued that inquiry and problem-based learning were not intended to be minimally guided, and in fact require extensive scaffolding and guidance for students to actualize the benefits of working in complex environments. The key would seem to lie in teacher professional development opportunities. However, studies on teacher professional development aimed at increasing inquiry based instruction have had mixed success. Factors such as deep content knowledge, access to inquiry experiences, teachers preconceived beliefs about their students' ability to learn science, and institutional support mechanisms all play a significant role in the efficacy of inquiry based professional development (Banerjee, 2010; Johnson, 2006; Leonard et. al. 2011).

In an effort to help teachers scaffold inquiry, Banchi and Bell (2008) suggest there are four levels of inquiry based learning in science education: confirmation inquiry, structured inquiry, guided inquiry, and open inquiry.

a. Confirmation inquiry is useful when a teacher's goal is to reinforce a previously introduced idea; to introduce students to the experience of conducting investigations; or to have students practice a specific inquiry skill, such as collecting and recording data

b. In structured inquiry, questions and procedures are still provided by the teacher; however, students generate an explanation supported by the evidence they have collected.
c. In guided inquiry, the teacher provides students with only the research question, and students design the procedure (method) to test their question and the resulting explanations. – Because this kind of inquiry is more involved than structured inquiry, it is most successful when students have had numerous opportunities to learn and practice different ways to plan experiments and record data.
d. At the fourth and highest level of inquiry, open inquiry, students have the purest opportunities to act like scientists, deriving questions, designing and carrying out investigations, and communicating their results. This level requires the most scientific reasoning and greatest cognitive demand from students.

Scaffolding inquiry experiences in the classroom along these lines can help students become familiar with inquiry skills and move towards greater autonomy in a structured and supported manner. I plan to use these layers in scaffolding inquiry in my classroom.

The Thorny Issue of Student Motivation

One of the critical factors in student learning is motivation. Early work by Pintrich et. al. (1993) described four aspects of motivation that affect conceptual change, where a concept is described as a belief, idea, or way of thinking. He found that students with a goal orientation of mastering subjects pursue deeper learning strategies, and that students perform better on tasks when they value them, when they believe they can do well on them, and when they believe they are in control of the outcome of their own effort. To this end, more authentic tasks, more student autonomy, and more student authority are associated with higher levels of student motivation. Inquiry learning often includes these features. Unfortunately, research relating inquiry and student motivation is sparse. Early research by Mistler-Jackson and Songer (2000), as well as, Patrick and Yoon (2004) both observed small numbers of students throughout an inquiry based unit, however, their results were not linked to typical motivational constructs such as that developed by Pintrich, and results were difficult to categorize in a useful way. Sandoval and Harven (2011) analyzed urban middle school students' perceptions of the value and difficulty of specific inquiry tasks in the context of Expectancy-Value Theory developed by Wigfield and Eccles (2000). They found that students rated the utility of inquiry tasks highly and furthermore they found that students valued the utility of knowing how to back up their ideas with evidence. Underscoring the necessity of clearly communicating the relevance of inquiry, a study exploring professional development focused on using guided inquiry in high school classrooms found that while 83% of students liked guided inquiry, and 54% felt that inquiry helped them to improve their self confidence, students did not think that inquiry was useful in preparing for graduation tests and college courses because they have learned from their older peers that hardly any inquiry is done in college courses (Banerjee, 2010) .

These seemingly dissonant views on inquiry point to the importance of student perceptions about their own learning and link back to Pintrich's ideas on motivation. Does the student see value in what they are learning? An effective analysis of the use of guided inquiry as a framework for teaching science will need to address not only student content knowledge and inquiry skill development, but student engagement and motivation levels as well. A failure to address the interconnected nature of learning and motivation will undermine any attempts at serious pedagogical reform and render the results of such a study ambiguous at best. It is my belief that this exact situation plagues the current research on inquiry and educational reform in general.

My Definition of Inquiry

Consistent with the literature, I define inquiry skills as observation, questioning, exploring, researching, and connecting. These practices make up more than just good scientific practice; they provide the foundation of reasoning with which to view learning and the world around us.

Observing includes refining attention to detail, pattern and anomaly recognition, and cultivating patience while suspending judgment. Students usually treat observation in a self-explanatory and rote fashion, but in actuality it is a subtle skill that requires practice and cultivation over a long period of time.

Questioning, is perhaps the most intuitive of the inquiry skills. Humans are innately curious creatures, and our capacity to generate questions about our environment is nearly infinite. As a class exercise I recently had students generate questions about class discussions and readings every day. By the end of the week we had a phenomenal question bank on scientific phenomena. The challenging aspect to questioning is to develop questions that allow for exploration. Testable questions are more difficult to frame, especially for students new to the inquiry process. Creating testable questions around which an experiment may be developed will require careful scaffolding.

Exploring combines the execution of experimental steps, data collection, data analysis, and supporting a claim from evidence gathered. This is probably the most significant and difficult portion of the inquiry process requiring the most guidance before students feel comfortable with the steps involved.

In order to bridge the gap between the novice nature of student inquiry skills and the goal of content acquisition, I have added researching as an inquiry skill. This allows for students to consult the literature on their topic and learn from experts. Scientists keep abreast of the accumulating literature in their field of interest, building on their knowledge base. It is imperative that students who are just beginning to construct a knowledge base, access expert opinions to help form accurate concept schema of the discipline being explored.

The final step in the inquiry loop is connection. Discussing, publishing, or presenting claims and evidence from exploration helps students anchor their work in the broader community and engages them in the global discourse around their area of study.

Conclusion

If implemented with careful scaffolding, inquiry learning has the potential to promote an understanding of authentic scientific practices and address many of the issues surrounding student motivation, such as providing more authentic learning experiences, increasing student choice, and promoting student ownership of learning. Teasing out where inquiry learning intersects with motivation has the potential to reform how educators and students view the learning process. What aspects of the inquiry process resonate most with students? When do they feel ownership of the process? How much guidance is necessary for students to feel successful? How can I effectively teach the inquiry skills and what does mastery look like for my students? What is my role in motivating students? Does ownership of motivation rest with the students? To answer these questions I look forward to exploring **how I can effectively scaffold inquiry learning in my classroom and analyzing how it affects student motivation**.

Setting the Scene:

About the School

The Gary and Jerri-Ann High Tech High charter school (HTH) was founded in 2000 and is currently one of five high schools in an integrated network of eleven schools across San Diego County spanning kindergarten through twelfth grade. Located within a central campus of six schools in the Point Loma area of San Diego, High Tech High's 572 students in grades 9 through 12 are accepted through a blind lottery system based on zip code to ensure a representative sample of ethnicities and economic status from around the county. High Tech High is a charter school under the San Diego Unified School System and as such, our students take all the required state standardized tests. However, we do not 'teach to the test' and are instead, encouraged to teach our academic passions and interests.

The High Tech High system of schools was founded on four design principles: personalization, common intellectual mission, real world connections and teacher as designer. Personalization is achieved through small class sizes, group learning, advisories, and a high degree of student choice in project work. Ideally, projects focus on real world connections to bring relevance to the material taught in the classroom and professionals and experts are encouraged to participate in the learning environment. The High Tech High model is untracked and students of all abilities are fully integrated within the classroom setting. Project based learning allows students with diverse abilities to engage in the pursuit of a common intellectual mission while group members benefit from each others learning styles and reasoning. Encouraging educators as the designers of curriculum ensures content is taught from genuine interests and passions, which hopefully translate into a higher degree of student engagement.

Transparency is a key component of the High Tech High model. The brick and mortar structures are built to promote collaboration, with open learning environments fostering discussion and communal support, and large classroom windows creating a sense of connection between students and visitors. Technology is also utilized to promote transparency, with students and educators sharing work publicly on the Internet, through videos, digital portfolios of work, or other media. Students have access to computers and a variety of software, including Geometer's sketchpad, Microsoft Office Suite with Word, Excel, and Powerpoint, as well as the Adobe Suite of programs including Photoshop, Premiere, Soundbooth, Dreamweaver and Flash, to fulfill project requirements and showcase their work. Student created digital portfolios can be found at http://www.hightechhigh.org.

Students

Due to the blind lottery system of entry, the student body at High Tech High comes from diverse socio-economic backgrounds and prior academic experiences. The largest spread in abilities and common skill sets is usually seen in grades that serve as entry points into the system (sixth and ninth). All students in my class have spent one or more years in the HTH system. As such, they are accustomed to working in a project-based environment, understand expectations, and feel comfortable with school norms such as revision and multiple drafts to achieve beautiful work (Berger 2003). In addition, thanks to a consistent emphasis on social-emotional development within the HTH system of schools, there is very little focus on differences between the students. Heterogeneous classes operate smoothly with little sign of segregation by obvious factors, such as status or race.

Students are not tracked in the High Tech High system and English learners, IEP students, and 504 students are fully integrated in the learning environment. Teams are purposefully organized to be diverse in abilities, gender, and ethnicities. Teachers design projects with multiple entry points and personalize instruction to meet the differentiation demands of their particular students, while academic coaches (instructional assistants) provide extra support within the classroom setting to promote equitable access to learning

Scientific skills, such as observation, questioning, and analysis are more evenly displayed throughout the team, with a few students exhibiting outstanding abilities, and the majority having only rudimentary skills in these areas, albeit, developmentally appropriate for tenth grade.

Family and Community Context

Home life, however, differs greatly for students and given the wide range of geographic locales from which HTH students travel to get to school, their access to family and community resources varies widely. Occasionally students on my team have limited access to the Internet and must visit local libraries or use the computers at school to accomplish homework requiring Internet research. In light of this fact, I try to give ample time for students to use the team laptops to get computer assignments out of the way during class.

HTH Student Demographic Profile

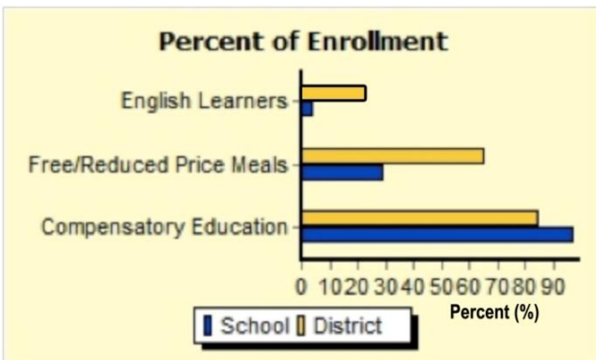

Figure 1: Percentage of English Learners, students who qualify for free and reduced lunch, and students participating in the federal Title 1 and/or the state Economic Impact Aid/State Compensatory Education (EIA/SCE) program. These programs provide supplementary services to low-achieving students from low income families. The goal is to improve student achievement in reading and mathematics. Image from Ed-data.com.

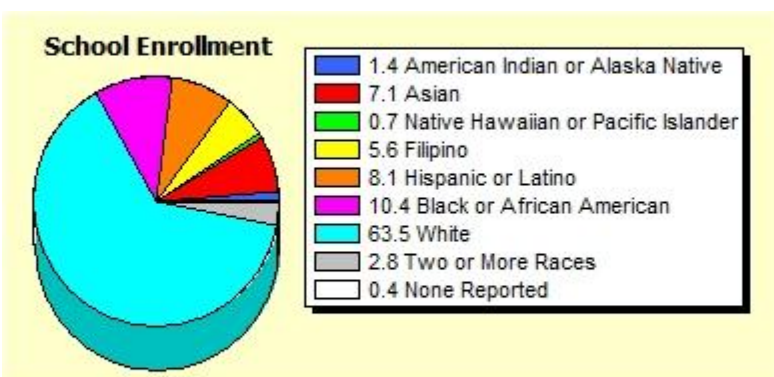

Figure 2. Demographic breakdown of High Tech High student population. Image from Ed-data.com.

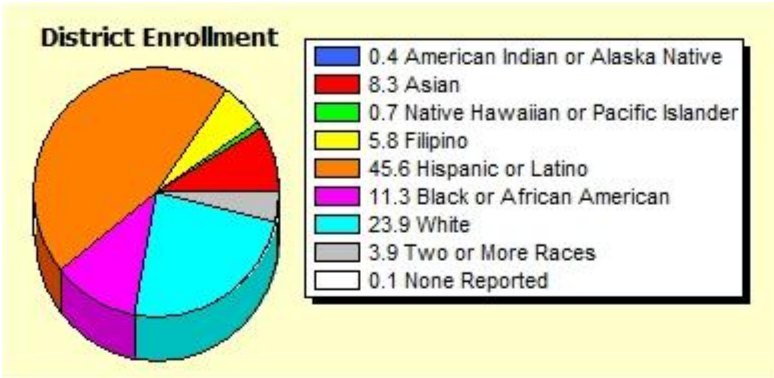

Figure 3. Demographic breakdown of San Diego Unified School District student population. Image from Ed-data.com.

Social Development

The High Tech High system of schools is purposefully designed to promote student socialization and collaboration. The focus on group work, accountability, communication and creating a respectful working environment is reinforced throughout the network of schools. Classes are intentionally small to promote close relationships between students and teachers, and differences are celebrated and accepted as the norm. Student safety from violence has never been an issue in my three years at High Tech High, and students are encouraged to work out problems in a calm and respectful manner.

Students come from a variety of backgrounds and problem solving strategies, however, the inverted structure of the K-12 schools located on the Point Loma campus (one elementary school, two middle schools and three high schools) allows each school to be seeded with students that have participated in the social-emotional curriculum practiced throughout the HTH system. In addition, the HTH staff works to create an environment where students feel appreciated, respected and valued, to optimize the learning environment.

Each adult participating in the administration or teaching at High Tech High has an advisory – a group of students selected from each grade that meet every Friday for forty minutes. Advisory plays an important part in student socialization by creating across grade relationships throughout the four years of high school. Advisory activities like the school wide Olympics, eleventh grade internship visits, and college day, promote school culture as well as forging respectful relationships and encouraging tolerance.

Coursework

Students in the High Tech High system study physics in ninth grade, chemistry in tenth grade, biology and engineering in eleventh grade, and environmental science and physics again in the twelfth grade.

In the tenth grade students are organized into three teams of roughly fifty students and three educators representing math, chemistry, humanities or Spanish. The three cohorts of students rotate through two of three possible teaching teams, covering math, chemistry, humanities, and Spanish in the course of their tenth grade year. Due to the pairings of teachers this results in two cohorts that receive double humanities over the year and one cohort that receives double chemistry (see figure 1 below).

	Semester 1	Semester 2
Cohort A	**Chemistry** **Humanities** **Math**	**Chemistry** **Spanish** **Math**
Cohort B	**Chemistry** **Humanities** **Math**	**Humanities** **Spanish** **Math**
Cohort C	**Humanities** **Spanish** **Math**	**Chemistry** **Humanities** **Math**

Figure 4: Rotating student cohorts

Students do not have a choice in the cohorts they are assigned to and the assignment is random and based on providing balanced classes with regard to ability, race, and gender. The students are further split into two classes that alternate between teachers to keep class size small. Collaboration is highly encouraged in curriculum design so students can make interdisciplinary connections and deepen understanding of content material.

The chemistry curriculum follows the science framework for California public schools: atomic structure, thermodynamics, compounds and reactions, gas laws, acids and bases, properties of solutions, oxidation-reduction reactions and nuclear chemistry. Students are also encouraged to explore experimental design and data collection, to write about scientific concepts and their applications in nature, and to think critically and deeply about how scientific discovery shapes society.

Major instructional resources include: Internet resources for student-derived projects, projects of my own design, experts, worksheets, games, current research, and ScienceBridge resources from the University of California San Diego (UCSD).

Internet resources such as online videos from the Khan Academy, video demonstrations and how-tos on YouTube or Instructables.com, procedures and background research for class work and student projects, have all been invaluable to both students and myself. Occasionally students have read original research papers to help with projects. During a recent green chemistry project one student pair read and followed a procedure they found in a scientific paper on how to extract chitin from shrimp shells to use as a biodegradable plastic alternative.

The ScienceBridge resources from UCSD provide training around labs that have real world relevance and examine issues that are currently being studied by scientists, for example ocean acidification as a byproduct of increased atmospheric carbon dioxide accumulation.

Three of the four founding principles - specifically personalization, real world connection, and common intellectual mission, inform all of my project designs and an ideal project is rich in all three. Often if a project is successful other teachers will use it with their students as well. This type of collaboration fosters a learning community between staff members and I use it to inform my practice.

Two recent projects that my students have completed was the publication of 'Chemisty and Conflict' a joint project with Peter Jana, a 10th grade humanities teacher. And 'Trash: the Science and Ethics of consumption'. In the 'Chemistry and Conflict' project students analyzed an element or molecule in the context of an historical event (such as uranium and the cold war) and then linked the historical event to a current conflict (Iranian nuclear program) and described the chemistry involved. The book was illustrated by photographs of copper etchings of student selected images related to their chapter focus. The etchings were created through an oxidation reduction reaction. Copies of the book and a project description can be found on my digital portfolio here: http://dp.hightechhigh.org/~dsharrock/projects-10.html

In 'Trash: the Science and Ethics of consumption' students conducted green chemistry experiments related to consumption and documented their process on a student created website. The humanities component looked at consumption through different philosophical lenses. The website can be found here: http://dp.hightechhigh.org/~dsharrock/webdesign/pages/Navigation%20pages/index.html

In both of these projects student choice guided the topics explored. The cross disciplinary nature reinforced the common intellectual mission aspect of project design, both projects examined real world issues and resulted in a public exhibition and a publicly available product, and whenever possible students contacted community experts for guidance further reinforcing the real world connection.

My Classroom

The chemistry classroom in which I teach is situated at the southeast corner of the building with large windows that let in lots of natural light. Most days students sit in groups of four at six tables. Counters line both ends of the classroom with storage shelves housing craft supplies, chemicals and glassware. A fume hood occupies part of the counter space and my sink empties down a storm drain, not a proper sewage line, much to my chagrin. The room is also bereft of gas lines or other useful laboratory infrastructure.

Methods

To explore the question of "How can I effectively scaffold inquiry learning in my classroom and what role does motivation play in the process?" I will use a variety of data collection techniques, including surveys, interviews, timed observation, journaling, and assessment data.

Surveys

Two initial surveys (Appendix A) will assess student views on the inquiry process and motivation. These surveys will serve as baseline data for the class. From the survey on the inquiry process the class will come up with a list of skills that we will focus on for the semester. Questions from these surveys will be included on subsequent surveys at the middle and end of the semester to monitor changes in student understanding of inquiry skills as well as student perceptions about the four aspects Pintrich (1993) found to contribute to motivation; student self assessment of goal orientation, whether or not they value the work they are doing, whether they believe they can succeed, and whether they feel in control of the outcome of their effort.

Interviews

Six students, three girls and three boys, will be selected based on initial observational data and their survey responses indicating lower motivation, medium motivation, and high motivation. These students will participate in three recorded interviews over the semester, one in the beginning, one in the middle and one after the semester is over. Interviews will seek to explore student perceptions on both inquiry as well as personal views on motivation and motivating factors that promote interest. These interviews will serve to illuminate issues and ideas that may not have presented themselves otherwise, and will provide feedback for revising the survey questions and other data collection methods.

Interviews will be audio recorded or videotaped and transcribed for easier analysis. Trends in ideas or word choice will be color coded according to inquiry or motivational parameters and analyzed for change over time, as well as in relation to each other at any one time. Random tangents and other miscellaneous information will also be analyzed for possible inclusion in future surveys, interviews, journal assignments, or assessments.

Timed Observations

Weekly timed video observations of 10 minutes each will focus on one of the focus students and their surrounding group during work time. I have six groups of four students each in the classroom. These recordings will focus on one group every week so that every six weeks all groups will have been observed once. These observations will be treated as field notes and provide anecdotal data about engagement and inquiry skill development, as well as a snapshot of student interactions in the classroom environment. These videos will be used to inform additional class surveys and interview questions for the focus students.

Videos will be watched on a weekly basis and field notes generated. Particular attention will be given to observing inquiry skills used, as well as indicators of student motivation and engagement, such as on task conversations, questions, and goal oriented behaviors.

Journaling

Students will keep inquiry journals to document their evolving understanding of chemistry and the inquiry process. At least once a week journal assignments will pertain to inquiry skills learned or analyze the class activity in terms of the motivational benchmarks established previously.

One major weekly journal assignment will be copied for analysis from the six focus students as well as any random classmates that have something to add to the research at hand in order to provide a snapshot of student reflections. The journal copies will be analyzed for conceptual understanding of chemistry content, motivation, and inquiry skill development.

Motivation Task Force

A group of students from both classes in partnership with myself will be tasked with designing research methods investigating factors that influence student motivation. All aspects of the classroom learning environment will be fair game, my teaching strategies included, provided the lens through which research methodologies are designed have a solid foundation in respecting student privacy and reputation, building a classroom culture of mutual respect and integrity, and promoting student learning. These students will collect and analyze data through surveys and informal class discussions/interviews with classmates. They will participate in a focus group style reflective dialog once a month that I will analyze for data on student motivation and engagement based on their increased role as participants in the research process.

Assessment Data

Finally, data from content related journal assignments, tests, and exit cards will be tallied and graphed to track content understanding and accurate scientific cognitive schema development on a whole class basis. In particular, exit cards and in-class journal assignments will be used to give regular snapshots of student understanding or misconceptions. These will be used to revise instruction as needed.

Timeline (ends in January)

August - 1st week of September

- Inform parents of research and get all necessary paperwork out of the way
- Gather baseline data about students – surveys & formal assessments
- Conduct initial student interviews
- Inform students about research area
- Select student researchers and focus group participants

September

- Monitor student thoughts about inquiry and motivation
- Monitor student skill acquisition (observing, questioning, connecting, reflecting critical thinking, problem solving, and confidence in abilities)
- Student researchers develop plan to track class motivation

October

- Student researchers implement research plan
- Continue to collect data
- Refine research questions and finalize focus

November

- Enter a phase of addressing questions or issues that arise with action and observation and repeat

December

- Collect final survey, interview, observational, and focus group and journal data
- Collect final assessment data
- Wrap -up research
- Debrief with student researchers and the class about the experience

January

- Begin to write up research findings

Appendix A

Survey I – initial student survey on inquiry– whole class

How knowledgeable are you about the inquiry process?

1. Not at all, never heard of it.
1. A little, I've heard the term before
2. Pretty knowledgeable, it was a focus in other classes
3. Very knowledgeable, I can list related skills and how they apply to the inquiry process

List skills you think are important for scientists to develop.

Do you possess any of these skills? Yes/No

Which ones?

Are any of these skills important in other professions or areas of life? Yes/No

Which professions or areas of life?

How confident do you feel about designing your own experiments?

1. Not confident at all
2. Somewhat confident
3. Pretty confident, I've done it before
4. Very confident, I've done it more than once before

Rate how comfortable you feel about using evidence from an experiment to support a claim.

{Example: *In three different trials salt water froze at a lower temperature than fresh water. From this evidence we claim that dissolved salt lowers the freezing temperature of water.* }

1. Not confident at all
2. Somewhat confident
3. Pretty confident, I've done it before
4. Very confident, I've done it more than once before

Survey II– initial student survey on motivation – whole class

Write about a time when you felt motivated to achieve something. Please be as descriptive as possible. What about the event made you want to do it?

Rate each of the following for how significantly they contribute to your motivation levels to do a task.

I am a very goal oriented person and I try to do well on most everything I try.

1. This relates to me not at all
2. This relates to me a little
3. This relates to me quite a bit
4. This is just like me!

I feel motivated when I can clearly see the value of a task beyond just the classroom.

1. This relates to me not at all
2. This relates to me a little
3. This relates to me quite a bit
4. This is just like me!

I feel motivated when I have freedom about how to accomplish a task.

1. This relates to me not at all
2. This relates to me a little
3. This relates to me quite a bit
4. This is just like me!

I feel motivated if I feel confident I can succeed at a task

1. This relates to me not at all
2. This relates to me a little
3. This relates to me quite a bit
4. This is just like me!

When faced with a new task that you've never done before what strategy do you rely on **most** to accomplish the task?

- Skills I have developed previously, I can usually figure things out on my own
- I usually ask another student for help
- I usually research how others have solved the problem and use their ideas
- I usually ask a teacher or academic coach for help

Interview questions – first interview – focus students

1. What does inquiry mean to you?

2. What skills do you think are involved?

3. Tell me about a time when you used these skills?

4. Tell me about a time when you felt very motivated to accomplish something difficult.

5. When something is hard, what do you do to get through it?

6. What do you find demotivating?

Initial journal prompts – whole class

- What is motivation? What helps motivate people? What motivates you?

- You have come across an interesting phenomenon. When you tap a clear liquid with a glass stirring rod it suddenly crystallizes into a sold form. What do you think is going on? Design an experiment to test your idea. Write a detailed procedure and include your reasoning for your steps.

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