Investigating the impact of beliefs, norms, and culture on teachers in both a comprehensive middle school and STEM-focused middle school

by

Raul J. Madera

SUBMITTED TO THE DEPARTMENT OF MATERIAL SCIENCE AND ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIRMENTS FOR THE DEGREE OF

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Signature of Author: Signature redacted
Department of Material Science and Engineering
April 28, 2016

Certified by: Signature redacted
Justin Reich
MIT Teaching Systems Lab
Thesis Supervisor

Accepted by: Signature redacted
Thomas W. Eagar
Professor of Material Science and Engineering
Department Thesis Reader

Approved by: Signature redacted
Geoffrey S.D. Beach
Professor of Material Science and Engineering
Chair of the Undergraduate Thesis Committee

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Abstract

Teacher perception of control, teacher beliefs, and school culture are important variables in shaping a STEM classroom. This pilot study explores the connectedness of classroom practice, teacher perceptions, and school culture through observational case studies of two classrooms, one in an urban public school and another in a suburban private school. Evidence including classroom observations, teacher interviews, and examining documentation was evaluated by using an established observation protocol called the Reformed Teaching Observation Protocol, or RTOP (Sawada, Piburn, Judson, Turley, Falconer, Benford,, & Bloom, 2002). Interview data suggests that both teachers had similar perceptions of effective STEM education, yet their classroom practice was very different. While teacher's perceptions were similar, the school culture as portrayed by the school websites and documentation was very different. The urban public school was focused on student character development and standardized test preparation, while the suburban private school focused more on fostering student thinking. This small glimpse into the relationship between beliefs, practice, and norms could suggest that different school cultures may influence the teachers' practices.

Thesis Supervisor: Justin Reich

Title: MIT Teaching Systems Lab

Thesis Reader: Thomas Eagar W. Eagar

Title: Professor in Material Science and Engineering

Study Goals

This study investigates how the perceptions of STEM teachers, their beliefs about control in their classroom, and the cultures of the schools they work in shape their in class practice. In order to do so, I worked closely with an educational researcher at MIT's Teaching Systems Laboratory to identify a conceptual framework for how beliefs are related to practice, and to use an existing observation protocol as a guideline for understanding best practices. We developed and submitted and IRB protocol to the COUHES Protocol- 1603506648. I used these frameworks we had identified to compare two different science classrooms. One school was a private suburban STEAM (science, technology, engineering, art, and math) middle school and the other was an urban public comprehensive middle school. Each classroom was observed using a consistent observation protocol in order to be able to compare the two. Additionally, the TSL researcher accompanied me during the observations and interview so we could compare notes and share ideas. In order to understand the roles the teachers' perceptions had on the lesson, I interviewed the teacher after the classroom visit. Public information on the schools website was used to develop an understanding of school culture as well as communication with the teaching staff. Developing an understanding of both teacher perception and school culture allows me to consider how and to what degree these two factors may play in these two STEM classrooms.

Background

STEM education focuses on the multidisciplinary relationships between science, technology, engineering, and math (STEM) in order to foster a scientific way of thinking within students

(Beane, 1997). Some schools even include art as a fundamental component and therefore refer to themselves as STEAM schools. There is a common misconception that STEM education is any teaching curriculum that at some point covers science, technology, engineering, and mathematics, but the key is the multidisciplinary nature of authentic STEM education where students connect skills in different learning environments.

A true multidisciplinary approach to STEM education is in sharp contrast to what is seen in some comprehensive schools across the United States. In schools that have not yet developed modern STEM curriculums, science, technology, engineering, and math disciplines are taught in silos, whereas STEM career work is multidisciplinary (Wang et al. 2011). This encourages a one dimensional understanding of the content and alienates content learned in nonintegrated science, technology, engineering, and math classes from the real world (Wang et al. 2011). Instead, successful STEM schools are creating multidisciplinary curriculum in order to create a seamless transition from the classroom to the STEM job market. Students are exploring multiple subjects simultaneously and are able to not only learn content, but also the connectedness of the content. This more appropriately prepares students that have interest in pursuing a STEM career.

Scientific thinking is a core component to modern STEM education. Didactic learning that focuses on memorization of factual information, fails to encourage full comprehension of what it being learned (Honam, 2002; Loverude, Kautz, and Heron, 2002). STEM education focuses on the thinking that is involved with the content. According to the report: *Improving Undergraduate Instruction in Science, Technology, Engineering, and Math*, students engage in activities and labs that foster inquisitiveness, cognitive skills of evidence based reasoning, and an understanding and appreciation for the process of scientific investigation in effective STEM classrooms (National Research Council, 2003). Promoting STEM thinking helps students truly understand what they are learning and builds an appreciation for the content. Students are more able to appreciate the value of the lessons and pay attention to furthering their understanding. Encouraging STEM thinking has become a procedural learning goal in some classrooms. Some of these more modernized learning goals include having students build and investigate their own labs, create their own structural connections of content, and think abstractly with material (Corbett, 2012).

Why is STEM Education Important?

The United States and other technically advanced countries require a strong technical work force in order to meet the demands of a modern society. While European and Asian countries are remaining globally competitive in STEM markets, the United States is falling behind (Wilson, 2011). One large problem facing the technical job market is that jobs now require multidisciplinary STEM content knowledge in order to be executed successfully (National Academies, 2006; National Center on Education and the Economy, 2007). Graduating students are expected to have this understanding, but there is a disconnect between how and what schools teach and the skills of the job market. There in turn has been decades of inadequate preparation for STEM professionals that has led to a widening disparity for the United States global industrial workplace (Cooney & Bottons, 2003). Even in professions not classified as STEM careers, a bachelor's degree level of content understanding is often deemed necessary to be successful (National Science Foundation, 2015). In California alone it is predicted that by 2025 there will be a shortage of 1 million college graduates to satisfy the demand for STEM professions (Offenstein & Shulock, 2009). As a result, the United States' future success and title as a global leader rely on its ability to act on the current inadequacies of the current American STEM workforce.

Standardized test scores are used to compare US students with students in other countries in STEM preparation. The United States ranked 35th out of 64 countries on the 2012 Program for International Student Assessment or PISA (Desilver, 2015). On the nationwide 2013 National Assessment of Educational Progress (NAEP), 64% of students scored below proficient in the math section (Desilver, 2015). These results can be seen in Figure 1. Although results of standardized exams are not capable of showing all aspects of learning and success in a classroom, they do provide some insight in to learning that goes on in a classroom. While the United States performance is trending favorably as seen in Figure 1, it is not at a rate that would suggest future national success in STEM fields when compared to other world powers (DeJarnettie, 2011).

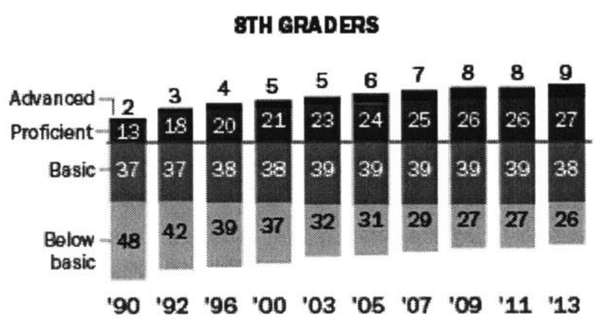

Figure 1. United States math results on the National Assessment of Educational Progress (Desilver, 2015)

Teacher Perceptions of Control, Teacher beliefs, and School Culture

With the relevance that STEM education will play in the future success of the United States, it becomes vital to understand the variables that influence effective STEM classroom practice for. This pilot study focuses on the effects of teacher perceptions of control, teacher beliefs, and school culture have on effective STEM practice. These three variables are known to be to be connected to effective STEM education, but there is still little understanding on the relative effectiveness of these variables as well as explicit contributions to effective STEM practice.

Teacher's perceived control within a classroom refers to the amount of freedom a teacher believes they have in their classroom. Freedom can vary to such degrees that it can be restraining on the teacher or it can allow the teacher to do as they please. A teacher will only perform acts in their classroom that they believe falls within the amount of control they perceive they have in the classroom. When a teacher perceives to have a significant control of the classroom this can allow them to instruct classroom practices according to their intended liking. In turn even if a teacher understands how an effective STEM classroom operates, the amount of control they have over their classroom will inhibit their ability to execute on these beliefs. Understanding the amount of control a teacher has brings insight in to possible limitations on their ability to execute their beliefs of what STEM education should look like.

Alongside what teachers perceive they can do in a classroom there is also an important concept about how they think about STEM education. There are disputed avenues in which to teach STEM and based off of a teacher's beliefs about STEM they may choose to create a classroom in a certain way. However STEM beliefs not only refer to how a teacher believes content should be taught, but also how the teacher feels about the content they are teaching. It has been seen that a teacher's belief on STEM can have direct influences on the environment of the classroom and the ability to engage students with STEM topics (Nadelson 2013). Teachers that have positive attitudes about STEM are more likely to have classrooms that foster positive attitudes amongst students (Knezek, Christensen, & Tyler-Wood, 2011). These feelings help to shape how students receive the content and in turn serve as influential drivers for directing effective STEM practice.

School culture may also influence how teachers teach because it creates expected environments that teachers abide by in order to foster school connectedness. Some schools look towards creating environments that foster certain areas of student growth. In many cases schools release official mission statements, so that the goals of the school can remain transparent for students, teachers, and parents. Schools use the culture they create to attract certain kinds of teachers and students in order to facilitate the growth of certain facets within students. Teachers will in many cases align themselves with the school goals, even if they do not completely resonate with them, to guarantee that the goals of the school are being met in order to foster a school community (MacNeil, Prater, & Busch, 2009). If the goals of a school align with the practices that lead to effective STEM practice, then this school's culture can support teachers' creation of effective STEM instruction.

Theory of Planned Behavior

Understanding how these three drivers ultimately influence behavior could bring insights on how to direct effective classroom instruction. This study uses Icek Ajzen's framework of the Theory of Planned Behavior to organize and understand how teacher perceptions of control, teacher beliefs, and school culture could influence behaviors in STEM classrooms. The Theory of Planned Behavior states that intentions lead to behaviors and that these intentions can be mapped back to three beliefs: behavioral beliefs, normative beliefs, and control beliefs (Ajzen, 2006).

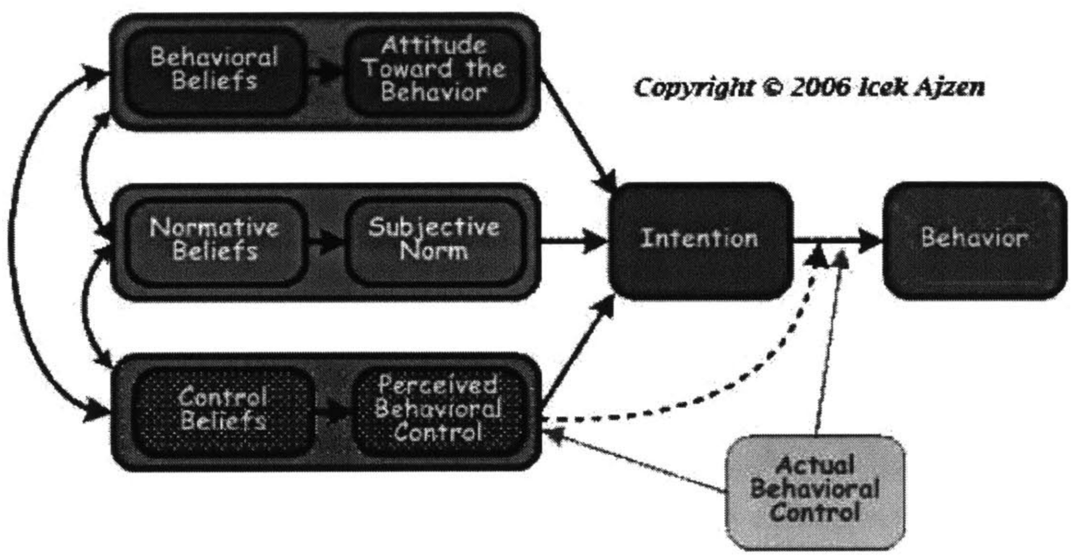

Figure 2. Theory of Planned Behavior framework (Ajzen, 2006)

Behavioral beliefs refer to the expected outcome of a certain behavior as well as the evaluation of these outcomes (Ajzen, 2006). With a perceived consequence there is the attitude associated with that outcome. If an individual feels positively about that outcome they will move forward with the behavior however, if they feel negatively about it they are not likely to continue with that behavior. In turn a person's individual beliefs about the outcome, regardless of their validity will likely contribute to behavior.

Normative beliefs describe an individual's tendency to obey social pressures to behave in a certain way (Ajzen, 2006). Pressures from peers or those observing one's actions can drive one to reconsider something that would otherwise challenge the status quo. This inhibits some people to take risks and instead abide by what people consider to be normal. In turn if a teacher feels that their own beliefs on how to conduct a classroom are contrary to those around them, this may influence them to modify their instruction.

Lastly control beliefs describe any factors someone may perceive as having an influence on their actions (Ajzen, 2006). These factors could be physical limitations such as rules instated by a larger institution. When many restraints and barriers are put before someone, this may limit their ability to act on their own beliefs. In some cases it is important to consider both perceived behavioral control and actual behavior control as direct drivers for behavior, by passing intention, because of limitations in choices for certain behaviors.

Teacher Practice

In order to understand how teacher perceptions of control, teacher beliefs, and school culture affect effective STEM practice, it is important to know what effective STEM practice looks like. Modern STEM education is one that embodies teacher empowerment, development of students' critical thinking, and a culture that supports change (Anderson et al. 1994, Shymansley and Kyle, 1990). The Arizona Collaborative for Excellence in the Preparation of Teaching used the NSF's Collaborative for Excellence in Teacher Preparation Framework for Reform to outline the three components that are vital to an effective classroom practice for STEM education. These components are: a) standards based, b) inquiry oriented, and c) student centered (Sawada et al.,2002).

Standards based teaching reflects the idea that the content learned in the classroom is reflective of the content that is expected of that age group or sequential in a curriculum within the specific content matter. When content is comprehensible, students can build upon the fundamentals that they understand in order to explore even more complicated topics and areas (Barton, 2009). Learning is for the most part iterative, so without this baseline of knowledge that teachers are expected to teach to their students, students cannot easily further their own understanding within the topic.

While standards based education is common amongst many disciplines of education, inquiry oriented instruction is not seen as frequently seen yet fundamental to proper STEM teacher practice (Sanders, 2009). Inquiry oriented instruction does not have teachers emphasize lecture, but rather stress problem-solving approaches and faster active learning (Frantz, Lawrenz, Kushner, and Miller, 1998). Teacher's that use inquiry based learning have students experience ambiguity and explore this ambiguity using data to justify opinions (Sawada et al.,2002).One popular avenue for this exploration is project based learning. Project based learning allows for teachers to guide students through the discovery of content in a way that makes sense to them, rather than being delivered the content in the perspective of the lecturer (Springer, 2006). This allows for students to have a solid understanding of the content that they were able to create themselves. Knowledge learned this way is more relatable and understandable for the student, because they themselves created the framework for the content based off of their own experiences and questions.

Modern effective STEM practice is assessed on its ability to create a student centered environment. Marshal (2010) outlined in his nine principals framework that personalizing the experience for every student is vital to STEM education. Creating a student centered environment allows students to learn the content on their own terms and in a way that makes sense to them. STEM topics are often rejected by students because of their apparent irrelevance to their daily lives (Rivoli & Ralston, 2009). When the classroom has its focus on the students, the content can become tailored to the prior knowledge and understandings of the specific student. Students can then hopefully begin to see the real connection the content has in their lives.

Case Study of Two Schools

Preparation

The goal of this case study is to provide some insights on the connectedness of classroom practice, teacher perceptions, and school culture. This pilot study hopes to begin to understand aspects of the role do teachers' perception of control, teacher beliefs, and school culture have on effective classroom practice.

The pilot case study follows two teachers at two different schools: a private suburban school and an urban public school. These schools were chosen based on their accessibility and their apparent differences in school culture. The suburban private school identifies itself as a STEAM middle school while the urban public school identifies itself as a classic comprehensive middle school. At each school a middle school a science classrooms was observed.

Before the classrooms could be explored as a part of this study, it was necessary to get an Institutional Review Board (IRB) approval to make all intentions and goals explicit. This process required that the details of the study including goals, timeframe, consent forms, and interview planning material be provided beforehand to the IRB. This took approximately two weeks and with its approval I was able to observe and interview teachers in order to gain data.

Methods

In order to better understand how teacher's perceptions of control, teacher's beliefs, and school culture are connected to effective in class practice this study begins by using a bottom-up approach. Rather than surveying the school administration and teaching staff about their STEM education beliefs, which may in turn bias how they give the following lesson or word their mission statement, this study starts off with observation of the classroom. Each school is observed for about a two hour period using field notes to document the classroom structure, teacher-student interactions, student-student interactions, and assignments. The observation is then followed up by a 30 minute interview with the teacher. Using the information gained from the observation and backtracking this to the teacher interview as well as school documentation can help identify potential insights on how teacher perceptions of control, teacher beliefs, and school culture play in the classroom that students experience.

In order to organize what is being observed in the classrooms in a way that is conducive for comparison observations were taken both by open ended field notes and by using a tested observation protocol. For this study the Reformed Teaching Observation Protocol (RTOP) is used because of its ability to quantify reform within a STEM classroom and its proven reliability (Sawada, Piburn, Judson, Turley, Falconer, Benford,, & Bloom, 2002). The RTOP provides a quantifiable method for comparing the two schools, and the results will be used as a baseline for understanding the level of reformed STEM education that is experienced both classrooms.

The Reformed Teaching Observation Protocol (RTOP) is a way in which STEM teaching practice can be quantified on the metric of effective reformed teaching. The RTOP quantifies the effectiveness of STEM classrooms by "having observers make holistic judgments about broad categories of lesson design and classroom culture" (Sawada, Piburn, Judson, Turley, Falconer, Benford,, & Bloom, 2002). Protocol design was heavily based on three sets of standards: (1) Principles and Standards for School Mathematics (NCTM, 2000), (2) National Science Education Standards (NRC, 2000), and (3) Benchmarks for Scientific Literacy (AAAS, 1993). For organizational purposes the RTOP is divided in to three areas of focus: Lesson design and implementation, Content, and Classroom Culture. Both content and classroom management have ten sub sections, while lesson design and implementation has five sub sections. Each sub sections can be given a score of 0-4 allowing a maximum score to be 100 points. A basic overview of the observation protocol can be seen below in Table 1. Details of the subsections can be seen in Appendix E and Appendix F. These score results of this protocol have been proven to be predictive of how much students learning is occurring in the classroom.

Observation Protocol Sections	Amount of Subsections	Max Total Points
Lesson Design and Implementation	5	20
Content	10	40
Classroom Culture Communicative Interactions	10	40

Table 1. Organization of the Reformed Teaching Observation Protocol

In order to extract relevant information from the observations about why the teachers chose the actions they did, I interviewed the teachers and reviewed planning documents (lesson plans). The interview questions were constructed using the RTOP as a reference in order to have direct connections between what was being recorded during the observation process and what is asked during the interview. Aside from general background information, the interview questions cover eight main parts of the lesson: (1) Communicative interaction, (2) Student/teacher relationships, (3) Content-propositional knowledge, (4) Students' preconceptions, (5) Content-procedural knowledge, (6) Classroom culture, (7) Normative Beliefs, and (8) Control. The full teacher interview can be seen in the Appendix A.

School culture is being understood through two avenues. The first approach will be through the teacher interview and the second being through the school documentation. Receiving the information through two different sources can help me understand if the teachers' ideas align with the schools' stated ideals. Ideally this study would have also included an interview with the administration, but time did not permit this. For future work on this study, communication with the school administration will definitely prove valuable for better understanding school culture.

In order to organize and understand the sources of teacher's behaviors this study maps the data collected from both schools to the Theory of Planned Behavior. It is of interest to the pilot study to begin understanding what beliefs lead to certain behaviors and what the sources of these beliefs are. Comparing the beliefs of each teacher side by side will allow for some of the differences to be focused on. These differences in beliefs may be influences on the differences in the classroom execution. Findings from the study will suggest directions for future investigations about the area.

Results

Suburban Private School

Observation

During the suburban private school observation, students were expected to test different solutions in order to make the best "Fruit Gusher recipe". Students were first given a fifteen minute overview of the variables that would be within their control and were given "Fruit Gusher" gummies as a reference to what their final product should emulate. Students were asked to form groups of three to four students for this lab. These groups worked together in the lab and experimented with the variables in order to create gummies that both tasted and felt like the gummies students were exposed to earlier in the class. Each group approached the experiment differently and asked many questions throughout the class due to some parts of the lab procedure purposely being left vague. In the end students seemed to be having fun and were excited about the products they were able to create. The complete observation notes are included in Appendix C.

Interview

The teacher that this suburban private school case study follows is that of the middle school science lab teacher X. X is a teacher with 6 years of experience teaching (4 years with the suburban private school and 2 years within a public high school), that originally worked in industry within biology and chemistry disciplines before transitioning to teaching. Teacher X originally taught biology at an urban public high school, but found the opportunities at the suburban private school to be appealing after 2 years.

X traces the influences to his current teaching practice to both his experience in industry and his experience at his former high school. From industry teacher X learned that, "[one] spends most of [his] time wondering why something isn't working. In order to make this experience seamless for students, [one should] test students to work with frustration and fixing things". "Students learn the skills to figure out what they need to do, rather than just forcing content that may not even be needed in the future". As a result "when students control [their own] destiny, it keeps students accountable and responsible". At his former high school teacher X learned a lot about effective lecturing through a coworker he shared a classroom with who taught drama. What this coworker showed teacher X was that minimizing lecture to 15-20 minutes keeps student attention and focus. Following the lecture, students are able to experience the content for themselves rather than just being told something is true.

In practice teacher X's classroom was as he put it was like "diving into the cave of mystery". Mystery is a hallmark of teacher X's classroom. "The teacher is not the gatekeeper of knowledge; they are more like a private investigator that clears away the blockages to success". He believes that by having mystery in either the procedure or the results of a scientific experiment allow students to discover on their own. Students naturally learn important scientific concepts like holding variables constant for comparison or how to create an experimental setup that is time efficient. This allows students to own the knowledge and internalize the skills taught in class.

Review of School Culture

The suburban private school website states the school mission is to:

- "Engage each child in project-based, contextual learning across disciplines.
- Inspire students to become problem-solvers, innovators, creative thinkers and leaders of tomorrow.
- Create a microcosm of what is possible in education
- Engage communities in a new dialogue about innovation, creativity and joy in STEM education." (Suburban private school website – details withheld to preserve anonymity)

I noticed during my observation of the school that the school also really cares about student freedom with content exploration and student ownership of responsibility. Students are constantly being encouraged to explore their own interests rather than being prescribed content to investigate. This sometimes finds its way into explicit class time such as the Science Poster Exploration Project which students worked on during the end of the class we observed. In this project students were responsible for exploring their own topic of interest and present it to teachers and professionals. From the discussions with teacher X and other school administrators it seemed that encouragement of independent student exploration was also common within the school. In these cases teachers made sure to provide students with the appropriate support and resources in order to investigate topics on their own successfully.

The safety students feel in order to take risks is created by strong student to teacher relationships. In order to encourage a safe feeling environment, teachers at the suburban private school are called be their first names in order to create an almost "colleague"-like relationship. Ultimately what makes this student exploration effective is that all students are expected to have a certain level of responsibility and own what they are doing. There is a mutual understanding between the school, teachers, and students that students will dedicate the independent time needed to see learning progress. Content learning does happen in classrooms, but since much of classroom time is used towards creating opportunities for student exploration, much of the content and technical understanding become responsibilities of the students to explore themselves. This in turn builds a confidence in students that makes them eager to show a classroom visitor such as myself the soap they created or explain their failures in a cricket reproduction experiment.

Urban Public School

Observation

The classroom at the urban public school that was observed was a bit atypical when compared to a traditional school day. There was an assembly that had gone on during the morning and in turn made the afternoon classes shortened. During the class period students were instructed at the start that they were responsible for completing two outline and summaries for two different textbook chapters. Those students that finished early could move on to complete a third outline and summary for extra credit. Students were prompted that they could work in groups or individually, but due to the time sensitivity of the assignment many students decided to work individually. The classroom was typically quiet, but when a disruption did start the teacher was quick to stop it. When the period was over students turned in the outline and summaries to the teacher regardless of how much or little progress was made. The extensive observation notes are presented in Appendix D.

Interview

The urban public school case study focuses on teacher Y who is an 8th grade middle school science teacher that has been teaching for 18 years. Teacher Y stated that "[he] didn't choose to be a teacher, teaching chose him." Teaching at the middle school age for a Cambridge Public School is often labeled a very difficult position, but teacher Y is driven by challenges. Many of Y's teaching inspirations are rooted in his upbringing and how this experience connects with his students. Teacher Y grew up as a "poor inner city street kid", but through adversity managed to be "developed by science in Cambridge." Students in teacher Y's classroom connect to him through their common experiences and he uses this to help motivate students. This in turn has helped teacher Y create a classroom environment that is structured and organized in order to keep possibly otherwise unmotivated students responsible of their own education.

A core principle in teacher Y's classroom is to have students of different academic levels find success. Lessons are developed in such a manner that "no one puts their pencil down" because students are constantly being exposed to "rigor". Without differentiated rigor the "top students become bored and the lower students give up". In this particular class teacher Y cited that allowing the students that were ahead to work on an extra credit assignment is an example of a way in which teacher Y introduces rigor for the more advanced students. Teacher Y mentioned that student reflection is in particularly valuable for guaranteeing academic success amongst different students. Students are allowed to learn and build off of their failures, and as a result encourage learning to be an active process.

The class observed was not a typical class according to teacher Y. These classes were shortened due to an assembly in the morning, so teacher Y was not given enough time to execute a normal lesson. Normally a lesson is "20% [Y] talking, 20% class talking with [Y], and 60% students either working with each other or independently." With only 20% of the lesson being teacher Y talking, this reflects teacher Y's opinion that students should "interact all the time." Teacher Y's classroom was even arranged in a way that fosters a collaborative environment. All students were seated in pairs of two, with their desks slightly facing each other, and in the back of the room were large lab tables used for group seating. Even in this atypical lesson students were able to move to the back table to work together and some students worked together with the student adjacent to them. Having students work together and come to answers on their own help students become "good thinkers".

Review of School Culture

According to the school website the public urban school has five core values:

- "Passion for academic success and social justice
- Pride in one's identity
- Ownership over who we are and what we do
- Balance of academics, extracurricular, and out of school life
- Perseverance to never give up" (Urban public school website – details withheld to preserve anonymity)

These values emphasize the character development of the student as the most important goal of the school. Within the urban public school there is a large population of minority and low income students that typically face marginalization and difficulty for finding academic success when compared to nonminority and high income students. Focus on student growth and character development is intended to prepare students to be independent in order to be well equipped for typical socially induced barriers that they may face in the future. While academic success and content exploration are important for the urban public school, having students prepared to be in control of their own education and lives are the urban public school's priorities in guaranteeing students' future success in life.

During the interview teacher Y mentioned that he frequently keeps himself updated with the lives of his students and with their parents. Due to Teacher Y's personal connection with the student's lives and circumstances, teacher Y actively encourages the five core values of the urban public school throughout his daily routines as well as a physical poster of the values was in teacher Y's classroom. The school has even set a designated time of the day for conversations about these core values to happen regardless of whether teachers are making individual efforts themselves. At the urban public school they call this time advisory. During the advisory period all 8th grade teachers are encouraged to talk about the five core values of the school and help student build a portfolio that reflects how the student has showcased each one in their time at the urban public school.

The efforts towards improving standardized test performance were also mentioned during the interview. Historically the urban public school had not been performing to the standard they set for themselves, but recent focus on the area resulted in impressive improvement of the school's performance relative to the state average. As the dates of theses exams draws near, it is typical for the entire school to be preparing for these exams. High performance on these exams is highly valued by the members of this school.

Comparing the two schools

After the observation, the TSL research scientist and I reviewed our classroom notes. We then used the RTOP protocol to independently quantify each classroom along RTOP parameters. A grade out of 100 was assigned to each school by two different observers. Neither observer consulted with the other before giving the school its grade. The average score for the suburban private school was 80 +/- 3 and the average score for the urban public school was 51 +/-10 and can be seen in figure 3. The extensive individual scoring charts that contain all 25 fields for each school can be seen in Appendix E and Appendix F. The larger error in the urban public school observation was largely due to the fact that the class observed was atypical and as a result some extrapolation needed to be made based off example of work around the room and Teacher Y's mention of lessons to come in the near future. Ultimately the suburban private school scored higher on the RTOP from the perspective of both observers.

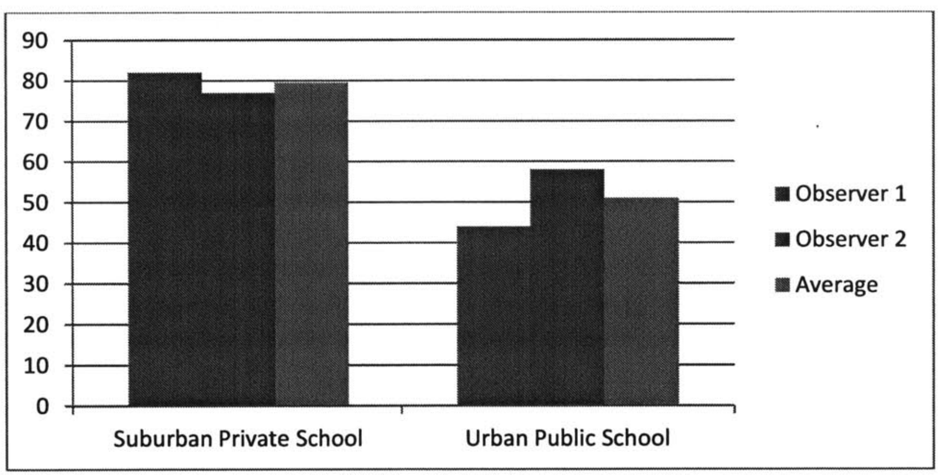

Figure 3: Results of the suburban private school and the urban public school on the RTOP done by two different observers without consulting.

Case Study Discussion

Suburban Private School

The like-mindedness of teacher beliefs and school culture led to a positive perception of control that was conducive for creating a relatively reformed STEM classroom. According to the interview with teacher X, both teacher X and the suburban private school shared behavioral beliefs about what is necessary within a STEM classroom. They shared the idea that by allowing students to freely explore technical topics, that they will build their own logical framework for the material and this in turn elicits a deeper individualized understanding of the material. The similar beliefs of the two, granted teacher X the freedom to conduct his classroom how he saw as appropriate.

Teacher X's freedom within the classroom was closely related to both the normative and control beliefs of the other teachers at the suburban private school with relation to the greater school culture. The suburban private school teacher felt free to structure his lesson in the "cave of mystery" format because within the school this type of lesson format was normal. Not only in teacher X's classroom, but in all the classrooms within the school, students were expected to explore content freely. The school wants teachers to use this inquiry method which does put a control on the teacher, but in this case this control aligned with the teacher's already existing beliefs. In this specific case the teacher beliefs were supported by the school culture and this lead to seamless transition to behaviors that were effective for STEM practice according to the RTOP grading rubric.

Urban Public School

The urban public school may have experienced less effective STEM practice due to the teacher's perception of less control over his freedom in the classroom. There was a strong emphasis on standardized exam performance within the urban public school which may have led to restrictive normative beliefs and strong control beliefs for teacher Y. Teacher Y's behavioral beliefs suggested that he valued the scientific thinking that would arise from collaboration and hands on projects. However the school emphasis on standardized exams possibly influenced his choice of how to structure class time. Teacher Y had limited time in the classroom, and could not satisfy his own values as well as those of the school.

The difference in value set on effective STEM practice by the urban public school and teacher Y, led teacher Y to feel both normative restraints and control restraints. It appeared that many teachers within the school highly prioritize performance on standardized exams and this has become the normative behavior of the school. The school also keeps records of teacher performance on standardized exams and keeps teachers accountable for attaining certain expectations. These expectations possibly create control beliefs within the teacher and may restrict risk taking. While the school has been successful at improving their performance on standardized exams, the teaching styles that were observed in this pilot case study don't closely abide by effective STEM practice as defined by the RTOP.

Comparison of the two schools

After the interviews with both Teacher Y and Teacher X it became apparent that both teachers actually had very similar perceptions on what STEM integration is and how it should be implemented in a classroom. Both teachers mentioned that a hands on project based approach to learning is one that is ideal for STEM education. They both supported this claim with discussions about the value of inquiry learning and how it is valuable to have students think critically about STEM topics, and that classrooms should be student centered to keep students accountable and more excited about exploring new topics.

Despite these similar perceptions of a good STEM classroom, the classroom observations and RTOP scores suggest that teaching practice is different in these two situations. This could suggest that the suburban private school classroom better aligned with the RTOP definition of a reformed STEM classroom than the urban public school classroom. The classroom at the suburban private school included more group work, student collaboration, and student freedom which in turn led to its greater score. While the suburban private school classroom did receive a greater score on the RTOP, it does not make it inherently a better classroom. The goals of a classroom are not always rooted in the delivery of the content, but in also the developmental skills that are learned by the students. Teacher Y's classroom has a strong emphasis on order and accountability that become components of classroom learning in his classroom just as any content standard.

I believe the differences in the execution of the classrooms despite similar STEM perceptions is possibly related to how the schools' culture supports STEM beliefs and the amount of perceived control this created for the teachers. In the two classrooms I observed, the instruction of the teacher was reflective of the school culture, seemingly independent of what the teacher's perceptions were. Teacher X's classroom at the suburban private school was focused largely on project based learning and problem solving, which were two components of the suburban private school's mission statement. In the urban public school classroom, standardized test preparation and student responsibility were major areas of concern. This reflected the urban public school's focus on ownership and perseverance. The teacher's beliefs were similar, yet their perceptions of control and school culture were different. Therefore, this pilot study indicates a possible link between school culture and classroom teaching.

Conclusions and Future Work

This pilot study ultimately serves as a starting point for further explorations in to teacher perceptions of control, teacher beliefs, and school culture. The time spent in classrooms for this case study was too short to make definitive conclusions. While this may be true, some interesting insights for future studies did arise. It appeared that in this case study the teachers experienced degrees of freedom due to the school culture. Whereas both teachers had similar behavioral beliefs about effective STEM practice, their classrooms looked different due to influences of the schools they worked in. The private suburban school was able to create a more reformed STEM classroom during the class I observed according to the RTOP that could have been linked to the private suburban school's culture alignment with effective STEM beliefs. According to the RTOP the urban public school classroom was less reformed during the class I observed. This could have been due to the control the school put on the teacher due to prioritization on other aspects that were not STEM related like student development and standardized test preparation.

Future work on this topic will need to cover many more schools and specifically teachers with different beliefs on STEM education. The insights from this study can serve as a foundation for future work, but conclusions can change as more information is gained. Dr. Thompson will be following up on this pilot study and gain further insights throughout the upcoming year.

This study will ultimately serve as a valuable resource for future educators. Once concrete conclusions can be made surrounding teacher perceptions of control, teacher beliefs, and school culture educators can better prepare themselves and place themselves in schools that will encourage effective STEM practice. This information will serve invaluable as the United States works towards building a stronger STEM workforce.

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Appendix

Appendix A.

STEM Study Interview questions - Teachers

Thank you for agreeing to speak with me today. This interview should take about 30 minutes. First I will review the consent form (review title, purpose, data collection, their role as on the consent form). Do you have questions for me? I have two copies, so you can keep one for your records.

Verbal consent – I want to make sure to get this on the recording. Is it OK for me to record this interview?

Background questions

1. How long have you been teaching middle school science?
2. Why did you choose to teach in middle school?
3. Do you have a teaching certification? If so, what subjects are you certified to teach?
4. What did you study in college? Did you do additional school after college?
5. What are some important experiences that influence how you teach?
    a. If asked for examples - scientific research, inspirational teacher, terrible teacher, great school etc.

Intentions and practice

I would like to have copies of any planning materials you used to prepare today, or any materials you gave to your students.

Content - propositional knowledge

6. Would you briefly explain the main learning goals you had for your students today?
7. How do you think the lesson went? What went well? What would you do differently?
8. Do you enjoy teaching this topic? Why or why not?

Communicative Interaction

9. How typical is the class I saw today to the way you usually teach?

    Possible follow up prompt if needed –

    9a. How often are students…. (*talking to one another/ doing projects individually/ doing projects together/ listening to one person talk at a time*)

    9b. Why do you decide have students interact in this way for today's class?

Students' preconceptions

10. In what ways did you draw upon students' preconceptions (or ideas) about this topic?
11. Did you gather student ideas before this class? If so, how?

11a. If noticed during observation.... I noticed during the observation that you (mentioned student ideas, had students write down or discuss their initial ideas) *potentially one or more of the following on list below)* Can you explain why you chose to do that?

Content - procedural knowledge

12. In your plan for this lesson, how did you intend for students to interact with the material (through discussion, modeling, using different materials?)
13. How successful were these activities during the class?

13a. If noticed during observation.... I noticed during the observation that you (*had students use models, drawings, graphs, manipulatives OR made predictions OR reflected on their learning)* Can you explain your rationale?

14. How do you assess student learning? What types of evidence do you collect?
    a. How do you communicate learning to parents (example: report cards)?

Student/ teacher relationships

15. What strategies do you have to encourage student participation during class?
16. How would you describe an "ideal relationship" between students and teacher? Are you a mentor, friend, a guide, a parental figure, or something else entirely?

Classroom culture

17. In you plan for this lesson, how did you hope students would communicate their ideas to each other?

17a. *If communication happened* - How successful do you think these activities were during the class?

Normative Beliefs

18. When someone asks you what the mission of SCHOOL NAME is, what do you tell them?
19. How does the philosophy of teaching and learning at SCHOOL NAME influence how you teach?

18a. Can you give me any examples from today?

Curriculum choice/ control

20. When you are planning your lessons, how do you decide what topics you will cover?

19a. Possible follow up - How much freedom do you have in what and how you teach?

21. How would you change your situation (school, classroom, students, funding) to enable you to teach the way you would like to teach?

Conclusion

22. After I review my notes and this interview I may have some questions, may I email you to make sure that I'm understanding your ideas correctly?

Please remember to send me copies of your planning materials for this class, so I can review them. That's all the questions I have.

23. Is there anything else you would like to say or ask me about this project?

Thank you so much for your time!

Appendix B.

STEM Study Interview questions – STEM Experts

Thank you for agreeing to speak with me today. This interview should take about 15 minutes. First I will review the consent form (review title, purpose, data collection, their role as on the consent form). Do you have questions for me? I have two copies, so you can keep one for your records.

Verbal consent – I want to make sure to get this on the recording. Is it OK for me to record this interview?

Background questions

1. How long have you been working in STEM related field? Can you explain the work you have done in that area?
2. When you hear the term STEM, what does it mean to you?
3. Why do you believe that STEM education is important?
4. What do you think is one success story that you have heard about or been involved in regarding STEM?
5. What are the big challenges in the next five years for STEM education?

Conclusion

6. After I review my notes and this interview I may have some questions, may I email you to make sure that I'm understanding your ideas correctly?
7. Please remember to send me copies of your planning materials for this class, so I can review them. That's all the questions I have.
8. Is there anything else you would like to say or ask me about this project?

Thank you so much for your time!

Appendix C.

Suburban private school School - Tuesday April 12th

Science class – Teacher X

Meredith's notes

Memo:

Lesson design and implementation

Lesson design and implementation did respect students' prior knowledge. They explored Fruit Gushers in person first, and Teacher X did ask who had done a similar activity before. Students discussed together as a community and worked together in groups. Students were given a procedure but encouraged to do the exact procedure their own way. The students were excited about the activity, but didn't formulate it themselves, though the teacher commented that he did draw from students' ideas for explorations at other times during the year.

Content - Propositional knowledge

Content was not a focus of this lesson. Exploration was more of a focus. Students were not given much framing for what was going on before they did the lab. The teacher clearly knew a lot about the science, and discussed some complicated concepts (Molality versus molarity) but did not provide traditional instruction on those topics. Students were not asked to draw symbols or equations to otherwise model what was occurring in the lab. The teacher did make connections to other content disciplines, mentioning how calcium chloride is used in cheese.

Procedural knowledge

Students did not graph or draw unless they chose to, but did manipulate materials in the lab. Students were not asked specifically to make predictions about what would happen. Students critically assessed the procedures in the form of figuring out two specific parameters that were not part of the given procedure. Students reflected on their learning by trying out the procedures and revising them accordingly, though this was a messy and individual process. It was not clear how much each group questioned their procedure in terms of optimizing the fruit gusher recipe.

Communicative interactions

Students communicated the entire time with each other and freely asked the teacher and coteacher questions. They primarily discussed and shared ideas on paper and through doing the lab. Teachers circuled around the room and asked questions to prompt the students to think about what they were doing and how to improve their approach, suggesting cutting off the end of the pipet in order to pick up larger "blobs" of material. Teachers maintained a positive attitude about students' ideas throughout the time. The coteacher Eric mentioned "I love the enthusiasm, but let's keep the volume down", always framing the talk as positive.

Student teacher relationships

Students were actively encouraged to participate in the lesson. Students asked many questions throughout the procedure, and the teachers encouraged them to come up with their own ideas for how to interpret the evidence and how to set up the experiment. The teachers were generally very patient with students, and answered questions and helped source materials, but also prompted students to consider their approach, consider taking notes, and to remember safe procedures. In fact, safety concerns were a common theme during the lab, especially in making the results food safe.

Both teachers were experty listeners. At one point during cleanup, two students had a disagreement. Eric stopped, asked both if they were OK, and listened to both sides of the situation before making any judgement about what should go next. Both students discussed their point of view and they were able to resolve the situation pretty easily.

Before class:

Raul and I spoke with Teacher X briefly. He mentioned that the students would be doing a lab on making Fruit Gushers.

Introduction/ Student exploration

10:15am

17 students in the class – 9 boys and 7 girls

Teacher X introduced the activity in the core classroom. Students were seated in three tables of four in a "U" shape, though students freely rolled about the carpeted classroom on chairs with wheels.

The core teacher asked about the students' posters for the upcoming symposium on Thursday, who wanted to work on them, then told the students to get their lab notebooks. Some students responded, and others didn't.

A couple of students approached Teacher X with questions about the activity but he said "I'm not answering questions yet because it's not yet time for lab." Later, he qualified that statement by saying "If I say it now I will just have to repeat it.".

Students turn to face Teacher X and he starts the class
Teacher X: "Hello, how is everyone doing?" Students responded politely. Teacher X continued "Today from 9-10:30 we are going to begin to think about our candy making unit". (The students respond with enthusiasm).

Teacher X: "Who has done this project before with Eric" (a few raise hands – apparently this is also done after school in a program).

Teacher X: "Today we're going to make Fruit Gushers.

Student (boy): "I love those things!"

Teacher X: "Before you were given all of the instructions, now we're not going to do it that way this time."

Student (boy 2): " I want a fruit roll up"

Teacher X: "You can't have a fruit roll up now" "Why am I giving this to you? I want you to think about Fruit Gushers. What types of things should you notice"

Students offer texture, that there's "goop inside", and color

(Teacher X opens a box of Fruit Gushers and starts tossing them out to the groups in the class. Students open them up and eat immediately. Eric, a second teacher, talks to a group).

Eric: Are we taking notes or observations? (To one student) You have a loose tooth? It came out? OK, go get a tooth container. (Student leaves class and gets a tooth container).

(Teacher X writes procedure on whiteboard while Eric circles, talking to groups).

Eric: In this group I see you're taking notes. That's good.

Student: My mouth doesn't feel weird. Usually it feels weird with these
Eric: OK. You have some prior knowledge about this.

To other students

Eric: Abby's taking notes. (Pointing to answer) Nice, I like that.

Eric (to another student named Eric, who was not taking down notes) Eric how are you doing, would you like to get some notes from others about this?

Eric: (To group 4) what about texture? (Continues to ask questions to the groups and check in with individual students).

Framing the experiment

Teacher X: As you're finishing, turn around briefly. I've put the materials on the board and also the general procedure.

(Discusses molality and molarity, appears students have discussed this before but not clear if they all understand it.

Tells students they won't be able to eat their results today, one student is upset, but explains that it's not foodsafe).

(Teacher X writes the procedure on the board while the students chat amongst themselves. Two students are in the back of the class, one hops along on his knees. Eric notices this and intervenes.

Boy students: I already did this with Eric.

Teacher X: Great. He had all of the solutions made & timing set – I have left two things open. You have to figure out 2 things 1. How much CaCl dissolve 1 to 5 grams in 250 ml – how much? I don't know, it's up to you.

Teacher X: You have two variables to explore, there are two things you have to modulate.

Boy student: What is alginate?

(Teacher X discusses that alginate is a functional group, that it's a complex question and you will know it when you take organic chemistry, discusses how cyanide is just s C triple bond N or amino group NH2

Girl student: What is sol'n

Teacher X: fancy way to abbreviate solution.

(Teacher X discusses handwriting, how his handwriting is not great, he got Cs in it in school. The core teacher says she got an A in it).

(Discusses how to leave pages free in a notebook when a student needed to finish another part first).

(Let students form their own groups of 3-4 people).

Moving to the lab

(A couple of students stay behind in classroom – core teacher mentions "I would have printed out the instructions – the point of this is not whether they can write the instructions". Teacher prints out the instructions and then gives them to students who are lagging).

Lab activity

During the lab activity students work very independently. Teacher X and Eric answer questions. Eric talks with every group purposefully, while Teacher X takes more questions when he is approached and makes more whole class oriented announcements.

All students wear purple nitrile gloves, but otherwise, students are all at different paces and have different set ups based on what they want to put together the way they want to put it together.

Teacher X: (Holding wrapped glass stirrers) I ordered new stirrer – this should take a week for you to break these.

Eric: Eyes on me – I love the level of excitement, but the volume is high – it's difficult to hear each other talk. Talk to your partner.

Teacher X: What happens when we talk louder?

Students: everyone else talks louder.

Teacher X: Benefit of having someone not drill today (in the adjacent engineering lab).

Eric and Teacher X circle around checking in with students.

Eric: My friends, who is taking notes for this group?

Teacher X: Hey are you using lab water (not potable) we can't drink the lab water.

Eric: (To small group) How could you modify these tools, perhaps modify this pipette to pick up the larger piece? Perhaps cut it open at the bottom (shows students how to cut open the pipet).

Teacher X suggests putting pipets down on a paper towel instead of the lab bench.

Teacher X notes that CaCl is used in making cheese. Eric mentions to us that this is the first year they are using lab notebooks, so they are getting used to how to do it. Eric took a picture of a results section that he liked by students to use as an example.

Teacher X tells us directly that he started working in high school in Everett, that "they let him do what he wanted", that he worked there for 2 years. Learned a lot of what he knew from the person he shared an office with there. Teacher X discusses how mystery is important in science – mystery in the results or mystery in the process in getting there.

Teacher X notes that Eric handles the class management because he will be a core teacher next year.

Girl student to Teacher X "Want to try a blob"?

Teacher X: Oh sure. (Eats a blob).

Cleaning up

Teacher X asks everyone to give him a "lovingly adoring glance". The students quiet down and he tells them it's time to clean up, and that Eric wins the prize for the most lovingly adoring glance.

After the rather chaotic lab activity, the students are surprisingly thorough about cleaning up. Teacher X and Eric do have to remind students to help their peers wash glassware, but the students return the materials, spray down the counters, and put things away pretty effectively.

Back in classroom

Teacher X talks to the students about their presentations on Thursday. Asks students not to multitask – meaning to pay attention.

Eric suggests it's time for mindfulness and Teacher X plays a chime.

Teacher X describes how students should have The Pitch, about 30 seconds, show excitement, and explain what is most interesting to you. Eric writes this on the whiteboard.

Teacher X talks about students who have moved on, giving examples of how other students projects didn't work the way they hoped but they still did a great job of presenting them.

Interview – Teacher X

During class, Teacher X told us a bit about his background.

2 years teaching in Everett HS – AP biology and the regular classes, 4 years at Suburban private school

Has a teaching certificate

Group comes in and Teacher X and Courtney speak to group

Teacher X explained to a group of visitors how this was project-based and hands on and also mystery based

They do chemistry and biochemistry – they extracted their own oils when they made soap, did steam distillation of essential oils

Going to do a molecular gastronomy unit after break – try making candy and chocolate (they're really disappointed – uses humor here too).

Teacher X discussed giving students a general process and that it's not about getting it perfect. He discussed how scientific frequently fail and they don't get it right on the first try – they have to repeat and how scientists deal with frustration.

Courtney mentions how Teacher X said during his interview "I wasn't good at science until I did science".

Teacher X discusses the traditional AP approach – pre lab questions, do lab, follow steps, don't get the results you should get then have to figure out why or the teacher would say just to pretend you did. Students don't control their own destiny – can't explain the results they got.

Students in the Fruit Gushers lab change the procedures in ways that he never considered,

Discusses how it's not critical that they know all the details about the lab – if they are interested then they will learn them. He queried his students and it's the vocabulary of science that turns them off – kids love the lab but have the vocabulary.

Courtney (school leader) This allows students to own what they learn. The whole school follows the idea of constructivism – there is a role for students to uncover and discover. That type of learning stays, allows students to feel empowered and engaged. There is "engagement and joy".

Teacher X: Kids and adults need to know how to find out information, how to apply it. You learn better when you do it. Even kids who aren't the science-y kids liearn better.

Teacher X:Discusses how he doesn't teach them about variables

Courtney: The students are brought into it

Teacher X: It's a truly project based approach – have materials ready, we know the safety requirements.

Interview resumes

Teacher X thinks this could work in level 3 schools as well. Everett was a challenging school, but he learned a lot about how to teach by watching the teacher he shared a room with.

He recommends treating kids with respect , treat kids like colleagues. Hes not a friend. Still, he lets students ask him anything (but doesn't always answer every question). Rather than being the gatekeeper, the teacher should be the principal investigator. In charge of lab, but remove him/ her self enough to help the students but not block them on their next step.

Discusses how not to immediately assume the kids are bad, but also how it's important to stick to rules so they know they can't goof off. There are rules in the lab. Safety is important and kids all go through a safety course at the start of the year.

Teacher X found out about Suburban private school while looking in SchoolSpring and liked its bigger approach. Thought the opportunity to teach gifted kids would be a good one. Also does tutoring for MCAS and test prep. Thinks of test prep as part logic, part game, teach kids what to look for and strategy and logic behind test taking.

A key piece of tutoring is to let the child continue to explain – wait until they are finished talking. New teachers struggle with this and interrupt too fast. Wait for the student to formulate his or her ideas.

Can't talk for more than 20 minutes.

Will send us a piece of writing he did for Courtney - making sure there is mystery somewhere in the procedure or the outcome.

Sometimes following procedure is important. Sometimes he doesn't give them either the procedure or the result – then he calls it the Cave of Mystery

Learning is very student-directed – he rarely says "no". If a student wants to do something iffy, he suggests doing it on the microscale and being extra careful with safety equipment.

He discusses how science in public school is basically MCAS test prep.

Appendix D.

Urban Public School – Wed Apr 13th

Science class – Teacher Y

Meredith's notes

Memo:

Lesson design and implementation

Lesson design was to read a chapter in the textbook and answer questions 3-3 and 3-4 about genetics, with 4-2 as extra credit.

Content - Propositional knowledge

Content the focus of this lesson, specifically to prepare for a protein building activity that will be happening on Thursday April 14th in the classroom. The teacher did not provide direct instruction on those topics, but allowed students to work at their own pace, though he reminded them about the shortened time period for the afternoon. Students were not asked to draw symbols or equations, just to answer the questions in the book. Although the teacher did not make connections to the content during the class, there was a graph on the board and evidence of a Mendelian genetics experiment that was ongoing with Mustard Seed plants.

Procedural knowledge

Students read from their texts and answered questions on paper. The primary form of student choice during the class was the topic they could choose for the extra credit questions. Students chatted with each other for some of the period, but worked independently on their own papers.

Communicative interactions

Students communicated for some of the time during the class, keeping their voices at a low level. Students asked the teacher questions, and he would respond to them individually, The teacher circulated around the room encouraging students to work quickly due to the shorter period, and not to waste the time that they had to work on the material. The teacher addressed the entire class a few times to remind them not to "waste their time".

Student teacher relationships

The teacher clearly communicated the learning objective on the whiteboard as a "students will be able to do" (SWBATD), and announced the work during class. Students worked independently, asking the teacher for feedback if needed. The teacher answered all questions matter of factly and with a dry no-nonsense humor. Students got up and sharpened pencils and retrieved new worksheets, and even changed their seats during class. The teacher allowed students to move in this fashion without questioning them.

The teacher responded directly and informatively to students when they asked questions. The teacher also suggested "you can choose to write about pedigree, since we spent 1.5 class periods on it" for extra credit. One student challenged the teacher gently a couple of times asking "What if we don't want to do extra credit, we have no choice, right?" The teacher gave him a knowing glance indicating that they had a mutual understanding. However, when a student could not stop laughing, the teacher sent her across the room to a counselor's office to avoid disruption.

Before class:

Raul spoke briefly with Teacher Y, Teacher Y shook hands with us both.

Classroom description

10:15am

8 girls (check) 7 boys.

Room description

The lab was sunny with lots of windows along the left side of the classroom and very clean and new. The three whiteboards at the front of the room contained the SWBAT "students will be able to" objective, the middle board was clear and was a smart board, and the left board contained dozens of post it notes which represented the height of mustard seed plants in an ongoing Mendelian investigation the teacher does every year. The posters include two earth maps, one moon map, a poster of the "atom", a periodic table, a solar system poster (including Pluto), and a student made poster "Face the Fat" containing different fast food containers. That was the only evidence of student work in the room. The teacher also had a Boston University terriers bumper sticker, a BU softball and BU hockey poster, and a BU fleece hung from the back of his chair.

The student desks had green Prentice Hall textbooks on them, and were triangular and grouped into pairs. In the back of the room there were lab tables 4 chairs to a table on wheels, with pull down outlets attached to the ceiling. The lab benches were clean, and there was a lab prep room.

Introduction

Teacher Y recounted the schedule, and announced the Candice can't make it so he will lead the protein folding activity tomorrow. Today they are going to "tie up loose ends" in preparation for tomorrow's activity, by completing 3-4 and 3-4, and doing 4-2 as extra credit.

Teacher Y then told the students that they had 20 minutes and they should start working. He passed back student work.

A student asked about the main point of a question and Teacher Y answered "explain how mutations lead to evolution". As he's passing back work, he checks in with students. He asks one student "What are you doing?" the male student responded "getting my stuff out" and the teacher replied "it doesn't look like it". The teacher circled around checking in, and spent some time at his desk. The students chatted with low level voices, and then gradually focused on their work.

The teacher noted "5 minutes left" and then "45 seconds left", and collected work from the students as they exited the room.

The second class proceeded pretty much the same. When collecting homework, the teacher mentioned "gotta turn in your work. Deadlines. Commitments."

The emphasis was on time, completion of work, and guidelines. The teacher had a dry no nonsense rapport with his students, which seemed to work well. The guidelines were clear, and the teacher did not appear to be unfair or to be too restrictive, though it was difficult to tell his teaching style from this particular set of lessons.

Appendix E.

Suburban Private School RTOP Results

Observation Protocol	Raul: 1 low	Raul: 2 low/ medium	Raul: 3 medium/ high	Raul: 4 high	Meredith: 1 low	Meredith: 2 low/ medium	Meredith: 3 medium/ high	Meredith: 4 high
I. Lesson Design and Implementation								
1. The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.		2					3	
2. The lesson was designed to engage students as members of a learning community. ****			3					4
3. In this lesson, student exploration preceded formal presentation.				4			3	
4. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving. ****				4				4
5. The focus and direction of the lesson was often determined by ideas originating with students. ***				4				4
II. Content								
Propositional Knowledge	1 low	2 low/ medium	3 medium/ high	4 high	1 low	2 low/ medium	3 medium/ high	4 high
6. The lesson involved fundamental concepts of the subject. ****		2			1			
7. The lesson promoted strongly coherent conceptual understanding.	1				1			
8. The teacher had a solid grasp of the subject matter content inherent in the lesson. **				4				4
9. Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so. *	1				1			
10. Connections with other content disciplines and/or real world phenomena were explored and valued. **				4			3	
Procedural Knowledge	1 low	2 low/ medium	3 medium/ high	4 high	1 low	2 low/ medium	3 medium/ high	4 high
11. Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena. **				4		2		
12. Students made predictions, estimations and/or hypotheses and devised means for testing them. ****			3				3	
13. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures. ***				4				4
14. Students were reflective about their learning ***		2				2		
15. Intellectual rigor, constructive criticism, and the challenging of ideas were valued. ***			3					4
III. Classroom Culture								
Communicative Interactions	1 low	2 low/ medium	3 medium/ high	4 high	1 low	2 low/ medium	3 medium/ high	4 high
16. Students were involved in the communication of their ideas to others using a variety of means and media. ***			3				3	
17. The teacher's questions triggered divergent modes of thinking. **			3					4
18. There was a high proportion of student talk and a significant amount of it occurred between and among students. ***				4				4
19. Student questions and comments often determined the focus and direction of classroom discourse. **				4			3	
20. There was a climate of respect for what others had to say. * **			3					4
Student/Teacher Relationships								
21. Active participation of students was encouraged and valued. ** *				4				4
22. Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence. **				4				4
23. In general the teacher was patient with students. ***				4				4
24. The teacher acted as a resource person, working to support and enhance student investigations. ****				4				4
25. The metaphor "teacher as listener" was very characteristic of this classroom.				4				4
	2	6	18	56	3	4	18	52
			Total	82			Total	77

Appendix F.

Urban Public School RTOP Results

Observation Protocol	Raul: 1 low	Raul: 2 low/ medium	Raul: 3 medium/ high	Raul: 4 high	Meredith: 1 low	Meredith: 2 low/ medium	Meredith: 3 medium/ high	Meredith: 4 high
I. Lesson Design and Implementation								
1. The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.			3			2		
2. The lesson was designed to engage students as members of a learning community. ****	1					2		
3. In this lesson, student exploration preceded formal presentation.	1				1			
4. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving. ****	1					2		
5. The focus and direction of the lesson was often determined by ideas originating with students. ***	1					2		
II. Content								
Propositional Knowledge	1 low	2 low/ medium	3 medium/ high	4 high	1 low	2 low/ medium	3 medium/ high	4 high
6. The lesson involved fundamental concepts of the subject. ****			3					4
7. The lesson promoted strongly coherent conceptual understanding.		2				2		
8. The teacher had a solid grasp of the subject matter content inherent in the lesson. **			3					4
9. Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so. *	1					2		
10. Connections with other content disciplines and/or real world phenomena were explored and valued. **	1						3	
Procedural Knowledge	1 low	2 low/ medium	3 medium/ high	4 high	1 low	2 low/ medium	3 medium/ high	4 high
11. Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena. **	1				1			
12. Students made predictions, estimations and/or hypotheses and devised means for testing them. ****	1				1			
13. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures. ***	1				1			
14. Students were reflective about their learning ***	1				1			
15. Intellectual rigor, constructive criticism, and the challenging of ideas were valued. ***	1							4
III. Classroom Culture								
Communicative Interactions	1 low	2 low/ medium	3 medium/ high	4 high	1 low	2 low/ medium	3 medium/ high	4 high
16. Students were involved in the communication of their ideas to others using a variety of means and media. ***	1					2		
17. The teacher's questions triggered divergent modes of thinking. **	1					2		
18. There was a high proportion of student talk and a significant amount of it occurred between and among students. ***		2				2		
19. Student questions and comments often determined the focus and direction of classroom discourse. **	1					2		
20. There was a climate of respect for what others had to say. * **			3					4
Student/Teacher Relationships								
21. Active participation of students was encouraged and valued. ** *			3				3	
22. Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence. **	1				1			
23. In general the teacher was patient with students. ***				4			3	
24. The teacher acted as a resource person, working to support and enhance student investigations. ****				4				4
25. The metaphor "teacher as listener" was very characteristic of this classroom.		2					3	
	15	6	15	8	6	20	12	20
			Total	44			Total	58