Investigating Student Motivation in the Context of Engaging in Authentic Science Practices

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Abstract

This paper addresses the problem that motivation and interest in science often decreases during middle grades. The purpose of this qualitative study is to determine in what ways, if any, an authentic paleontological project (Fossil Finders) affected students' motivation in science. Participants included students who would be described as traditionally underrepresented in the sciences and many received English Language Learner (ELL) services. We used the Self-Determination Theory (SDT) of motivational research as a framework to understand student motivation during a classroom authentic science investigation. The level of motivation was determined through analyses of student interviews. The research questions included: 1) Is there evidence of student motivation during an authentic school science investigation? 2) In what ways do particular factors foster or suppress student motivation in an authentic investigation? 3) How do social interactions encourage or discourage student motivation while participating in an authentic investigation? Data included semi-structured interviews of 40 students of diverse backgrounds from 4 classrooms in different areas of the U.S. Findings include nearly three-quarters of these students (29/40) demonstrated motivation and were enthusiastic about the authentic science experience; authentic science has potential to have both positive and negative impacts on student motivation; and that diverse students are particularly excited and motivated by the social interaction of helping others (scientists) while doing science.

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Increasing students' motivation in science is both an educational goal and a means to an end. Motivation is highly valued due to the consequences it can produce such as student learning and obtaining a good job in the future (Ryan & Deci, 2000). Motivating students is a challenge that is faced daily by science teachers (Shumow & Schmidt, 2014). Unfortunately motivation, interest, and student perceived competence often decreases during middle grades (Anderman & Anderman, 1999; Anderman & Midgley, 1997). This is a concern since during middle grades students start making decisions about what types of courses to take in high school. Lack of motivation in science can deter students from taking additional science course in high school, and students may not have background knowledge necessary to pursue careers involving sciences. Our study focuses on understanding motivating and non-motivating factors for 7th & 9th grade students involved in an authentic paleontological science project, Fossil Finders. In the study we had a particular focus on students from populations generally underrepresented in the sciences.

Understanding student science motivation is complex. Motivation involves an interplay of different contexts and factors that come together to make up motivation (Vallerand & Ratelle, 2002). It can be socially impacted and highly influenced by others (Vallerand & Ratelle, 2002). What makes it so complicated to study is that students in the same context can have factors impact them differently leading to different levels of motivation (Ryan & Deci, 2000). This is why it is important for educators to study student motivation in science to better understand what factors can enhance and suppress motivation.

The purpose of this study is to determine in what ways, if any, an authentic paleontological project (Fossil Finders) affected students' motivation in science. The level of motivation was determined through analyses of student interviews. The research questions are:

1) Is there evidence of student motivation during an authentic science project?
2) In what ways do particular factors foster or suppress student motivation in an authentic school science investigation?
3) How do social interactions encourage or discourage student motivation while participating in an authentic school science investigation?

Rationale

Previous research suggests that context can play an important role in impacting student motivation. Vedder-Weiss & Fortus (2011) found science motivation declines during middle years for students enrolled in traditional schools, but not for those enrolled in democratic schools. Suggesting that school context can be crucial for enhancing or suppressing motivation. Pickens & Eick (2009) compared strategies that work well for motivating students in different tracked classrooms, showing that for these groups of students, different factors impacted their science motivation. Liu, Horton, Olmanson, & Toprac (2011) studied learning and motivation of middle school science students involved in Problem Based Learning (PBL) noting that the PBL context significantly increased science knowledge as well as science motivation. All these studies confirm the idea that understanding contextual factors can be instrumental in understanding science motivation. There are many unique classroom science contexts that have not yet been studied. Relatively little research has been done on motivation in the context of an authentic science investigation project. There are more opportunities than ever for students to participate in authentic science, which makes it essential to understand how this context may impact student motivation.

Social interactions can play an important part in understanding students' motivation. Wentzel (1998) studied how motivation in middle schoolers was impacted by perceived support from peers, parents, and teachers. In our work we are also interested in how social interactions may impact motivation. We take a specific focus on science education and studying peers through concentrating on how group interactions during an authentic project impact motivation. Working with others is advocated as part of the social aspect of science, thus it is important to understand how these interactions can influence classroom motivation. There is also little research available on how social interactions with scientists impact student motivation. With technological advances it makes students and scientist social interactions more prominent making it important to understand how interacting with a scientist may impact student science motivation.

Though previous studies have attempted to understand factors that impact student motivation in the science classroom, most of this work has used highly quantitative data such as Likert-style surveys. Our study is different in that for our data we use qualitative student interviews to determine motivation. We believe that this method is vital to truly listening to students and understanding what they value and what is important in motivating them. This method is also one that allows us to see unique connections among factors for motivation.

An important area of education research is studying the gender gap between males and females. Numerous motivation articles have looked at differences in motivation between male and female students. Briter (2008) studied self-efficacy motivational differences between earth, life, and physical science classes based on gender of high school students. Patrick, Mantzicopoulos, & Samarapungavan (2009) investigated how kindergartners who participated in inquiry and science literacy units were motivated in science and compared that with students in a traditional science experience. They found that there was a gender gap in science motivation for students involved in a traditional science experience, but not for those participating in the inquiry and literacy intervention. Schmow & Schmidt (2013) found that female high school students were more likely to feel less competent in science and have a more negative attitude toward science. While we acknowledge that this work is essential to help close the achievement gap in science between males and females we think it is important to recognize that females are not the only group that has been traditionally underrepresented in the sciences. In this study we explore motivation of students who come from diverse backgrounds, many of which would be considered underrepresented in the sciences, including English Language Learners (ELLs). We believe that understanding student motivation in science *for all* is crucial for the goals of science literacy as well as for the innovation that having diverse individuals working in science can bring.

Theoretical Frameworks

Self-Determination Theory

We are interested in understanding student intrinsic motivation, meaning students' behavior based on interest or enjoyment during an authentic science project (Vallerand & Ratelle, 2002). This science project attempts to be autonomous meaning that it nurtures students' needs and interests (Reeve, Jang, Carrell, Joen, & Barch, 2004). We used the Self-Determination Theory (SDT) of motivational research as a framework to understand student motivation during an authentic science project. This theory is considered to be one of the most comprehensive models for human motivation (Shumow & Schmidt, 2014). SDT looks at the social-contexual conditions that lead to self-motivation and healthy psychological development (Ryan & Deci, 2000). Three basic inherent needs underlie human behavior according to Self-Determination Theory (Ryan & Deci, 2000; Ryan and Deci, 2002): (1) the need for autonomy (behaving based on interest and integrated values); (2) the need for competence (acquire competencies), and (3) the need for relatedness (feeling connected to others). These three needs support motivation and therefore are used in this study as the analytical lens for understanding students' experiences.

Sociocultural Theory

Motivation is highly individualistic with multiple factors interacting to impact it. Other people can have a huge impact on a student's' motivation (Vallerand & Ratelle, 2002). A particular social context can lead students to have different levels of motivation (Ryan & Deci, 2000). In this authentic science project there is a high amount of social interaction since students worked with their peers in a group to collect and analyze data and to answer research questions. Students also interacted and shared ideas with a scientist either within the classroom or by using internet technology to live chat.

Due to the high level of social interaction in this project we used Sociocultural Theory as a lens to understand how social interactions impacted student motivation. Students interacting with each other and with scientists are human social interactions taking place within a cultural framework of the science classroom (Cobb, 1994; Lemke, 2001). We looked at understanding social interactions within a time scale of a two-week classroom authentic investigation. We focused on students who participated in the investigation, as opposed to larger social structure of the school and community. This is because we subscribe to the belief we can only understand a certain amount of local reasons, within the timescale, and classroom contexts in determining how interactions during this authentic science project impacts students motivation (Lemke, 2001).

Research Design and Methods

Research context

Teachers of the participant students all had participated in a summer week-long inquiry-based professional development program focused on an authentic paleontological investigation. Teachers spent time in the field and the classroom working to answer the research question: How did sea life respond to changes in the environment during the Devonian Period in central New York? Teachers taught the same authentic project to their students during the school year. Each teacher was sent supplies and rock samples from an outcrop in upstate New York. This project was unique in the rock samples that were shipped to schools had not previously been studied by scientists. The students would be the only ones collecting data from these samples. Once collected, their data were uploaded to a website that could be used by other students as well as scientists.

In the classroom students worked in groups to collect data and answer a research question. Students used geological equipment such as hand lenses and calipers to observe and classify fossil specimens. Fossil taxa included bivalves, brachiopods, cephalopods, corals, gastropods, and trilobites. Data collected included number of fossils, type(s) of fossils, length, width, fragmentation of fossil, and coloration of rock. These factors were indicators of past environmental conditions of the research site. During the project, students could ask questions and share ideas with paleontologists either in person or through online video chatting. Students used an online database to enter the fossil data. Students, teachers, and scientists globally could view data reports and export data to a spreadsheet.

Classroom teachers

Table 1 below gives specific information about teachers of the classrooms involved in this authentic science project. This study is part of a larger project involving 30 teachers. The four teachers in this study were all experienced science teachers having five to fourteen years classroom experience. All were currently teaching in a public school setting in either 7th or 9th grade. Two of the classes (Andrew & Kendra) were more focused on earth science, while the other two (Darlene & Roger) were life science courses. All teachers taught students who would be described as traditionally underrepresented in the sciences and many of these students were receiving English Language Learner (ELL) services. For additional information on teachers in this study or the professional development program see Capps & Crawford (2013).

Table 1. Fossil Finders Teachers and Class Demographics

Teacher Pseudonym	Teaching Experience (years)	Certification	Degrees Earned	Grade/ Subject Taught	Region in US	Underrepresented Students
Andrew	14	Secondary	BS Geology; MA Liberal Arts	9th grade earth science	Northeast	Russian, Ukrainian
Darlene	10	ELL certification with biology supplement	BA Fine Arts; MA Science Education	7th grade life science	West	Asian, Hispanic
Kendra	5	Elementary	BS Biology; MA in Education	7th grade science with earth science emphasis	Midwest	African American, Albanian, Asian, Hispanic
Roger	13	Secondary biology & chemistry	BA Biology & Chemistry MS Biochemistry	7th grade life science	Northeast	African American, Asian, Hispanic

Student Participants

Forty students were interviewed following the completion of the project. Participants ranged in age from twelve to fifteen years of age. Table 1 above gives specific information about the different classrooms including grade level, region of the country, and which underrepresented groups were interviewed. Interviews were conducted in English. All students interviewed had participated in the entire Fossil Finders unit.

Data Collection

Teachers selected roughly ten students of different backgrounds to participate in qualitative semi-structured phone interviews, resulting in 40 student interviews total. Students were also selected based on representing different levels of science achievement. This was determined by the teacher based on previous grades and engagement in their class. Semi-structured interviews were completed at a time that was convenient for participants and did not require them to miss any class. Interviews started with general questions about a student's favorite subject in school and how science compares to other subjects as a way to get some background on the student and establish rapport. Interviews then moved to students discussing their experiences in the project including what aspects they found most and least engaging and why. Interview lengths varied from five minutes to twenty-seven minutes. Interview protocol is available from authors.

Data Analysis

Researchers used a qualitative approach to determine the nature of the students' motivation. Interview transcripts were analyzed systematically using a combination of a priori categories and inductive codes. All transcripts were open coded multiple times by the first author and fifth and sixth authors which led to creation of additional categories. A priori categories included (1) aspects of SDT including autonomy, competence, and relatedness (Ryan & Deci, 2000) as well as (2) expressions of meaningfulness, and (3) reform-based science teaching practices related to the project such as: authenticity, group work, interaction with scientists, inquiry, hands-on science, and use of technology. Categories that emerged included (4) feeling like a scientist; (5) problem solving; (6) science concepts; (7) Science Practices outlined in the Next Generation Science Standards (NGSS, Lead States, 2013); and (8) helping others including classmates and scientists. Throughout the process some of the codes changed as the process evolved. For instance the inductive code of motivation process was changed to Science Practices of NGSS to better reflect current science education reforms. This change ultimately made student ideas easier to categorize. The first author coded, categorized, and analyzed the interviews, and compared with other authors. The level of agreement between authors was 95.8%. For a complete list of categories and examples see Table 2 located below.

Table 2. List of Factors that Impact Student Motivation

Category	**Definition**	**Example:**
Authenticity	Science that matches with the practices of actual scientists such as: collecting & analyzing data, working with real samples	Yeah, cause it's better, cause it's real stuff not fake. So it's not just something somebody made for class. It's real (Virginia, line 42).
Autonomy	Behaving based on interest and integrated values (Ryan & Deci, 2002).	I liked working with stuff instead of doing experiments that people have already done before. This is brand new, and everything is cool (Serena, line 56).
Competence	Feeling successful in interactions with one's social environment and having the opportunity to show one's abilities (Ryan & Deci, 2002)	That was probably actually the easiest part about it. We log in all of our data for each rock and type of rock and um and so it was so scientists can use it (Mac, line 32).
Group Work	Collaborating with others in a peer group to work toward a goal or completing a task	It was fun. It was cool trying to look for fossils with your friends and stuff (Francis, line 78).

Hands-on Science	Science in which teachers have students use hands-on on investigations or experiments where students encounter empirical truths (NRC, 2007)	You like felt, I don't know. You just like, the texture [of the rock] and everything. It was really cool (Oksana, line 35).
Helping Others	Being useful and benefiting others through assisting in some way	Like no one else looked at those rocks before and you are doing something that would actually help benefit people (Reese, line 43).
Interacting with Scientists	Speaking with scientists face-to-face or virtually through the computer to discuss ideas, ask questions, and pose hypotheses	Well um, it was cool because everything we learned, I talked with someone about it. But then, everything I did and my findings I had. To talk to a real professional was fun (Audrey, line 55).
Problem Solving	The activity of using specific strategies to solve scientific problems	I think it's fun because you're working with things and acting like a scientist trying to solve something and try to figure it out. So when you measure it, you can show how big it was and see how big it was and have an idea of what the thing was that lived (Jill, line 83).
Relatedness	Feeling linked to others and fitting in with one's social group (Ryan & Deci, 2002)	It made it fun working as a group and finding it together (Mateo, line 46).
Science Concepts	Student expressed motivation based on learning about science content related to a life or earth science concept	…because we actually get to see what's inside the earth and what happened millions of years ago (Sophie, line 83). *This is an example earth's history
Science Practices	The eight science practices outlined by Next Generation Science Standards	My question was, what did this land look like millions of years ago? (Larry, line 156) *This is an example of Science Practice 1 Asking Questions
Technology	Use of science apparatus such as a microscope that can be used to accomplish a specific task	Yeah, we had to log the information that we found on our fossils in the computers and we used different microscopes and stuff like that (Mila, line 53).

In using SDT as a framework we looked at whether needs for autonomy, competence, and relatedness were being met by different factors such as group work or authenticity. For instance when Rory, a ninth grade student whose teacher reported that he did better than normal in the Fossil Finders unit, discussed working in a group he said "Cause we could talk to each other and ask each other what do you think this is and help each other out" (Rory, line 21). This simple student quote would be categorized multiple ways including: group work, helping others, competence, and positive interaction. To understand motivation it was vital to capture how multiple categories were interacting to enhance or suppress student motivation. For example in Rory's case his need for competence was met through the group work helping to motivate him during this authentic science project.

There were also times when students gave a single word answer such as answering "yeah" to whether they used technology which would be categorized as neutral and then therefore was not categorized as being related to autonomy, competence, or relatedness.

Each interview was coded and categorized multiple times by three of the authors in order to get a more complete understanding of each student's experiences with the authentic science project. Once all interviews were coded and categorized a table was created to determine the number of students who were motivated and unmotivated by this authentic science project. This was done by looking at interviews holistically as well as remarks throughout the interview to understand what each student's unique experience was during the project. Denise, an African American seventh grade student made many positive comments related to liking this unit so we analyzed her words to see whether or not she was motivated. When asked about her personal experience Denise explained "Yeah it was a lot of fun. It was fun to work and learn about fossils." (Denise, line 26). Later she recounts discussing the unit with her parents and says "Yeah I told them about Fossil Finders. I told them it was fun and that I liked it. It was rocks from like a different type of area and we were looking at them for different brachiopods" (Denise, line 35). Toward the end Denise tells a story to the interviewer about observing and identifying fossils with her group and says it sticks out her mind "because it was kind of fun to find new and more things in that rock" (Denise, line 44). Based on her words and enthusiasm throughout the interview, Denise would be characterized as a student who was motivated by this project. Knowing this is not enough though, we wanted to understand why she was motivated and what particular factors motivated her. Once we determined she was motivated additional analysis of the interview was then done to try to get at these factors. In her interview Denise communicated her positive group interactions and excitement about working with the samples. She recounted her positive experience,

> Me and my friends were looking at a rock, and it had like over 5 different kinds of fossils. There were a few cephalopods in it and a few fragments of like twig stuff [coral]. There was a lot of brachiopods on it too. It was a pretty fun experience (Denise, line 40).

Understanding these statements helps us to see that social aspects of working with others and analyzing authentic samples were motivating to Denise. However, not all students were motivated by Fossil Finders, as some students referred to it as "boring" or "not interesting". For those students it was also important to look at what factors might be associated with students not being motivated by the unit.

We then strived to understand specific factors and how their interactions might have increased and decreased motivation for students. We counted the number interviews in which a certain code was used and determined if that code was more often related to autonomy, competence, or relatedness. We were able to see patterns of how "having" or "not having" needs met for autonomy, competence, or relatedness, might either enhance or suppress student motivation. It was very common to see that one factor could either suppress or enhance motivation, depending on the student. For example "using technology" was one of the factors where we saw students having mixed reactions Ming told us "I'm not really a tech person, so I didn't really like the computer part" (Ming, line 110). For Ming using computers did not help her to meet her need for competence, so this did not motivate her. However, Audrey a ninth grade Caucasian student had a much different experience using technology explaining,

> Audrey: Yeah, for the data. We plugged it into laptops and after that we saw the graphs with all the ranges for species we had.

Interviewer: Was that helpful?
Audrey: Yeah, especially because the different time periods and what type of habitat they lived in. Seeing all our hard work (Audrey, line 64).

For Audrey the technology was a useful tool that helped her to analyze her data and she gained a sense of autonomy from doing something she was invested in.

After multiple rounds of categorizing, the categories were combined and split creating overarching themes related to motivation in authentic science for students. The three themes that emerged from the data are: (1) Reform-based science teaching practices can enhance or suppress student motivation in science, (2) Authentic, interdisciplinary science is engaging and motivating for students, including students generally underrepresented in the sciences (3) Social interactions during authentic science projects can both encourage and discourage student motivation.

Findings & Discussion

We set out to answer the following research questions: 1) Is there evidence of student motivation during an authentic science project? 2) In what ways do particular factors foster or suppress student motivation in an authentic school science investigation? 3) How do social interactions encourage or discourage student motivation while participating in an authentic school science investigation? Findings are arranged by research questions with constant focus on how themes impact student motivation in an authentic classroom science project.

Research Question 1

To answer our first research question we analyzed each student's interview separately and categorized students as either motivated or not motivated. Students who were negative about Fossil Finders or were neutral were placed into the not motivated category. Nearly three-quarters of these students (29/40) demonstrated motivation and were enthusiastic about the authentic science experience, while 11 students were neutral or not motivated by the project. We use two students, Mila and Jesse, who are representative of motivated students in that there were multiple factors that impacted their motivation, to showcase what student motivation looked for this authentic project.

Mila's experience with Fossil Finders. An interview with Mila a Ukrainian 9th grade student shows how statements were used to determine if students were motivated and what factors contributed to motivation. Mila explained her feeling towards Fossil Finders by repeatedly saying that it was cool and fun. When asked more specific questions about it she was able to explain why working with fossils is cool, "Cause they're really old and they're preserved in the rock" (Mila, line 29). We then asked an additional follow-up question to try to understand why the age of the fossils was important to Mila and she stated, "Cause they don't exist anymore and it's cool to see how it was so different back then" (Mila, line 65). This suggests that the authentic nature of working with real fossils is important as well as comparing fossils to current life on our planet. She also explained why the hands-on nature of this authentic project was important, "Because if you hold it, you can explore more and touch it" (Mila, line 62). For Mila working with others helped her to gain competence and enhanced motivated. She discussed how she felt about working in a group through saying "I liked it because if we had a question, we could just ask someone for their opinion. It was easier than working by ourselves" (Mila, line 50). However, help was not a one-way street. She was also motivated by the prospect of getting to help scientists by collecting data. Mila explained that collecting the data was important because, "It was really cool to actually help out" (Mila, line 76). This sentiment was one that we saw repeated by students. Fossil Finders gave students a chance to contribute to the science community by collecting data that anyone, including scientists can use and access. When asked how this project compares to science lessons that are normally done in her classroom, Mila contrasted it by saying "It's more interesting and you actually get to realize yourself what's happening, not just have someone tell you" (Mila, line 107). Mila's words are evidence that this project met her need for autonomy and it was important to her to find things on her own without being given answers. Her words are evidence that authentic aspects, hands-on science, and social interactions of working with a group and helping others all contributed to her motivation during the unit.

Jesse's experience with Fossil Finders. In looking at student interviews it became apparent that many students could be motivated by this authentic project, but due to very different factors. Jesse, a Caucasian seventh grade boy was also highly motivated by Fossil Finders, but for much different reasons than Mila. For Jesse the Science Practice of Asking Questions was very motivating. He told us "The question I came up with, I was very curious about, instead of having a question given I wasn't interested in" (Jesse, line 105). This curiosity about his own question was so important that he said "I definitely put more effort in since I was actually curious about it, not doing it for a grade" (Jesse, line 116). This suggests that he gained a sense of autonomy from this and found himself intrinsically motivated by answering his question, as opposed to being extrinsically motivated by grades. Like Mila, he also liked the authenticity of the project, but it was not the age of the fossils that he was interested in. He liked working with real samples and said, "I really liked how we measured the fossils" (Jesse, line 24) and went on to discuss using calipers. He also explained it was important to him to be working with data and fossils that no one else had analyzed. For Jesse it was important that no one had answered the research question, which can be seen in his words, "I liked that because it was more interesting than doing a worksheet that has an answer key" (Jesse, line 98). For 29 of 40 Fossil Finders students we saw multiple factors coming together associated with motivation.

Research Question 2

The question, in what ways do particular factors foster or suppress student motivation in an authentic school science investigation, enabled us to assess not only whether or not students were motivated, but to more deeply understanding the motivating factors. Our first two themes contributed to answering this question: (1) Reform-based science teaching practices can enhance or suppress student motivation in science, (2) Authentic, interdisciplinary science is engaging and motivating for students.

Theme 1: Reform-based science teaching practices can enhance or suppress student motivation in science. We found that students' experiences and motivations are so highly individual and that some reform-based practices such as hands-on science and problem solving and particular subject matter were more likely to enhance motivation while other factors: authenticity, technology and Science Practices would either enhance or suppress student motivation. Table 3 lists all of the factors related to this authentic science project that impacted motivation. For each factor on the table we looked at how many students related the factor to autonomy or competence. Plus signs indicate that it helped to enhance motivation, while minus signs indicate that it suppressed motivation. For instance if we look at the interaction of authenticity and autonomy 27 students had their need for sense of autonomy met leading to motivation, while six students did not have their sense of autonomy met leading to a suppression of motivation. Relatedness is not discussed in this section since it more closely aligns with the third research question on social interactions. Numbers summed across a row will not necessarily add up to the sum of the interviews present since a student may mention a factor multiple times in an interview. One time it may impact autonomy while the other time it may impact competence. Another reason that some rows may not sum up is some students were neutral about a factor such as technology. When this happened we could not record it as relating to autonomy or competence, because it was not suppressing or enhancing student motivation.

Table 3. Factors that Increase and Decrease Student Motivation

Categories	# of Interviews Containing	Motivation Associated with Perception of Autonomy +/-	Motivation Associated with Perception of Competence +/-
Authenticity	33	27/6	0/4
Hands-on Activity	28	24/0	2/0
Problem Solving	19	15/0	4/0
Science Concepts	23	23/0	1/0
Science Practices	21	10/3	5/6
Technology	24	5/0	3/8

How "hands-on" impacted motivation during an authentic science project. The 2011 Nation's Report Card found that 8th grade students who frequently did hands-on science did better on the National Assessment of Education (NAEP) than students who less often experienced hands-on science (National Center for Education Statistics, 2011). We found that in this study students' motivation was always enhanced by hands-on science. This is a positive finding, since this motivating factor correlates to doing better in science. For most students hands-on science helped to meet their need for autonomy. A Caucasian seventh grade student, Sophie explained why the experience was motivating to her:

> "It's kinda different cause you get to experience it and hold it and get actually get to look for it. But like, and when you read and stuff, you don't get to experience it you just get to read it" (Sophie, line 42).

Some students noted that this type of science was much different than they are used to doing in their classroom, "I think it was my first time this year that we got to do experiments and we actually got to do hands-on class work" (Serena, line 24). The Nation's Report Card also informs us that 68% of students do hands-on science once or more a week (National Center for Education Statistics, 2011). Though this is something that has been advocated for decades, our participant Serena's words remind us this this type of hands-on investigation can still be a novelty in some classrooms in the United States, especially for students that in classrooms is not in the 68% that are frequently doing hands-on science.

How problem solving impacted motivation during an authentic science project. Despite that problem solving is not necessarily one of the emphases in our authentic science project, we found that students spontaneously reported being motivated by problem solving during the unit. Problem solving was a factor that always enhanced motivation by meeting students' need for autonomy or competence. Jill, a seventh grade Hispanic student, was particularly clear about sharing her thoughts of how problem solving motivated her. She explained

> In Fossil Finders, it tells you what happened. It doesn't give you the answer right away. You have to solve it. It's like a puzzle. You have to like try to figure that out. And you get interested because you try to think of the answer but it may not be it. So you want to know the real answer to understand it better" (Jill, line 83).

Six minutes later in the interview Jill came back to the idea of problem solving and stated,

> I think its fun because you're working with things and acting like a scientist trying to solve something and try to figure it out. So when you measure it, you can show how big it was and see how big it was and have an idea of what the thing was that lived. And they can see immediately why and how it was layered in the rock. And like, did it stay in place?" (Jill, line 117).

This shows how she saw problem solving as a way to understand past environments and animal behaviors. Jill gives an explanation that was typical of a student who enjoyed problem solving. Many students often mentioned how problem solving helped them to feel like a scientist. Working on a problem that had not been solved or the answer was unknown helped to meet students' need for sense of autonomy. A seventh grader Serena contrasted Fossil Finders with typical school science explaining why it is better if the answer is unknown. Serena told us "I liked working with stuff instead of doing experiments that people have already done before. This is brand new, and everything is cool" (Serena, line 56).

Problem solving is important to use both in science and in everyday life to make inferences about cause and effect (National Research Council, 2007), so we see students motivation toward problem solving to be quite positive. However, we would also like to caution that students were not motivated by problem solving in general, but by the idea that no one knew the answer to their problem and they would be the first to solve or find the answer.

How Science Concepts impacted motivation during an authentic science project. Learning about science concepts was overwhelmingly something that students reported as increasing motivation. Specific science concepts helped meet students' need for autonomy. Table 4 below lists the science concepts students mentioned and how often they were discussed.

Earth's history was the science concept that students brought up most often during the interview. Students were often very motivated to understand Earth's history and changes that have occurred over time. Sophie, a Caucasian seventh grader, explained why she liked learning about this by saying, "I think it makes a big difference because we get to learn all about it …because we actually get to see what's inside the earth and what happened millions of years ago" (Sophie, line 82). Many students made comments suggesting that the age and history of the fossil and rock was an important motivating factor.

Table 4. Science Concepts Contributing to Student Motivation

Science Concept	Number of Interviews Discussed
Earth's History	12
Earth Systems	2
Structure & Function of Organisms	10
Understanding Ecosystems	7
Biological Evolution	5

The second most discussed science concept was structure and function of organisms. Ten students discussed their enjoyment of learning about content related to structure and function of organisms. They were motivated to find out more about the organisms including what they looked like and what their behaviors were when they were alive. A seventh grade Chinese student explained why he liked learning about fossils in saying, "Ya. You get see most of the parts and how they see how they lived and stuff" (Alan, line 25). Alan's comments demonstrated his interest in understanding what the organisms were like when living. His discussion of "parts" can be seen as his interest in learning about the structure of the organism. Students often expressed interest in multiple science concepts. It was not uncommon for students to not only be interested in understanding the lives of fossil organisms, but also to compare them with organisms living today.

The third most commonly discussed science concept was understanding ecosystems. Students were motivated by an opportunity to understand ecosystems and how these organisms interacted within their environment. Alexis, a Russian student explained her motivation by saying, "I like the ocean part, like what used to live in it. It was cool" (Alexis, line 24). Alexis expounded on this by explaining that learning about the ocean has been a long standing interest for her in science. A chance to learn about this environment was particularly motivating for her.

How authenticity impacted motivation during an authentic science project. Not all reform-based science teaching practices enhanced student motivation. This project was much more authentic than normal classroom science. We consider authentic science to be science that matches with the practices of actual scientists, such as working with real meaningful data (Crawford, in press, 2014). The project was authentic in that students were working with real rock and fossil samples that had never been studied, they were using science tools like calipers that a scientist would use, analyzing and interpreting real science data, and sharing their data with others, and doing an investigation important to practicing paleontologists. For most students the authentic nature of the project met their need for autonomy and increased motivation. However for others, authenticity did not help to meet students' needs for competence or autonomy, and motivation was therefore, suppressed. Students often mentioned the feeling of awe they felt at actually getting to work with and touch samples that were from the Devonian or excitement over finding a fossil that they saw as unique or special. Oksana, a Ukrainian student explained her thoughts related to working with authentic fossils and said, "so it seems like the fact that it's really, really old, you care about it. It's meaningful to you" (Oksana, line 69). It was very common for the age of the fossils to be a reason that students enjoyed working with authentic samples. Asher, an African American seventh grade student. elaborated on why he liked working with authentic fossils.

> I guess it was cool that they were real fossils. I've seen real fossils but not like that. I've never got to touch a fossil. I've seen them in museums and stuff but actually getting to touch is different. It's like, I actually get to touch a fossil that was before I was even born. It was pretty cool. The fact they are old, that really impressed me… So what's a road now used to be a shallow sea, I find that awesome (Asher, line 56).

We speculate that if the students did not see the samples as real or authentic they may not have had the same powerful connection to the project that they did. Students who found unique fossils were more likely to show greater motivation in the project. Nancy, a Caucasian 7th grade student stated, "We found this really awesome fossil that the rock was broken in half. Interviewer: So why did that stick out in your head? Because it was an amazing fossil, and there weren't any others like it" (Nancy, line 60). Had the sample not been authentic Nancy would not have had an opportunity to find a fossil that was special to her.

Students also valued that they were working with data that they saw as "real". Jack, a Caucasian ninth grade student explained why he liked working with Fossil Finders data and contrasted it with what they normally work with in class and explained "it wasn't like state data from [state standardized science test], we used actual data" (Jack, line 36). These students saw data they normally work with in class as contrived and therefore less motivating.

Unfortunately, some students did not have their sense of autonomy or competence met by the authentic nature of the project and were not motivated. One factor was that made a big difference to students was the variability in fossils from sample to sample. Real rocks were shipped to classrooms and distributed randomly to groups, which meant each sample was different. As these were authentic samples, some rocks had more fossils than others, and some no fossils. To scientists, this is still real and important data. A couple of the students internalized not finding many fossils as not being very competent. Bryce, a Chinese seventh grader explained his thoughts after being asked why he did not feel he was good at the project "Cause there were not really hardly any fossils in some rocks" (Bryce, line 5). A few students who found only a few fossils stated that by the end of the project, they lost interest. Kim, an Asian seventh grade student had this happen to her and said, "For me it was pretty boring and easy at the same time. Our rocks weren't interesting, we had a lot of rocks but only like five fossils" (Kim, line 158). Some students wished they had found certain unique fossils that other groups discovered, as exemplified by this 7th grader, Micah,

> The group next to us found, you know one of those tiny ice cream [shaped] shells, they found one in a rock and they cracked it open and it just fell out and it was like stone. It was really cool because the shape was in the rock but it was actually still preserved and it just like fell out. That would have been cool if I found something like that (Micah, line 21).

This students' sentiments were shared by a couple other students who also felt like their samples were not very interesting and did not have enough fossils. Conversely, Chase a Caucasian seventh grader who had many fossils, 17 fossils in one rock, had his autonomy suppressed and lost interest. He explained his thoughts,

> There was this one rock, there was like 17 little clumps on it, all like half a millimeter differences in size, and you have to measure every single one of them even though there is like 17 in one rock. I like to be able to say take one in the middle and find how many others are there, and say they are all the same size … it got a little tedious doing that because there were two rocks like that, one had 11 and one had 17. Measuring with calipers with blah, blah, blah, millimeters (Chase, line 132).

We believe that while many students are motivated by doing authentic classroom science there is also a point at which the work may become too authentic and motivation can be lost for students. This idea will be discussed in the implications section.

How engaging students in Science Practices impacted motivation during an authentic science project. Engaging in Science Practices, as outlined in NGSS was another factor that both enhanced and suppressed motivation for students. Table 5 below shows the six practices that students discussed whether they increased or decreased motivation. The most common science practices that were mentioned were (5) Using mathematics and computational thinking, (4) Analyzing and interpreting data and (1) Asking questions. All three of these practices both enhanced or suppressed motivation, depending on the student. Students always discussed practice 5 in reference to the measurements and the quantitative data that students recorded about the fossils. Millie, a Caucasian seventh grader explained her motivation in working with fossils "We actually get to do stuff with fossils. Like measure them. We get the data. It's different than the rest of the stuff we do" (Millie, line 18). Millie's statement showed that she enjoyed measuring fossils and collecting data which was different from a typical science classroom experience. When we asked Bryce if there were parts he liked besides finding fossils, he answered " finding how big and small it is and the lengths and sizes" (Bryce, line 15). For Bryce working with this mathematical data was something that helped to motivate him. Unfortunately, other students did not have the same feelings about the mathematical aspects of this authentic science investigation.

Five students reported either not enjoying working with calipers or not feeling competent about working with them which made collecting and analyzing quantitative data on the fossils unmotivating. The frustration of Ming, an Asian can be seen in her words,

> Well measurements, it was fun at first but then the calipers, I didn't really know how to do it. I was like, I should have been using normal rulers because the calipers were so difficult to use (Ming, line 120).

We see this issue as highly related to the authenticity issue discussed earlier. Some students were unenthusiastic to mathematical parts of Fossil Finders, since they had difficulty using the tools that scientists would use. While using calipers was more authentic and more accurate than ordinary measuring devices, difficulty with using calipers decreased motivation for some students. Ultimately, the goal of motivation and authenticity are in conflict in this particular scenario. Since we did not have these students work with rulers it is impossible to know if switching tools would have increased motivation for these five students.

Table 5 How Science Practices Impacted Student Motivation

Science Practices	Number of Interviews Containing	Motivation Associated with Perception of Autonomy +/-	Motivation Associated with Perception of Competence +/-
1. Asking questions	5	1/1	3/2
2. Developing and using models	1	0/0	1/0
3. Planning and carrying out investigations	3	2/1	0/0
4. Analyzing and interpreting data	7	5/2	0/0
5. Using mathematics and computational thinking	10	2/1	3/4
6. Constructing explanations	2	2/0	0/0

Practice 4: Analyzing and interpreting data was something that students also had mixed feelings about. Those who enjoyed analyzing and interpreting data often thought of the historical aspect as being like a story, where they were trying to figure out what happened to the organism or environment throughout time. Larry, a Caucasian seventh grader is an example of a student who was motivated by doing this interpretation,

> Well, you get to uncover them, like wash them off and we also go to do the, go back and see how many years it lived. I remember like what we did, it was kinda neat because we went through this whole process stepping backwards. And then like, we wrote down, this year, this is what happened and then the next couple years there was this (Larry, line 27).

Though Science Practice 4 was motivating for most students, two reported that doing the data analysis part was somewhat boring for them. Reese, a seventh grade student reported he enjoyed collecting data, but then stated, “but when it got down to actually identifying the fossils, that part got pretty boring” (Reese, line 46). Unfortunately the interviewer could not get him to expand on these thoughts leaving it unclear as to why this was boring.

The science practice of asking questions had differential affect on motivating students. For the most part whether or not students were motivated by asking questions depended on whether or not they felt competent. Jill’s lack of confidence at asking her own question is evident when the interviewer asked if she would rather pose her own question or have her teacher pose the questions. Jill responded, “Probably the teacher. She’s really good at asking the questions and I’m not good at asking questions” (Jill, line 73). Although overall Jill was very positive about her experience, this aspect did decrease her motivation. Her thoughts are quite different from her classmate, Asher, who placed great importance on asking his own question. To Asher it was very motivating to answer his own question. He stated,

> Because taking somebody else’s question, you can go and search it. But if you think of your own question, you think of it yourself, you can come up with a

> hypothesis and answer. And if it's someone else's question, you don't think of it yourself. And if I was to work, if someone was to give me a dollar or rather work and earn it myself (Asher, line 97).

Asher's metaphor of earning a dollar suggests it was motivating to answer his own question that no one knew the answer to.

How technology impacted motivation during an authentic science project. Students' feelings towards using technology was also very fragmented with just as many being neutral as having motivation enhanced or suppressed. We found that students almost always related the idea of technology to using computers, though a couple of students also mentioned that microscopes could be considered technology. Generally it seemed that students who saw themselves as computer people or technology savvy were motivated by technology, while other students who did not like computers or thought using technology was hard or confusing were not motivated.

For instance Keith, a Caucasian ninth grader discussed wanting to work with technology as a future career. He felt researchers could make the project even more interesting "Um, like, more on the laptops than we did" (Keith, line 63). For this student using technology matched with his personal interest and helped to keep him motivated in the project.

Students who reported that use of technology decreased their motivation often gave explanations that showed they did not feel competent working with computers. One ELL student explained her negative feelings toward the experience "Ya, but I don't I don't see any resource from the computer because I don't know what, like I'm not really good at it, good at computers." (Zhen, line 117). She did not see computers as helpful resource because she did not feel competent in using computers. A few students in this study reported a history of feeling incompetent with computers. For some students a bad experience using technology decreased motivation. Justin recounted how the negative part of the project was using technology. "I just couldn't learn how to do stuff, like putting the data on the computer" (Justin, line 29). Patrick, a Caucasian male who is in the same class as Justin, also had difficulty with the computers and said "you had to put stuff in and if you got it wrong, you couldn't delete it. It was hard" (Patrick, line 20). Our findings suggest that using technology in the classroom may not always be something that enhances motivation in the classroom, especially if students do not have their sense of competence met.

Theme 2: Authentic, interdisciplinary science is engaging and motivating for students. Based on student interest in content related to both life science and earth science concept we assert that interdisciplinary science was a factor that fosters student motivation in this authentic school science project. In our sample of forty students, roughly half were taking life science and participated in Fossil Finders as a life science unit. The other half were in classes that were earth science focused and they completed Fossil Finders as part of an earth science unit. Some students were more motivated by biological aspects, other students were motivated by geological aspects, though many were motivated by both.

In examining Table 6 one can see that students in earth science were just as motivated to learn about life science concepts, as they were about earth science. Conversely, the same is true for the students in the life science classes. We were intrigued to see the crossover in student motivation based on the different subjects. Vincent, an African American seventh grade student, explained what he liked learning and informed us, "I'm interested in fossils because you can find out what was living back then and maybe find out today and like you could see what is similar to it" (Vincent, line 72). Though Vincent's class was studying Fossil Finders as part of a geology unit learning about the fossils as living organisms and comparing them with life today motivated him. Zhen, who was taking life science explained why she liked Fossil Finders and said "I think for fossils it's just like learn more about the earth the history of the earth" (Zhen, line 121). For Zhen it was the historical aspect of geology that kept her motivated. In answering our second research question, interdisciplinary science units such as Fossil Finders appear to have potential motivating science students.

Table 6 Science Concept that Motivated Students in Earth Science and Life Science Courses

Science Concept	Number of Earth Science Students it Motivated	Number of Life Science Students it Motivated
Earth's History	7	5
Earth Systems	1	1
Structure & Function of Organisms	5	5
Understanding Ecosystems	5	2
Biological Evolution	3	2

Research Question Three

Society's view of scientists as isolated individuals is now understood as outdated since science in a highly social process (NRC, 2007). We know that social processes and meaningful interactions are important to both doing science and learning in general (NRC, 2007). Students in our study reported that this authentic science project involved much more social interaction than they normally experienced in science classes and in other classes in school. Unfortunately research tells us that students from underrepresented groups do not have enough opportunities for positive social interaction in science (Gilbert, Yerrick, Hall, & Carolina, 2001; Rodriguez & Berryman, 2002).

Our third research question: How do social interactions encourage or discourage student motivation while participating in an authentic school science investigation is best answered by theme three, social aspects of authentic science can both encourage and discourage student motivation.

Social interactions that students mentioned during their interviews included working in a group, interacting with scientists, and helping others. Table 7 gives evidence that working in a group and interacting with scientists both encouraged and discouraged motivation for students, while helping others was something that encouraged motivation of our participants. This table includes autonomy, competence, and relatedness since all three factors impacted student motivation.

Table 7. Social Interactions that Impacted Student Motivation

Categories	# of Interviews Containing	Motivation Associated with Perception of Autonomy +/-	Motivation Associated with Perception of Competence +/-	Motivation Associated with Perception of Relatedness +/-
Group Work	37	14/3	6/0	6/8
Helping Others	12	8/0	0/0	5/0
Interaction with Scientists	23	13/0	5/2	0/0

Group work. The social interaction that students most often mentioned was group work. It increased motivation for some students, while decreasing it for others. Working in a group was something helped students meet their needs for autonomy, competence, or relatedness. Some students reported they enjoying working in groups because it was a chance to work with friends or get to know classmates. For these students this authentic science project helped to meet their need for sense of relatedness with classmates. Francis, a Hispanic male student told us that "It was fun. It was cool trying to look for fossils with your friends and stuff" (Francis, line 78). It is possible that his experience would not have been so positive if he did not relate with his classmates. Richard, a Chinese student explained how he felt working with a group and said "I would do my best, that's why I would put a lot of effort" (Richard, line 107). For students like Richard, working with others motivated them to excel and be a productive member of the group. Traci, a Caucasian 7th grader appreciated the exchange of ideas that are possible when working with group. She explained, "Yeah, cause you could compare your different ideas that you had, different measurements, you could check your measurements to make sure they were accurate" (Traci, line 42). For Traci this met her need for competence.

Sadly, not all students experienced productive interactions while working in a group. In general when this happened students were not able to relate with classmates or had groups that were not on task, which decreased the student's sense of autonomy. All of the students who reported decreases in motivation by working in a group were concentrated in two of the four classes. Students reported having groups that either could not get along or were not equally sharing responsibilities. Tyler, a Caucasian seventh grade, had a response that was typical for his class

> I just remember it being really difficult to do because none of the class was being very helpful. They were all talking and being distracting and the few groups that were actually trying to work didn't get much done because of everybody else (Tyler, line 28).

Micah, who is in the same class had a similar experience and stated,

> I'm sure other groups had fun but it's like my group could have been better. It was me and three other people that wouldn't collaborate. So they would just go walking off and then I couldn't really do any work. It's just we could have finished if our group stuck together (Micah, line 9).

Micah ended up disappointed that this group did not get to finish and input all of their data, which other groups in that class did get to do. Task identity is when an individual has the opportunity to do a task from beginning to end and complete that task (Brophy, 2004). In general, those who have the opportunity to finish something that they are working on feel a sense of accomplishment and are further motivated (Brophy, 2004). We believe that students like Micah who reported being upset that their group did not function well and could not finish lost motivation due to the group dynamics. They also did not have a sense of accomplishment from finishing a task they had worked hard on, and wanted to complete.

Interacting with Scientists. Almost all students saw interacting with scientists as a positive social interaction that met needs for autonomy or competence and was therefore motivating. Students reported that talking with scientists was not something they were used to doing. When asked about interacting with a scientist Sophie explained "Yeah, we got to talk with David. That was pretty neat. We got to see what he said and stuff about it. What he thought.

And he gave us new ideas. And Tammie gave us new ideas too" (Sophie, line 73). For Sophie interacting with scientists was enjoyable, because of the new perspectives and ideas that a scientist brought to the classroom which helped her feel more competent in her project. Other students reported that talking to a scientist helped them to better understand science processes. For instance, Asher reported,

> Yeah, so like, they showed me, what I can do different, like if I made an observation that was more an inference or prediction. They helped me have a better understanding of what I'm doing and how I'm doing it. (Asher, line 69).

Two students who reported not liking the idea of interacting with a scientist were ELL learners from the same class. Zhen reported a fear that the data she collected might not be good enough for scientists to use. It seems like Zhen was worried about possibly letting scientists down. While discussing talking one-on-one with a scientist Richard said "I don't think I could do that" (Richard line 76). It is likely that Richard's limited English made him feel uncomfortable with the idea of talking to a real scientist.

Helping Others. An exciting finding was that over a quarter of our students reported being able to help others was an important motivating factor while working on this authentic science project. Students always viewed helping someone as a productive social interaction that brought meaning to doing science in school. Our participants felt good about being able to help those in their peer group or others in the scientific community through providing their data. One participant, Virginia, was described by her teacher as a lower-achieving science student. When we talked to Virginia she explained why working in a group in Fossil Finders was important to her, and she said, "Like me and my partner, when we had the fossils, like she couldn't tell what it was and whatever and I helped her" (Virginia, line 55). We believe that it was valuable that students like Virginia, who are not viewed by others as strong in science, get the chance to contribute help others. When asked about collecting data for the database and Dewey, a Caucasian ninth grader reported it made him feel "Special. Helpful" (Dewey, line 55). We then asked if he had done a project like this before stated "No. This is the first time I've gotten to do like this. Yeah. It was fun. It was better than we usually do" (Dewey, line 59). For many students, including Dewey, they felt good knowing their classwork had a larger meaning by contributing to the science community.

Conclusions and Implications

How Authentic is too Authentic?

We found that while most students enjoyed the authentic aspects of the science project, for some, not having needs for competence or autonomy met led to motivation being suppressed. We think of authenticity as a continuum with everyday classroom science being on one end, and the investigations completed by scientists on the other end of the continuum. We would place our authentic science project somewhere in the middle of the continuum. Our findings suggest that authentic science projects in the classroom can be a powerful motivator to a point. However, too much authenticity can actually decrease motivation.

Mateo, a Hispanic a seventh grade student explained his personal interest, "Well in this one rock, we found this big shell. It was cool" (Mateo, line 24). Many students who found fossils that they were larger, oddly shaped, or seen as less common, such as trilobites, enjoyed authentic aspects of working with real fossils and real data (Asher, Jack, Nancy, Oksana), but this could also be contrasted with Bryce who felt he was not good at the project because he could not find many fossils, Kim who reported being bored by lack of fossils, and Chase who got frustrated by having too many fossils to catalogue. Though it is very authentic to have samples be so different we believe that students who receive a sample that was not interesting enough did not have their sense of autonomy met and lost motivation.

An implication for those creating an authentic science project for K-12 classroom students is that it is important to think about the level of authenticity and whether it may serve or suppress student interest. For teachers who are implementing authentic science in the classroom small adjustments can go a long way towards ensuring that authenticity will enhance student motivation. Though some classes had some students acknowledge decreases in motivation based on authentic aspects, we observed less of this in Andrew's class. A clue to why this may be came from Andrew's student Rory. In his interview, Rory explained how his teacher set up the project.

> We divided them up in different groups. We were in groups of four. Each day we had the whole time to look through with magnifying glasses and everything. And the next day, we'd switch it up since they had different stuff… I kept wondering what some stuff was and looking forward to coming back and looking the next day to see what else was there (Rory, line 15 & line 107).

Andrew's class was the only classroom out of four where we have evidence that groups switched samples and had a chance to work with multiple samples. We would recommend this to classroom teachers, since it seemed to foster a sense of wonder and did not lead to feelings of jealousy and disappointment that were felt in other classes.

Another adjustment that could be made is for teachers or researchers to check samples first and attempt to distribute materials more evenly among groups so that students get a more equal experience and all students get a chance to experience the thrill of finding something in their sample.

Let's Practice Science Practices

In this study we observed that student motivation was both enhanced and suppressed by four of the eight science practices. We know from our students' interviews that this authentic science project was much different from the way science class was normally conducted. Earlier in the paper we learned from Serena that Fossil Finders was very different than how science was normally taught in her classroom. Ming who is also in the same class informed us that she does not like asking questions in science because, "I am not really good with getting questions. Well, I have always had a hard time in science with thinking of experiments" (Ming, line 105). This lead us to hypothesize that the issue might not be disliking using science practices, but rather, not enough experiences with using them. We believe that teachers must give students more opportunities and experiences throughout the year to use these practices and feel more competent.

Teaching Interdisciplinary Science

Mamlok-Naaman (2011) noted that the amount of student interest in a particular science subject depends on level of familiarity with the subject. Interdisciplinary science is a way for students to gain familiarity with different science subjects and to gain repeated exposure to different sciences. Our findings suggest that students in life and earth science classes were motivated to learn both earth and life science, and this has implications for the classroom. We believe if science projects were designed to be more interdisciplinary that they could help to motivate more students and deepen interest in the subject. Earth science in particular offers rich opportunities to combine learning about physical and chemical science as well as life science.

Social Interaction in the Classroom

Based on the variability on how students responded to social interactions in the classroom we believe that the teacher has a central role in setting up a classroom where students will have productive interactions. In 2011, 47% of US 8th grade science teachers reported they had their students work together on projects or activities once or twice a week (National Center for Education Statistics, 2011). Our study showed that while many students enjoyed the benefit of working in a group and this was a motivating factor, about a quarter of our participants had negative group interactions that decreased their motivation for the project. We find it curious that all of these students were concentrated within two classrooms. The participants also noted repeatedly through interviews that this project was very unique and different from almost anything else they had ever done in school. For instance a ninth grader Aaron told us "I took bio last year and we didn't have anything like this" (Aaron, line 61). Aaron told us that he liked Fossil Finders much better than what he normally did in class. Since this authentic group science project was so different this leads us to wonder if students had been taught how to work productively in a group setting.

All the teachers who took part in our professional development were highly experienced in teaching science. The professional development did not explicitly address issues of how to facilitate students working productively in groups. Since all of the group work issues were concentrated in two classes, we suspect that teachers in those classes may not have been as experienced in having students work in groups and may have needed additional support. It may be important to include opportunities for teachers to learn how to orchestrate effective group work in classrooms.

We believe that interacting and collaborating with a scientist is a great way to help students better understand processes of science and motivate students. Since a small number of students were intimidated by the idea of interacting with a scientists we believe these concerns should be addressed. An implication for classroom teachers is that teachers acknowledge ELL and other students may be uncomfortable or intimidated by taking with a real scientists and should help ease these fears. For students who might have limited English skills the teacher could set aside time before the scientist visits the classroom for groups to come up with questions to ask or a list of topics that they would like to talk about. Thinking about this in advance may make it easier for all students to converse with a scientist.

Our study also found that students were particularly excited and motivated by the social interaction of helping others while doing science. Since many students explained that collecting real data that could be used by others was a new experience, this is an area of future research.

The findings in this study led to implications for both classroom teachers, and researchers creating curriculum for students or professional development for teachers. Since some factors can lead to implications for both populations the implications are listed by factor. All implications connect to our central idea of enhancing student motivation during an authentic school science project.

In summary, an important finding of this study is that authentic science investigations conducted in science classrooms can have positive impact on student motivation, including for those students from populations generally underrepresented in the sciences. Some students noted that this type of science work was much different than they had experienced in other lessons. However, our findings also indicate that reform based instruction is not a panacea. Authentic science experiences can have both positive and negative impacts on student motivation. School science cannot be exactly like scientist's science. In the case of Fossil Finders having too many or too few fossils affected students' continued interest in the project. Social interactions also appeared to be important, thus, having students work in groups must be carefully orchestrated by the classroom teacher.

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