Urban Students' Motivation, Collaboration, and Thoughtfulness During Science Inquiry

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One of the objectives for inquiry based science is to promote students' motivation for science, not just in the classroom but as an area of interest and enjoyment outside academic settings (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991). It is generally believed that when students enjoy learning about science and their science classes they will likely engage cognitively with the tasks, and try and persevere – behaviors that should promote their learning and understanding. Indeed, motivation researchers have found just such associations. For example, attitudes and beliefs such as interest, confidence in one's ability to learn, and perceived value in the task have been associated with greater attention, behavioral engagement, thoughtfulness, comprehension, and memory (Pintrich & De Groot, 1990; Schiefele, 1991; Tobias, 1994). Interest may be conceptualized of as personal interest (e.g., being interested in science, or in particular science topics), or as a situational experience (e.g., finding specific classes interesting). Both types of interest are related to students' thoughtfulness and learning (Pintrich & Schunk, 1996).

Inquiry based science aims to foster both personal and situational interest (Blumenfeld et al., 1991). By connecting curricula to issues that interest students or affect them directly, students can see that science relates to their lives and will be relevant to them outside the classroom and after the class has finished. Further, incorporating investigations, technology, and collaborative group activities is believed to foster interest and motivation, in addition to supporting and enhancing learning.

One pervasive limitation of motivation research is that it has been conducted primarily with White, middle-class individuals; minority urban students are typically not included in this research (Graham, 1994). There has tended to be an assumption that motivational theories and relations among beliefs and behaviors operate in the same way for all students, although this has not been addressed empirically. The lack of attention to minority students is important to address, however, given the well-established finding that African American students report considerably higher confidence in their ability to learn material and do well at school than do students from other racial backgrounds. The first objective of this study, therefore, was to investigate relations among a large sample of urban African American middle school students' reports of their motivation for science (personal interest), enjoyment of science class (situational interest), collaboration, and thoughtfulness during inquiry-based science.

Although associations between students' reports of their motivation and thoughtfulness may be characterized across all students, there is typically considerable variability among individual students. Motivational theory, however, assumes a consistent relation among motivation, collaboration, and thoughtfulness for all students. For example, students who express interest in learning about science and who find their science class interesting are expected to engage in the tasks thoughtfully. Furthermore, collaboration with others in the learning process is believed to foster thoughtfulness. And, as mentioned, these general associations have been found consistently across samples of students in the extant motivational literature. However, it is important to consider the extent to which these relations are apparent for all students, or whether there are different patterns of associations. Additionally, if there are different types of associations between motivation, collaboration, and thoughtfulness, it will be important to consider reasons for those different relations. For example, do some students find science really interesting but do not engage in science tasks thoughtfully, perhaps because they are interested in tangential features (such as novelty) that are not part of the science content? Or do some students enjoy science class and believe they have support from group members, but are not thoughtful, perhaps because the reasons for the enjoyment and perceptions of collaboration are related to social factors and being with friends, rather than to task engagement? Indeed, Lee and Anderson (1993), with a sample of 12 students in two science classes, found four different patterns of students' motivation and behavioral engagement. The present study similarly seeks to identify whether there are different patterns of students with respect to their motivation and engagement. It builds on the research by Lee and Anderson (1993) by: (1) including students from regular, rather than demonstration, classes, (2) including a greater number of students, and (3) having urban, and primarily African American, students.

Another persistent criticism of motivation research is that it tends to be based almost exclusively on students' self-reports. Researchers do not often triangulate these reports with observations of students engaged directly in tasks, or with more open-ended accounts of students' perceptions of themselves, the tasks, and the learning context. Thus, researchers are not able to investigate how well their survey questions, and students' responses to them, relate to students' actual attitudes and behavior. There is a real need for research that focuses intensively on students while they are engaged in classroom tasks and interacting with others, charting what they do and say over the length of many weeks or months.

Similarly, there is a need for intensive and long-term research regarding how students engage in inquiry-based science programs. Issues to investigate include whether students are interested by content that refers to their own lives and experiences and is linked to their communities; whether they do find hands-on learning, including conducting investigations and the incorporation of technology in the classroom, interesting; whether they experience working in small groups as supportive to their learning and understanding; and how thoughtful their comments, hypotheses, and explanations are. That is, to what extent do students' experiences of engaging in inquiry-based science match the outcomes that science educators hoped for and intended? There has been some research that has addressed students' engagement in, and motivation for, inquiry-based science (e.g., Krajcik, Blumenfeld, Marx, Bass, Fredricks, & Soloway, 1998; Lee & Anderson, 1993). However, these studies have typically come from demonstration sites or classes taught by researchers, rather than from regular classrooms. Furthermore, such studies have not focused on minority and urban students in regular classrooms. Accordingly, the present study sought to triangulate data from multiple sources regarding urban students' motivation, collaboration, and thoughtfulness. The study involved intensive observation of students while they were engaged in a ten-week inquiry-based science curriculum, in addition to semi-structured interviews about their beliefs and attitudes, and more traditionally-used survey measures. The third objective was to consider how students characterizing different profiles of motivational and thoughtfulness engaged in science inquiry, and what they said about inquiry-based science at school.

Method

Participants

The participants in this study were 737 seventh and eighth grade students who were engaged in inquiry based science. These students were drawn from classes taught by 11 teachers, within 8 Detroit middle schools. There were 627 seventh grade students from 26 sections, and 110 eighth grade students taught by three teachers in four sections. Almost all students were African American.

The second part of this study involved a sub-sample of these students who were selected for more intensive study. Teachers in eight target classrooms nominated 4-5 students, based on criteria of good attendance, average achievement level, and willingness to share their thoughts. We focus in greater depth on 25 target students, including 17 seventh graders (from 4 classes taught by 2 teachers) and 8 eighth graders (from 2 classes, 2 teachers).

Measures

The format for all items was a 5-point scale, ranging from 1 = “not at all true” through 5 = “very true”. Principal axis factor analysis guided the construction of all scales.

The measure of students’ science motivation (8 items, α = .87) refers to interest in science and wanting to understand and learn science. Sample items are “An important reason why I do my work in science is because I like to learn new things” and “I like learning about science”.

The measure of enjoyment of science class (3 items, α = .75) refers to liking science class. Sample items are “My science classroom is a fun place to be” and “I enjoy what we do in science”.

The measure of collaboration (6 items, α = .62) refers to perceived encouragement and opportunities to learn from others during science activities. Sample items are “Students’ ideas and suggestions are used during science class” and “In science class, I explain my ideas to other students”.

The measure of students’ thoughtfulness (9 items, α = .79) refers to concentrating and reflecting on one’s engagement in science activities and using strategies to assist understanding. Sample items are “When I am learning science, I try to make the ideas fit together” and “When I look at my data, I try to think about how it answers the question”.

Interview. We conducted semi-structured, in-depth interviews to investigate target students’ attitudes, beliefs, and perceptions about science in general and about their experiences during the science curriculum. The interviewers followed a protocol of questions but let the participants answer the questions in an open-ended manner and encouraged the students to give examples as illustration. The questions referred to how science relates to the real world, their attitudes towards science, to technology, and to group work, and their perceptions of collaboration in their science classroom.

Procedure

Regular science lessons were videotaped throughout the ten-week curriculum. During group work we focused on at least one of the target students and his or her group. At the end of the curriculum, trained research assistants administered surveys to students in their science class. Target students were interviewed individually by an experienced researcher. The interviews took place during regular school time, in a quiet location such as the library, were audio-taped, and typically lasted 30-40 minutes.

Results

Descriptive Statistics

Means, standard deviations, and correlations among variables for all students are presented in Table 1. As expected, all measures were correlated positively with each other. Students' motivation for learning science was associated with enjoying science classes ($r = .70$, $p < .01$), collaboration ($r = .44$, $p < .01$), and being thoughtful while doing science ($r = .63$, $p < .01$). Further, collaboration was related to thoughtfulness ($r = .53$, $p < .01$).

Cluster Analysis

We next focused more closely on the target students, in order to examine different patterns of student motivation, thoughtfulness, and classroom perceptions, as indicated by their responses to the survey. Entering the four measures, we conducted a hierarchical cluster analysis using the between-group average-linkage clustering method. A five-cluster solution was most parsimonious, in that it produced greatest interpretability while also minimizing the distance between adjacent cluster solutions. We followed up this interpretation with a MANOVA using the motivation, enjoyment, collaboration, and thoughtfulness measures as dependent variables. There was a main effect for cluster for science motivation, $F(5, 20) = 19.17$, $p < .001$, enjoying science class, $F(5, 20) = 30.06$, $p < .001$, collaboration, $F(5, 20) = 20.36$, $p < .001$, and thoughtfulness, $F(5, 20) = 7.53$, $p = .001$. The cluster means for each of these measures are shown in Table 2.

Cluster One: Very high science motivation, collaboration, & thoughtfulness. This cluster was comprised of 6 students. It was characterized by very high science motivation, enjoyment of science class, collaboration, and thoughtfulness. The means for all four variables in this cluster were greater than one standard deviation above the mean for all students.

Cluster Two: High class enjoyment but low collaboration and average science motivation & thoughtfulness. This cluster a was composed of 7 students. It was characterized by very high (mean > 1 SD) enjoyment of science class, above average science motivation and thoughtfulness, and below average collaboration.

Cluster Three: Average science motivation but high enjoyment, collaboration, & thoughtfulness. This cluster was composed of 3 students. It was characterized by average science motivation, and above average enjoyment of science class, thoughtfulness, and collaboration.

Cluster Four : Low motivation and thoughtfulness but average class enjoyment & high collaboration. This cluster was composed of 7 students. It was characterized by below average science motivation and thoughtfulness, very low (mean < 1 SD) enjoyment of science class, and above average collaboration.

Cluster Five: Low collaboration and thoughtfulness but average motivation & class enjoyment. This cluster was composed of 2 students. It was characterized by above average science motivation and enjoyment of science class, below average thoughtfulness, and very low (mean < 1 SD) collaboration.

Expected Behavior Patterns for Different Clusters

As indicated previously, the third objective of this study was to investigate the congruence of students' reports of their attitudes and behaviors with their observed behavior and comments made when interviewed. Because the means of these five clusters differed significantly from each other on the measures of motivation, collaboration, and thoughtfulness, we would expect there to be discernable patterns of behavioral engagement evident during students' inquiry and technology use, discourse indicative of thoughtfulness, and different attitudes expressed during the interviews. In order to determine whether there was in fact such discernable differences in students' motivation and engagement between clusters, and the extent to which their motivation and engagement concurred with their survey reports, we developed case studies of students from four of the five clusters.

Case Studies

Previous to conducting the cluster analysis, we watched the videotapes and wrote detailed descriptions of all the target students engaging in science. In order to gain a richer understanding of different patterns of students' motivation, collaboration, and thoughtfulness in science class we turned next to these observation descriptions and to their interviews. The following four case studies portray students from four of the five clusters. The students are all seventh graders who participated in the chemistry curriculum “What’s in our Air?”

Cluster One. We would expect that students from the first cluster (very high science motivation, collaboration, & thoughtfulness) would show indications of interest and enthusiasm, engage in discussions and share ideas with group members, and make comments that indicated thought.

Janelle is an African American girl of average height and build whose survey scores represented this cluster of very high science motivation, enjoyment of science class, perceived collaboration, and thoughtfulness. She appeared sociable, responsible, and generally attentive and thoughtful in class, and was called on frequently by the teacher to answer questions. During the unit Janelle worked mainly in a group with Monique, who did not appear interested in science and was often off-task, and Steven, who is presented in the next case study.

Janelle appeared to be interested in science. When her group gathered data she usually participated or watched Steven and talked with him about what they were doing. She seemed to want to be involved and found ways to participate if presumably he was being too dominant. For example, after he had tested the pH of the first two substances Janelle asked if she could test the next one, which she did. She and Steven continued to share testing the substances. On another occasion, when he had been setting up the apparatus and taking measurements, she announced that they needed group consensus on what the results were and she and Monique took measurements too.

Although Janelle appeared to always enjoy science class, she was not always focused on the science. Sometimes she talked with Monique about social topics or they sang or laughed together. Janelle, though, managed to successfully negotiate both involvement in science and interacting with Monique, who was clearly not interested in the tasks and usually copied from Janelle and Steven at the end of the activity.

Collaboration refers to explaining and interacting with others, using others' suggestions, and experiencing teamwork. In addition to Janelle discussing with Steven what they were doing, at times she attempted to have the whole group involved in conducting investigations, as evidenced by her demand for group consensus as a way to force her and Monique's participation. However more often, interacting and teamwork did not involve shared collaboration in the task; she typically told Monique the answers or gave her the notes to copy at the end of the activity.

We did see evidence of Janelle concentrating on what the group was doing and being thoughtful about how they engaged in tasks. Steven was usually the first person in the group to begin the group activity. Janelle tended to watch and check what he did. She often noticed when he made a mistake and she corrected it, such as when he was setting up equipment, or answering worksheet questions. We did not observe instances of Janelle making thoughtful comments in relating what they were doing to larger science concepts, although this was not suggested by the teacher. For example, Janelle, as did the other students in the class, approached forming hypotheses as making guesses, and these hypotheses were usually brief and without justification. As an example, prior to investigating the percentage of oxygen in the air Janelle hypothesized that air is composed of about half oxygen and half other gases. An exception to not relating the activity to larger concepts was during the final presentation, when Janelle and her new group reported information about CFC's. Janelle read the group's script, which reported that CFC's come from refrigerators, air conditioners in cars and homes, and aerosol cans. The group suggested that CFC's could be reduced by people using less air conditioning and winding down the windows of their cars. When all group members shared one thing they learned about investigating CFC's, Janelle said that she leaned that CFC's are increasing the weather temperature.

Cluster Two. From their survey scores we expect that students from the second cluster (high class enjoyment but low collaboration and average science motivation & thoughtfulness) would also show indications of enthusiasm and enjoyment but be less behaviorally engaged, experience little sharing of ideas within their group, and make few thoughtful comments regarding their observations and related conclusions.

Steven is a tall, slender, African American boy whose survey scores represented this cluster of very high enjoyment of science class, above average science motivation and thoughtfulness, and below average collaboration. He was talkative, an active participant in class, and appeared confident of his abilities. Steven was warmly supported by his teacher because he was always on task and conscientious about completing his assignments, even though his work exhibited conceptual misunderstandings and his academic performance tended to be poor. As already noted, during the chemistry unit Steven worked mainly in a group with Janelle and Monique.

Steven expressed interest in science during the interview. He talked about learning about pollutants and how he now thinks about air quality when he sees a smoke stack, or thinks about acid rain when it rains. In addition to wanting to learn science, though, Steven seemed to want to be perceived by others as being good at science. For example, during investigations and written tasks he told his group members that he was smart and bragged when he made accurate predictions.

Steven seemed to enjoy science classes immensely. He tried to assume a leadership role in this group, although the girls did not always let him. When Steven's group gathered data he was always involved and often carried out the procedure for the group. He usually positioned the experimental apparatus close to where he was sitting so he could record data conveniently. He appeared to enjoy having an opportunity to handle “dangerous chemicals”. When Janelle asked to test the pH of some of the substances Steven made certain that he kept substances such as sulfuric acid for himself to test. Consistent with our observations, during the interview, when Steven talked about what he liked most in science class he mentioned, “The part when we started messing around with sulfuric acid and stuff in the jar” and “fooling around with carbon monoxide and glass jars.”

Steven’s perceptions of the usefulness of student interaction and the presence of teamwork were different from Janelle’s, even though they were in the same group. Steven did not try to engage the others in the tasks, but seemed happier to work on tasks on his own. His interactions with the girls were predominantly telling them what to do, such as to stop singing and be more serious, or that they should put on their safety goggles. During the interview Steven said he liked working in groups in general, however he did not enjoy the group with Janelle and Monique. Steven spoke of Janelle as “the queen of the table”, who “would like to do everything”. He blamed the two girls for making mistakes and getting their information wrong. Steven also said during the interview that he did not find discussions helpful for learning. He said, “If people explain it, people ask questions and then you’ll lose track and then we won’t know what we’re talking about....and just talking about it, you can easily forget about it quickly.”

Generally Steven was on task during the investigations, and appeared to try hard. However our observations of his thoughtfulness were not consistent with his own reports. Steven routinely worked out answers quickly, then told the other group members or offered them his paper to copy - sometimes insistently. His work was often inaccurate, however, and Janelle corrected him frequently. Nevertheless, Steven appeared undaunted by making mistakes, saying "Whoops" and making the correction. During the interview, Steven admitted that there were many parts of the unit that he "did not get", however he always acted confidently during the lessons.

Cluster Three. From their survey scores we would expect that students from the third cluster (average science motivation but high enjoyment, collaboration, & thoughtfulness) would show indications of interest and involvement in class activities, engage in discussions and share ideas with group members, and make comments that indicated thought. We would also expect these students to express less interest in the science content during their interviews.

Brian is a skinny Caucasian boy of medium height with thick glasses whose survey scores represented this cluster of average science motivation, and above average enjoyment of science class, thoughtfulness, and collaboration. He was talkative, and an active presence in small and large groups. In class, his folders were always disorganized and he was continuously looking for or missing important papers. Brian's teacher constantly criticized him for this habit, and admitted to a researcher that his disorganization was the reason Brian was not doing well in her class.

During the interview Brian said that he was interested in science because he likes learning about how things work, and added that he intends to be a marine biologist in the future. He also expressed interest in learning about air quality because it was related to the real world; it "helps us see what different things hurt the air [and] make it not good for us, so that we, as adults, can eventually cut back on all of the pollution". He also felt it was relevant because he could conceive of having a conversation outside of the classroom about air quality.

Brian worked in a small group with another boy and two girls, and was one of two group leaders. He traded off setting up and executing the procedure for the group with Toshanda, while Robert and Victoria watched. When interviewed, Brian said that his science class could be both entertaining (such as when they did experiments or worked in the computer lab) and boring (when they took tests or memorized the periodic table). Whereas he could see the usefulness of learning about air pollutants, he could not conceive of having a conversation about the periodic table with someone. Brian said he liked doing experiments because, “It’s more exciting hands-on because it’s not as predictable -- you’re not exactly sure what’s going to happen”. He found experiments challenging because he had to be accurate. Brian also said that he enjoyed the final presentation, because he likes teaching. Even though he enjoyed using computers, largely because it is faster and involves less work than doing it by hand - “You just have to click and sometimes type”, Brian sometimes complained while working with his partner that using Model-it was not much fun.

Brian’s comments about working with others in his group and recognition that he learned from others are consistent with his cluster’s high collaboration. During the interview he said he liked group work because sometimes his group members knew something that he did not, sometimes he could point out where they were wrong, because he was exposed to other ideas besides his own, and because he liked discussing things with other people. He noted that when preparing for the final presentation, “instead of us all knowing the information, we all knew different parts of it”.

We saw numerous occasions of thoughtful comments and discussions while Brian and his group carried out investigations. The group made meticulous observations during experiments, and Brian, who showed generally strong understanding of science concepts, continually vocalized what he saw. When the group formulated a conclusion, a student would declare her conclusion as fact. Brian consistently acted as challenger, forcing the student to explain her reasoning, and then offering his own opinion about the conclusion. In one case, Brian instigated a full-fledged debate by opposing the conclusion formed by the rest of the group. His group never resolved the debate because Brian refused to give in. However in this instance, although his argument was sound and illustrated familiarity and understanding of the science content, he had not adequately observed the results of the experiment in question and was not correct. Despite him complaining during lessons that using Model-it was not fun, Brian noted in the interview that creating models had been useful for his understanding. The models helped him see how things worked, rather than simply memorizing information and showed him, “It’s not just one thing that pollutes the air, all of the pollutants together pollute the air”.

<u>Cluster Four</u>. From their survey scores we expect that students from the fourth cluster (low motivation and thoughtfulness, average class enjoyment & high collaboration) would also show indications of enthusiasm and enjoying class activities, be in a group that actively engaged in discussions and sharing of ideas, make few thoughtful comments regarding their observations and related conclusions, and express little interest in science.

Clarice is a mature, African American girl whose survey scores represented this cluster of below average science motivation and thoughtfulness, very low enjoyment of science class, and above average collaboration. She was a conscientious and thoughtful student, who was also insecure and concerned about giving the wrong answer. She needed considerable encouragement to venture answers to questions, although she was usually correct.

When interviewed, Clarice said that generally she liked science, even though it was hard. She expressed interest in learning about acid rain and the ozone layer, and started to think more and care about them. She also commented that the unit related to her real world because, "I learned how I could help my air since I'm young so when I get older, I can do stuff to stop my air from being polluted - at least in my community".

During science class Clarice worked in a group with two other girls and one boy. She and Lisa were the group leaders, sharing the work responsibilities. In the interview Clarice said that, in general, she liked doing experiments because " you can see and make observations up close…If she [the teacher] just tells you about it, then you won't get the full effect, you can't picture it in your head. But if you see it, and you do it yourself, then you really know what she's talking about. You will be able to understand it better." She especially enjoyed making the posters for the presentation, incorporating a play, and inserting comedy into the presentation so that it was not boring. Despite saying she enjoyed these aspects of her science class, Clarice noted that she was not doing well and it was not one of her best subjects. Generally she felt unprepared because she had not covered this material before. This uncertainty was evident when Clarice was working on Model-it, adding factors and relationships to the model; she was very concerned about having the correct number of each, consistently asking for feedback from Lisa or from an adult.

We observed little collaboration in Clarice's group, despite her high report on the survey. Usually Clarice and Lisa were the most actively engaged during investigations. Clarice typically set up and executed the procedures, placing the apparatus on her side of the table so that Sean and Denise could not see easily. Sean and Denise tended to be quiet unless the students were socializing. Clarice viewed Sean's lack of participation and effort condescendingly, saying in the interview that she lets him not do anything because she feels sorry for him. This group did not discuss the results of investigations and form conclusions together, but made conclusions individually. These were shared for the first time during whole class discussions, and tended to be conflicting. In the interview Clarice said she liked working in a group because everyone had an opinion, and since she collected answers from the whole group she figured she would always have at least one correct answer. She said she learned in her group that “You can’t always do things your way, you can’t do everything by yourself”. There was also little collaboration when Clarice used Model-it paired with Sean. She researched, composed, and inputted factors and relationships on the computer almost single-handedly. Sean made suggestions and comments that often contained accurate science content. However Clarice usually ignored these, perhaps because Sean spent most of his time teasing or trying to distract her.

We saw evidence of thoughtfulness from Clarice, despite her low report from the survey. During one whole class recitation, when group members gave conflicting conclusions for an experiment they had done together, it was Clarice who came to the correct conclusion and convinced her teacher she was right by using evidence from the experiment. When students used Model-it, Clarice was one of the first to begin to think about connections between pollutants. She was a little confused about how to separate causes from effects and build them as separate components of a relationship, however she could select relevant information, and they illustrated understanding of pollutants’ sources and effects. During the interview Clarice mentioned how creating relationships on the computer helped her to learn because they provided visual examples of the content, even though she sometimes had trouble explaining the rationale for them.

Discussion

Motivation research has suggested that thoughtful learning is related to students’ interest and enjoyment. However, it has been suggested that much of this prior research has examined trends in student beliefs and behaviors without consideration of the variation among individuals.

Moreover, criticism has suggested that beyond self-reports, it is necessary to examine students in the context of their classrooms (Blumenfeld, 1992). Finally, there has been a suggestion that present theories of motivation have been based largely on white samples or have compared racial groups; studying samples of predominantly African-American students may contribute to our understanding of motivation and learning (Graham, 1994).

The present study has shown that, for urban middle school students as with the students from more advantaged backgrounds who are more often the focus of motivation research, self-reports of motivation for science, enjoying science class, collaboration, and being thoughtful while engaging in science are strongly and positively related to each other.

Of greater interest than these general associations, however, are the quite different patterns of motivation, collaboration, and thoughtfulness amongst these students that the present study has identified. These different patterns were masked when the large sample of students are considered as a homogenous group. These findings support the assertions of Lee (1997), who has stated that cognitively rich curricula and teaching styles that support science for understanding models do not affect everyone in a classroom equally. She states that the student's "personal agenda" to engage or disengage in science learning acts as a mitigating variable for student achievement, and implies that students who are engaged will benefit more from cognitively-oriented curriculum and instructional reforms.

The intensive focus on individual students, including observations of them engaged in science inquiry and interviews, added a much richer description than considering only students' self-report survey scores. Interestingly, and not unsurprisingly, our observations of specific students' engagement were not always consistent with their reports, either in the survey or the interview. This was particularly noticeable for Steven, who reported high levels of thoughtfulness in the survey but admitted in the interview that he often did not understand what was happening or what he was supposed to do. Additionally, Steven was observed to be overly hasty in his actions and his interest in science appeared to be related to a concern about garnering status, for example, by answering questions first and handling dangerous materials. Similarly, self-reports of student collaboration were not consistent with our observations, particularly with Clarice and Steven.

Just as students vary in their approach to learning, they also vary in their motivation. Interest, enjoyment, classroom support for learning may act independently or in conjunction as motivational hooks. Understanding motivation from this perspective informs future research in motivation as well as curriculum development and instruction. Researchers can no longer conduct research only as a relation among self-report scales but must consider students in action as they grapple with classroom learning. Teachers need to provide a variety of motivational “hooks” ranging from relevant tasks, to interesting activities, and an environment supportive of thinking. Knowing that there are some “Stevens” in their classroom who are enthusiastic in the classroom but not thoughtful about their learning strategies as well as some “Janelles” who take charge and dictate answers to other students may make teachers more thoughtful in their orchestration of the classroom. They can not think of a formula or recipe to motivate students. Instead, teachers need to provide a variety of experiences and an environment that supports and guides learning through innovative curricula and collaborative activities.

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Table 1

Correlations among Motivation, Collaboration, and Thoughtfulness (N = 734)

	1.	2.	3.	4.
1. Science motivation	-			
2. Enjoyment of science class	.70**	-		
3. Collaboration	.44**	.37**	-	
4. Thoughtfulness	.63**	.45**	.53**	-
M	3.80	3.01	3.61	3.57
SD	.91	1.20	.75	.71

*$p < .05$ **$p < .01$

Note. All scales measured on a 5-point scale.

Table 2

Means of Motivation, Collaboration, and Thoughtfulness by Cluster

	1. (n = 6)	2. (n =7)	3. (n = 3)	4. (n = 7)	5. (n = 2)
1. Science motivation	4.83_{a}	4.59_{a}	3.79_{bc}	3.27_{bc}	4.38_{ab}
2. Enjoyment of science class	4.67_{a}	4.43_{a}	3.44_{b}	2.14_{c}	3.17_{c}
3. Collaboration	4.78_{a}	3.36_{bc}	4.22_{a}	3.93_{b}	2.50_{c}
4. Thoughtfulness	4.48_{a}	4.14_{ab}	4.15_{ac}	3.13_{c}	3.22_{bc}

Note. Means with different subscripts differ significantly at $p < .05$ in the Tukey significant difference comparison.