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A Look at Student Action in the Science Classroom

DAVID TODD CAMPBELL, *New York Institute of Technology (dtcampbe@nyit.edu)*
IBRAHIM ERDOGAN, *University of Iowa, Iowa City, (ibrahim-erdogan@uiowa.edu)*

ABSTRACT *This research investigated the impact the level of constructivist teaching practices had on student actions emerging in science classrooms. Twenty-two K-12 in-service teachers from north-central Iowa involved in a one-year professional development project, Iowa Chautauqua for Current Reform (ICPCR), were asked to share a videocassette of their instruction of a unit developed as part of the project. Fourteen videos were collected and rated using the Expert Science Teacher Educational Evaluation Model developed by Burry-Stock (1995). Two groups were formed using the two highest and two lowest rated tapes. Student actions emerging from the groups were qualitatively analyzed. Student actions in the group rated highest were more often found exhibiting outcomes suggested in Pennick and Bonnstetter's (1993) goals for students in science, including: 1) using knowledge learned to identify and solve problems, 2) developing creativity, 3) communicating science effectively, 4) given opportunities to recognize the applicability of acquired knowledge, and 5) taking actions based on evidence and knowledge.*

KEY WORDS: *Constructivist teaching practices, student actions*

Introduction

In 1996, the National Research Council (NRC) published the National Science Education Standards (NSES) with the intention of presenting "a vision of a scientifically literate populace" (p. 2). The NRC created the standards around a central theme "science standards for all students" (p. 2). This theme emphasizes the importance of inquiry in the science process, allowing students to "describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others" (p. 2). In teaching science with an inquiry emphasis, the assumptions of the diverse populace are considered, and critical and logical-thinking skills are fostered.

If the standards are going to become a reality in the classrooms in the United States, a shift will be necessary from what has traditionally been experienced in the nation's K-12 science education classrooms. Brooks and Brooks (1999) describe what students typically experience in traditional classrooms A summary of their description is presented in Table 1.

The NSES emphasizes teaching for meaning and understanding. McTighe, Seif, and Wiggins (2004) identified five key principles necessary for teaching for meaning and understanding:

- Understanding big ideas in context is central to the work of students.
- Students can only find and make meaning when they are asked to inquire, think at high levels, and solve problems.

Table 1
The Traditional Classroom Experience

Curriculum is presented part to whole, with emphasis on basic skills
Strict adherence to fixed curriculum is highly valued
Curricular activities rely heavily on textbooks and workbooks
Students are viewed as "blank slates" onto which information is etched by the teacher
Teachers generally behave in a didactic manner, disseminating information to students
Teachers seek the correct answer to validate students' learning
Assessment of student learning is viewed as separate from teaching and occurs almost entirely through testing
Students primarily work alone

- Students should be expected to apply knowledge and skills in meaningful tasks within authentic contexts.
- Teachers should regularly use thought-provoking, engaging, and interactive instructional strategies.
- Students need opportunities to revise their assignments using clear examples of successful work, known criteria, and timely feedback.

All of these principles are found in the National Science Education Standards and represent a shift the tradition classroom experiences.

In addition to the five key principles identified for teaching for meaning and understanding, science teachers themselves identified goals that are congruent with the outcomes targeted in the standards (Pennick & Bonnstetter, 1993). The goals for students were:

1) Having a positive attitude toward science
2) Using knowledge learned to identify and solve problems
3) Developing creativity
4) Communicating science effectively
5) Feeling that the acquired knowledge is useful and applicable
6) Taking actions based on evidence and knowledge
7) Knowing how to learn science

A focus on teaching for meaning and understanding, and achieving these seven goals requires changes in teacher practices. The focus of this study was to investigate what impact even the slightest changes in teacher practices might have on the student actions. If teachers move away from the more traditional approaches outlined by Brooks and Brooks (1999), and toward more constructivist teaching practices, which facilitate teaching for meaning and understanding, will the goals science teachers have for students emerge?

Methodology, Findings, Interpretations, and Discussions

Stapleton and Taylor (2004) argue that a danger exists when relying on traditional approaches to structuring research involving qualitative research.

"We believe that succumbing to the structural template of positivism, interpretive researchers are in danger of creating distorted portrayals of their inquiries as timeless, lacking in contingencies and without an emergent nature" (p. 2).

Because of a significant reliance on qualitative research methodologies, there seems to be a possibility that the concern will be validated when looking at the methods employed in this study. In addressing this concern, Stapleton and Taylor (2004) suggest that "a diachronic structure that allows the narrative flow of the inquiry to be revealed" (p. 2) might allow the reader to better understand the emerging directions taken by the researcher as well as the results arising from the inquiry. In an effort to speak to this concern, the methodology, findings, interpretations, and discussions in this study are merged into one narrative to provide a more accurate portrayal of the sequence through which this study was completed.

Perhaps, the best starting point for describing the diachronic nature of the research lies in specifying the lens through which the research was completed. The researchers in this study were both doctoral students at the same Midwestern science education program. While they brought distinctly different experiences forward in guiding their observations, as one researcher was from Turkey and the other was from the United States, the philosophical beliefs about education, teaching, and learning of the two researchers were closely aligned and focused on the constructivist learning theory and a belief in the appropriateness of the reforms called for in the National Science Education Standards.

This study arose from work with twenty-two K-12 in-service teachers from north-central Iowa in the one-year professional development project Iowa Chautauqua for Current Reform (ICPCR). Through participation in the project, participants developed and implemented science units focused on employing the "Changes in Emphasis" found in the NSES (NRC, 1996, p. 52). Fourteen of the twenty-two participants responded to a request for videocassettes of the lesson they developed as part of the workshop. The videocassettes served as the major source of data for this study.

Each of the fourteen videocassettes was assessed by two researchers using the Expert Science Teacher Educational Evaluation Model (ESTEEM). The ESTEEM is an instrument constructed through the collaborative efforts of nine science education experts to describe the ideal practices of an expert science teacher based on the constructivist perspective (Burry-Stock, 1995). The researchers completing the videocassette ratings with ESTEEM both participated in a training session with a competent trainer/researcher experienced in using the instrument. Reliability for the ESTEEM was established through the efforts of the two researchers. After the training session with the trainer/researcher, the researchers became more familiar with the ESTEEM through discussions and trial ratings of videocassettes of classrooms instructed by teachers not participating in this study. After each of the trial video ratings, scores for each of the eighteen indicators within the four subcategories on the ESTEEM (Table 2) were compared and differences in scores were discussed allowing each rater to articulate the basis for the score given.

Table 2
The Eighteen Indicators within the four Subcategories of the ESTEEM

Facilitating the learning process from a constructivist perspective
Teacher as a facilitator
Student engagement in activities
Student engagement in experiences
Novelty
Textbook dependency
Content-specific pedagogy
Student conceptual understanding
Student relevance
Variation of teaching methods
Higher order thinking skills
Integration of content and process skills
Connection of concepts and evidence
Context-specific pedagogy
Resolution of misperceptions
Teacher-student relationship
Modification of teaching strategies to facilitate student understanding
Content knowledge
Use of exemplars
Coherent lesson
Balance between depth and comprehensiveness
Accurate content

This allowed each of the rater to become more aware of aspects of the teachers' classroom performances that they may not have initially recognized. Based on the ESTEEM ratings from the two researchers given to the fourteen videotaped lessons, two tapes with the lowest scores and two tapes with the highest scores were selected to form a Low Levels of Constructivist Teaching Practices group (LLCTP) and a High Levels of Constructivist Teaching Practices group (HLCTP) group respectively.

Examples of the differences found between these groups can be seen in the different indicators used in describing the two groups. The average score for the HLCTP group was four on a one to five scale, whereas the average score for the LLCTP group was a three in the same one to five scale. Examples of differences between indicators described as a three compared to those described as a four, taken from Burry-Stock (1995), are found in Table 3.

The LLCTP and HLCTP average group scores indicate that although these are varying degrees of constructivist teaching practices, both groups are implementing constructivist-teaching practices to some extent.

A short description of videotapes observed from the four classrooms offer a better understanding of what transpired:

> *Teacher A: Fourteen first grade students were sitting in a mini-amphitheatre like section of the classroom in a large group discussion. Students sat on the steps of the mini-amphitheatre, while the teacher sat on the sunken floor facing the students. A student brought in potatoes for the class and the teacher used the potatoes as a starting point*

Table 3
Examples of the Differences Between Indicators From the ESTEEN Describing the Practices from the Two Groups of Classrooms: HLCTP and LLCTP.

Indicator	Indicator Descriptor for a Rating of Three (The Average Rating for the LLCTP Group)	Indicator Descriptor for a Rating of Four (The Average Rating for the HLCTP Group)
Teacher as a Facilitator	Students are not always responsible for their own learning experience. Teacher directs the students more than facilitates the learning process. (Teacher-student learning experience is more teacher-centered than student-centered.)	Students are often responsible for their own learning experience. Teacher facilitates the learning process. Teacher-student learning experience is a partnership.
Higher-order Thinking Skills	Teacher sometimes moves students through different cognitive levels to reach higher order student thinking skills.	Teacher often moves students through different cognitive levels to reach higher order thinking skills.
Modifications of teaching strategies to facilitate student-understanding	Teacher has a general awareness of student understanding and occasionally modifies the lesson when necessary.	Teacher has continuous awareness of his/her student understanding and often modifies the lesson when necessary.

for the class. This classroom arrangement remained constant throughout the lesson.

Teacher B: Six kindergarten students were sitting in a small group around a table. The teacher started the lesson by reviewing the questions the students had about butterflies. After the review, the students used available materials to make observations while the teacher stepped back away from the group. Throughout the lesson the teacher moved in and out of the group discussions.

Teacher C: The lesson began with the teacher giving directions to fourteen seventh grade students. Upon completion of the directions, four students moved into the hallway and began an experiment with balloons. The teacher monitored the group working in the hallway by visiting a few times throughout the lesson.

Teacher D: Thirteen first grade students were sitting in their seats facing the teacher. The teacher asks the whole class questions from the front of the classroom. The students made observations about worms during the lesson. At various times in the lesson, the students were seen moving around the classroom freely.

Once the two groups were established, a researcher involved in the ESTEEM ratings and another researcher not involved in the ESTEEM ratings transcribed the qualitative data from the two groups. The second researcher involved in completing the qualitative transcription and an interpretation of the videotapes, after they were placed in the two groups, also attended the workshop with the trainer/researcher and was familiar with the ESTEEM, but did not have knowledge of groups to which the tapes had been assigned.

Prior to the rating of the two groups of videotapes, the two researchers discussed the methodology to be used in transcribing the student actions, practiced transcribing using a videotape not in the study, revisited instances of disagreement and discussed until agreement could be reached. Once the researchers felt comfortable with the methodology to be used, the researchers viewed the tapes. The question, "What are students doing in the classroom?" guided the collection of data. Throughout the viewing of each tape, each researcher recorded details about student actions in each of the classes. Upon completion of each of the videotapes, the notes from the two researchers were compared, discussed, and checked through several viewings of the videotape before finalizing the data set for the videotape. This research methodology was undertaken in an effort to increase internal validity through peer examination by more than one investigator (Merriam, 1998, pp. 204-205).

In an effort to identify the differences in student actions coming from classroom facilitated by high and low levels of constructivist teaching practices, the data units from the two groups were divided and analyzed separately. All units of data coming from the two lessons rated Low Level Constructivist Teaching Practices (LLCTP) comprised one group, and all units of data coming from the two lessons rated High Level Constructivist Teaching Practices (HLCTP) comprised the other group.

Through the constant comparative method of qualitative analysis (Glesne, 1998), the categories of student actions emerged and are shown in Table 4.

The Student Actions of the HLCTP Group

The HLCTP classroom can be described as one in which the students were autonomously engaged in active investigations as a result of the enabling facilitation of the teacher. A major action found in the HLCTP classrooms was students sharing ideas with other students. The autonomy and freedom associated with this group of teachers' facilitation led to student-initiated collaboration with peers. Examples of the sharing that occurred can be seen in the following:

> *As a cut potato is passed around the room, one student tells another student: "they cut it open and there is a flower. Maybe this is it (seed)?"*
>
> *While making observations of potatoes, student exclaims: "the seed is inside."*
>
> *When lenses were made available to facilitate student observations of butterflies, a student holding a lens over a page in a book shares, "they are all different sizes you see?"*

Taylor and Fraser (1994) describe the importance of students' engagement in discussion with other students, declaring that students should be learning collegially with peers in a classroom, where neither the textbook, nor the teacher, serves as the gate keeper of scientific knowledge. This type of activity in the classroom mirrors the exploration of notions and beliefs of others through discussions and debates that have been identified as precursors to increased student achievement (Inagaki, 1981; Yerrick, 2000).

The students in the HLCTP classroom were rarely found initiating *sharing of ideas* with the teacher; instead they preferred sharing their ideas with peers. This is not to say that meaningful teacher and student interactions did not occur, only that when given autonomy, students preferred to begin negotiations of their understandings with their peers. This might suggest that students feel more confident and motivated in constructing knowledge with individuals possessing comparable

Table 4
The Categories, Subcategories, and the Frequencies of Student Actions from the LLCTP and the HLCTP Classrooms

Categories	Number in Each Category LLCTP	Number in Each Category HLCTP	Subcategories	Number in Each Subcategory LLCTP	Number in Each Subcategory HLCTP
Student Attitude	8	4	Student Distracted or Displaying Unengaged Behavior	5	4
			Student Demonstrating Excitement about Activity	1	0
			Positive Interactions with the Teacher	2	0
Student Statements	52	50	Student Sharing Ideas with the Teacher	8	1
			Student Sharing Observations with Other Students	6	25
			Student Negotiating/Sharing and Refining Ideas	0	3
			Student Defending Reponses with Evidence	0	1
			Student Responding to Teacher Questions	18	18
			Student Questions	1	4
			Student Providing Explanation for Phenomenon	3	0
			Student Collaborating	15	0
			Student Elaborating on What the Teachers Says	1	0
Scientific Processes	35	63	Students Making Their Own Observations beyond Those Planned by Teachers	2	5
			Student Searching for Resources	1	1
			Students Using Resources (unsolicited)	1	13
			Student Offering Idea for Approaching Problems	0	15
			Student Bringing in Resources to Study	0	2
			Student Using Alternative Forms of Communication	0	3
			Student Making Observations	1	24
			Student Communicating Data	4	0
			Student Recognizing Errors in Process	2	0
			Student Designing Experiment	24	0
			Student Communicating Data	4	0
Student Initiated Actions	38	18	Student Asking for Attention of Group (Raising Hand)	3	14
			Student Listening to Teacher	11	4
			Student Moving Around the Room	15	0
			Student Following Teachers Directions	9	0

levels of understanding. Research comparing vertical (represented by adult-child interactions) and horizontal (represented by child-child interactions) negotiations has indicated similar results (Inagaki, 1981). Collins, Brown, and Newman (1989) recognized that vertical models, such as those that arise from apprenticeships, are much more directed at the reproduction of knowledge; while horizontal models of interaction are more conducive to construction of knowledge. This also aligns with the NSES, a document congruent with the constructivist perspective of learning (NRC, 1996). The NSES calls for shifts in teaching practices through "less emphasis on asking for recitation of acquired knowledge . . . more emphasis on providing opportunities for scientific discussion and debate among students . . . less emphasis on maintaining responsibility and authority . . . more emphasis on sharing responsibility for learning (NRC, p. 52)". Although student initiated responses with the teacher were rarely found, students were often observed responding to openended teacher questions, many of which were directed toward approaches to solving problems.

Students in the HLCTP classrooms experienced greater opportunities to engage in science processes. *Student observations, offering a variety of approaches to solving problems,* and *initiating the use of resources* are congruent with those processes most commonly associated with scientists doing science. Bruner and Schwab (1962) provide a rationale explaining the importance of a focus on science processes in the classroom as a means for promoting student learning. They explain,

> *The teaching of science should be as much as possible a simulation of the scientific process itself. The concepts of the disciplines should be studied rigorously in relation to their knowledge base. Thus, science would be learned as inquiry. Further, the information thus learned would be retained because it is embedded in a meaningful framework (cited in Joyce and Showers 2002, p.46).*

The science processes that occurred in the HLCTP classrooms were:

Observations:

When students are given time to observe butterflies, four students move close to the flask on the middle of the table.

As one student looked at a butterfly through a lens, she states,

Student: "It's so big."

As one student is observing a butterfly in a flask, he remarks,

Student: "This one is smaller [describing the butterfly's size in relation to other butterflies]"

Offering Approaches to Problems:

When teacher asked students how they could grow potatoes, a student responded, "We could ask the grocer."

A student suggested an idea for growing potatoes,

Student: "Grow potatoes by putting them in the ground."

When trying to decide how potatoes were grown, a student suggested,

Student: "Cut a big potato to see if there are seeds in there."

Using Resources:

During free observation time allowed by the teacher, students take initiative to reference books and use lenses on the table to look at butterflies.

The HLCTP classrooms were both found to empower students with ownership. This was accomplished through the teachers' role as facilitator and partner rather than distributor and source of knowledge. While the teachers were focused on student observations, actions, and discussions, their voices were not central in making decisions in the classroom. Students in these classrooms seemed to move closer to becoming self-directed learners "who are able to use their knowledge in their everyday decision making (NSTA, 1982, p. 1)". In written reflections completed by the teachers after the lessons, Teacher A describes the method he used to move students closer to becoming self-learners.

I believe I have started my Inquiry unit. We are going to try and figure out what the sharp things (roots) are in a book we were looking at. They were coming out of a bean seed and the boy thought it looked like a potato (the seed that is). I agreed and said, why don't you bring in some potatoes and we will see what we can do.

Students initiated actions observed in the HLCTP group were frequent and harmonious with qualities of a scientifically and technologically literate person who "offers explanations of natural phenomenon . . . (NSTA, 1990, p. 250)". An example of students sharing explanations occurred when a student in one class found a picture of a butterfly (Dialogue1).

Dialogue 1: Students Sharing Explanations:

Student 1:	Oh, this one's got big eyes [student sharing with other students overheard by teacher]
Teacher B:	Oh, where do you think the eyes are on this? Got a question for you. Student 1 has found an awesome picture. Now look at this, do you think these are the eyes?
Students 1-5:	Yes
Student 6:	No
Teacher B:	Student 6 says no, the rest of you said yes. Why did you say no Student 6?
Student 6:	Cause they're on his wings. They should be up on his head
Teacher B:	Ah, these are the wings. Look guys. His eyes should be up on his [pause]
Students 1-6:	head
Teacher B:	Head like student 6 said, so what do you think that is? [Pointing at butterfly in book]
Student 4:	Colors?
Teacher B:	Colors:
Student 6:	They're probably to confuse the other animals.
Teacher B:	What do you mean?
Student 6:	Well, if an animal was walking up on it, they wouldn't know which end was the head.

Students were comfortable articulating their ideas and negotiating with others in the classroom.

The Student Actions of the LLCTP Group

Students in the LLCTP classroom were more dependent upon the teacher. LLCTP students were found more often sharing their ideas with the teacher instead of other students. Teacher confirmation occurred frequently in these classrooms. Examples of the confirmations and students seeking to share their ideas with the teacher can be seen in the following example (Dialogue 2):

Dialogue 2: Students Seeking to Share Ideas with the Teacher

The teacher is asking the students questions about larva.

Teacher:	How many body parts does an insect have?

Student: Three

Student: This one only has one.

Teacher: Three, and it is really hard to tell on a larva . . . as I was reading, my information says that our larva actually have three body parts . . . [student interrupts]

Student: We found a small one [teacher interrupts]

Teacher: Listen student A, the only difference is that our larva has three body parts, but our larva might have a whole bunch of segments. [Teacher begins to explain by drawing on the board and requesting student's attention]

Even though student collaboration and design of scientific experiments in this group was very high, students rarely shared observations with each other. The high level of collaboration came from only one of the two classes. While student collaboration is a high priority in the constructivist classroom, they were more focused on the logistics of an experimental procedure rather than articulation of ideas and negotiation. Dewey (1963) addressed the need for increased attention to the quality of students experiences, "An experience may be such as to engender callousness; it may produce lack of sensitivity and of responsiveness (Dewey, 1963, pp. 25-26)". Even though collaboration was occurring while students were doing the experiment, the level of cognitive engagement was not as rich as those envisioned in the NSES (National Research Council, 1996). The content standards for scientific inquiry for grades 5-8 are:

- Identify questions that can be answered through scientific investigations
- Design and conduct scientific investigations
- Use appropriate tools and techniques together, analyze, and interpret data.
- Develop descriptions, explanations, predications, and models using evidence.
- Think critically and logically to make the relationship between evidence and explanations. (NRC, 1996, p. 145)
- The students did design and conduct an experiment, but they did not identify the question. The teacher challenged them to design an experiment to measure the speed of motion. While they used tools and techniques, which seemed appropriate for answering the challenge, no analysis or interpretation was observed; few descriptions, explanations and predictions occurred; and no relationships between evidence and explanations emerged.

The following exemplifies the type of interactions that were observed from students (Dialogue 3):

Dialogue 3: Student Interactions without Presence of Teacher as Facilitator [Students are determining the amount of time it takes a balloon to travel down a string]

Student A: Okay, down set hut one

Student B: [giggles]

Student A: 1.13 seconds

Student C: You gotta do it three times.

Student D: [Releases next trial. The balloon travels half way down the string. As

	another student corrects the problem, two students are attempting to open locked closet in the hallway]
Student A:	Okay we going on two. Down set hut one, hut two [balloon released] 1.28.
Student B:	That actually hit it.
Student C:	So our fastest one was our first one, 1.18.
Student A:	We better do it again. We better do it again. We will do it six times. [Students continued through six trials. Conversations similar to the ones observed in first two trials occurred through all six trials]

No discussions about potential changes or student wonderment interactions were observed in the form of how and why questions between students: i.e., why is one trial different than another? How can we make the balloon travel faster? Vygotsky (1978) argues that the teacher's facilitation in this, the zone of proximal development, is necessary to help students progress to more complex thought. "What is in the zone of proximal development today will be the actual developmental level tomorrow—that is, what a child can do with assistance today, she will be able to do by herself tomorrow" (p. 87). The students in this experiment asked each other questions, but even after the sixth trial with the balloon, they seemed to be locked into a repetitive sequence. The absence of the teacher questioning leading to descriptions, predictions, relationships to other phenomenon, explanations, and presentation of evidence failed to reveal students' alternative points of view and logic (Pennick, 1996) and resulted in a leveling off of students' engagement and thoughts.

A richer experience would have students meeting multiple content standards for scientific inquiry throughout the experiment. This lesson was rich, in that students were doing hands-on manipulations and working in groups, yet rich discussions, negotiations, and new approaches to understanding phenomenon were absent.

While many of the categories of student actions demonstrated actions less desirable and consistent with the calls for "Changing Emphasis" found in the NSES (NRC, 1996, p. 52), categories of actions that were consistent with these calls did appear in the LLCTP group and in some cases more often than in the HLCTP group. When looking at the "Student Statements" category, students were found collaborating with other students fifteen times in the LLCTP group, while the same action was not observed in the HLCTP group. While recognizing that the overall occurrence of scientific processes was almost double in the HLCTP group, it is also important to note the students in the LLCTP group were found "designing experiments" twenty four times, while these same actions were not documented in the HLCTP group. Lastly, when looking at "Student initiated actions" the LLCTP students were found more freely moving around the room.

As suggested, much of what was interpreted as happening in the LLCTP class did not compare favorably to the actions that were found in the HLCTP classrooms. Duffy and Cunningham (1996), and Lebow (1995) suggest that if students are to take ownership of learning, they need to be more engaged in self regulation that entails the selection of resources to enhance understanding. In many cases, this was happening more frequently in the HLCTP classrooms, but in some cases students in the LLCTP classrooms were found engaging in actions that could be interpreted as more consistent with the tenets of constructive learning. Those results demonstrating more favorable actions in the LLCTP classrooms, although not as pervasive as those found in the HLCTP classrooms, offer interesting topics for future investigations.

Conclusions

In summary, while neither of these groups of classrooms can be compared to the traditional classrooms described by Brooks and Brooks (1999), the differences in levels of constructivist teaching practices between the two groups resulted in students in the High Level Constructivist Teaching Practices (HLCTP) group exhibiting more outcomes suggested in Pennick and Bonnstetter's (1993) goals for students in science. Students in the HLCTP group where more often found 1) using knowledge learned to identify and solve problems, 2) developing creativity, 3) communicating science effectively, 4) given opportunities to recognize the applicability of acquired knowledge, and 5) taking actions based on evidence and knowledge.

To varying extents, the five key principles of teaching for meaning and understanding identified by McTighe, Seif, and Wiggins (2004) seemed to guide the rationale behind the teaching practices facilitating instruction in both groups. Examples of principles that seemed to emerge were:

1) Understanding big ideas in context is central to the work of students.
2) Students can only find and make meaning when they are asked to inquire, think at high levels, and solve problems.
3) Students should be expected to apply knowledge and skills in meaningful tasks within authentic contexts.

This investigation demonstrates the differences that can and do occur as a result of teacher practices used to facilitate science instruction. This study not only suggests the importance of focusing on the student actions exhibited in the classroom, but also emphasizes differences in teaching practices that lead to meaningful results. Considering student actions surfacing in classrooms as predictors of the scientific literacy allows educators to identify what is important in science education and strive to move closer to the call for reform put forth in the National Science Education Standards.

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