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ABSTRACT

Student-centered classrooms are characterized by shared responsibility, curriculum adjustment to reduce the number of topics or to increase emphasis on a subset of topics, a high premium placed on student-generated questions and investigations, and collective validation of students' ideas as a central feature of the teaching and learning process. This paper focuses on the processes of collective validation and proposes that engagement has everything to do with what students learn. This study examines privileging and other mechanisms at play over a period of 6 classroom days. How the claims and ideas of a number of students fare in the larger classroom community discourse is described and supported by brief case studies of student pairs and groups. Transcripts of interactions are included. Contains 11 references. (DDR)

# Student Decisionmaking and Teacher Privileging in a Student-Centered Science Classroom

by

R. Paul Vellom

# Student decisionmaking and teacher privileging in a student-centered science classroom

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Can a middle school science classroom be 'student-centered' and still support students learning accepted scientific concepts?

Lately, much ado has been made over the term 'student-centered' learning. Some classrooms, previously called learning communities, are now being called student-centered classrooms. The defining features of this kind of classroom include *(check for refs and connections on this list)*:

- an **adjustment of teacher and student roles towards shared responsibility** for content, process, and path;
- an **adjustment of curriculum to reduce the number of topics, or to increase emphasis on a subset of the topics**, so that more in-depth explorations can occur;
- a high premium on **students generating questions and proposing investigations** to address them;
- **processes of collective validation of students' ideas as a central feature of the teaching and learning process** (rather than summative validation or rejection by authority (teacher or text).

This paper focuses mostly on the last feature of these four, processes of collective validation. Whether students are working in pairs, in groups of four, or in larger group or whole-class settings, how decisions are made about the veracity of data, and how students create *thresholds for acceptability* of data, and claims related to data, is seen as critical to students' continuing engagement in the process, phenomenon, or problem being addressed. Engagement has everything to do with what students learn (Newmann, 1992).

In the instruction described below, students' ideas formed the *currency for interaction* in the classroom. Yet, the initial set of student ideas included much that wasn't scientific, as well as a substantial amount of erroneous data. In classrooms where teachers are expected, at some point, to determine the "right answers" and to direct students towards fruitful ideas and avenues of study, teasing out the mechanisms at play in student decision-making, and eventually in how the teacher handles student-generated data, yields the potential for greater understanding of the term, 'student-centered'.

This study was focused by the following research questions:

1. In what ways do students working in pairs make decisions about what counts as scientific knowledge? When these pairs are combined into groups of four, how do these groups decide what to value from each of the pairs?
2. When groups of students present data summaries in a student-centered classroom, what role does teacher *privileging* play in the acceptance, modification, or rejection of these ideas in the whole-class setting?

Privileging is a process of valuing some ideas over others (Wertsch, 1991). The study examines this and other mechanisms at play over a period of six classroom days, describing how the claims and ideas of a number of students fared in the larger classroom discourse community (Swales, 1990). Brief case studies of student pairs and groups, including transcripts of pairs, group, and whole-class interactions, elucidate the strategies of these students and the teacher, and the results of these strategies in terms of student ownership of the ideas and artifacts of the investigation. Resultant effects on student engagement are noted.

## The Setting:

This research was conducted in a 6th grade urban mixed-ability classroom, where teacher and students were studying about the nature of matter. At the outset of instruction, the activities of scientists seeking to build new knowledge about substances were characterized in a simple framework, identified by the acronym TOPE (Anderson, 1994).

| Letter | Activity | Examples |
|---|---|---|
| T | Developing and learning **techniques** | trying to figure out how to make interesting things happen with substances, like stacking different liquids or dissolving something fast or slowly. |
| O | **Observing** carefully and recording what they see | using one's senses (and instruments) to notice details as well as the obvious things when you compare substances and changes in them. Making careful notes and drawings so that you can tell or show others what you observe. |
| P | Finding **patterns** | looking for patterns in the data from your observations. Sometimes, testing your ideas about patterns to see if they always work is important. |
| E | Developing **explanations** | explaining the patterns you found, and matching patterns with reasons why they happen. Often, scientists develop ideas to explain something, and then later change their explanations when they see new patterns. So, your ideas can change, and you can write new explanations to replace old ones. |

As a representation of the activities of scientists, this framework is elegant in several ways. Perhaps the most immediately appealing is its simplicity; yet, it retains an internal consistency that reflects accurately a hierarchical approach that a scientist might take. Between the lines, however, are descriptions of activity that characterize and distinguish scientific inquiry from the kinds of inquiry that students might undertake on their own.

As an example, when a scientist encounters an unknown substance that he or she wants to learn more about (describe), the scientist begins with the T and O actions (see Examples column) to develop an initial characterization of the substance, and then to further describe it. Then the initial characterization is elaborated and refined as the scientist examines the data for patterns (P) and develops explanations (E) for them.

Scientific description does not follow a uniform path (that is, all scientists would not necessarily perform the same acts; order and reasoning might differ as well). But all of their actions are directed at essentially the same larger goal, that of describing the substance in ways that are valued in the community of scientists. To do this, scientists often act with mediational means-- tools of various sorts, including lab equipment and measuring devices, as well as intellectual tools like concepts and understandings about the nature of matter. In these actions, they observe standards for acceptability of their actions established and maintained by the community. One of these standards has to do with careful observation and recording of data. And, each of the scientists' actions adds to the understanding he or she holds of the substance. This is because the scientist focuses on the connections between new attempts to describe and what has been learned in previous ones. To the outside observer, then, these actions appear to have a consistency and logic that are reflected in the evolving description of the substance.

One part of instruction of matter consisted of learning about the concepts of mass, volume, and density through a system of colored solutions of varying densities, a modification of the ESS Colored Solutions problem (Education Development Center, 1966).

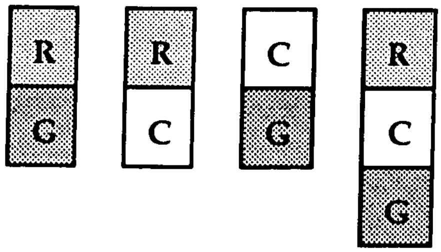
Students were first introduced to three colored solutions:

| Color | Symbol* | Ingredients |
|---|---|---|
| RED | R | water, food coloring |
| CLEAR | C | weak salt water |
| GREEN | G | strong salt water, food coloring |

(*the symbols R, C, G will be used to refer to the solutions, for simplicity's sake).

These solutions differ in density, and with care can be layered or "stacked" one atop another according to density. Thus, the only order in which three solutions would stack (from the top down) was Red/Clear/ Green (R/C/G); other stacks of two solutions could be made as well, following order of density (R/C, C/G, and R/G). These are the only possible stacks.

<u>POSSIBLE STACKS</u>




The teacher (Mr. V) introduced the lesson cluster by showing students two phenomena: when the Red solution was squirted slowly (with a dropper) into a vial of Clear solution, it floated to the surface; students were also shown that a Red solution would stack on top of a Clear solution in a soda straw. The students were then challenged to make as many different stacks as possible.

The flow of the lesson cluster is described in the table below in terms of the sequence of activity, the various social arrangements, and the products for each activity.

| Activity | Social setting | Product |
|---|---|---|
| Initial attempts to make stacks | Pairs | Claims about stacks, as well as other visual effects. Some recorded observations. |
| Gathering pairs data | Groups of 4 | Compiled data as list of claims |
| Reporting class data | Whole class | Verbally reported claims recorded as part of class data |
| Identification of conflicting claims in class | Whole class | List of claims to be re-tested |

| | | |
|---|---|---|
| data | | |
| Retesting conflicting claims | Pairs | Test result, either stack or no stack |
| Reporting class data by accepting/refuting claims and modifying class data list | Whole class | List of possible/ impossible stacks |

In this classroom, the teacher valued students' ideas and language as they worked together to try to understand the system. He held consensus as the model for decision-making, and attempted to provide an even playing field for students to make decisions about what was right based on scientific evidence.

## Theoretical Framework:

In student-centered science classrooms, individual ideas about how things work or what is important often form the *currency for interactions* (my term) as teacher and students work together to try to understand particular phenomena or systems. Often, students' ideas are heavily influenced by past experiences and incomplete knowledge of the topic, which bring them to the instructional setting with incomplete or non-traditional understandings, as illustrated in much of the conceptual change research literature (e.g. (Driver, Guesne & Tiberghien, 1985)). Based on these understandings, they may examine a system or phenomenon and then bring forward explanations that seem logical to them.

The process of bringing ideas from more private individual or small-group settings into the larger arena of the whole class is a critical one, if student ideas are meant to stay at the center of negotiations of meaning. What the teacher does at this juncture is critical; a study by Wells (Wells, 1992) indicated that student ideas are often modified or rejected in situations where the teacher utilizes the common Teacher Initiation-Student Response-Teacher Evaluation (IRE) interaction pattern. As a result, student ownership of these ideas may cease, and student engagement in the problem may dwindle. Engagement is seen as an indicator of motivation to learn (Newmann, 1992).

In a consensus-based classroom, however, teachers may work hard to avoid the typical IRE response patterns, for this very reason. In these classrooms, students' ideas usually go through some form of *collective validation* (c.f. (Miller, 1987)). Miller described this as a process in which members either accept, reject, or argue about ideas generated within a group. Knowing that classrooms are complex social settings in which language, thought, and action of individuals are inextricably meshed to form larger social settings and interactions, this study brings together sociocultural and conceptual change approaches to portray particular interactions nested within the larger classroom context.

## Methods and Data Sources:

Data for this study spanned six classroom days, tracing the ideas of two pairs of students as they were introduced into groups-of-4 and whole-class settings. Data in the form of videotapes of group and whole-class interactions, student logbooks, group project materials, and fieldnotes were collected.

Videotapes were viewed and catalogued, and promising interactions noted for further analysis. Class sessions in which these interactions occurred were transcribed, and the tapes viewed in conjunction with examination of all other evidence to try to fully understand students' moves in both group and whole-class settings. This kind of data analysis was conducted with the aim of tracing the products and interactions of individuals, pairs, and groups within the developing discourse community of the classroom.

Analysis presented in this paper focuses on annotated transcripts of videotaped interactions in pairs, as well as two groups of four (labeled Group 1 and Group 2). Transcripts of whole class sessions, as well as logbook entries for some students, provide additional perspective.

**Data and Interpretation:**

The data presented below is organized by activity and social configuration (pairs, groups of 4, whole class), and follows the chronological sequence of events in the classroom.

Student work in pairs

In Group 1, Adam and Lisa (a working pair) performed three tests in vials and three in straws, with one success (one trial in which the liquids clearly stacked) in a straw. Sandra and Kyle, their partners in Group 1, ran nine trials in vials and one in a straw, reporting three successes in vials.

Below, Adam and Lisa explored the solutions:

1 Lisa- The observation is that it turns olive green. (Adam passes materials to Lisa)
2 Adam- What do you want to do?
3 Lisa- Is this how you dump it?(Adam describes how to use dropper, then shows her.)
4 Lisa- One dropper of red, one white, one clear. (doesn't know how to use it. Adam shows her again. She changes her mind once she gets one dropperful of red in.) Let's take two. Now we'll take the white. (squirts it roughly in, then takes green and squirts it in.)
5 Adam- (to himself) It turned olive green. (to Lisa) Is that olive green again?
6 Lisa- It turned colors. (they both write)
7 Adam- You put red in first, right?
8 Lisa- (writes) Two eyedroppers of... red, green, white. And what happened? (pause) It kept on changing colors. Each color we put in, it turned that color.
9 Adam- Okay
10 Lisa- Now....
11 Adam- Just a second, just a second. (shows her how to put something in a straw. He asks her what color should go first.) Green. Then red.
12 Lisa- What happened? What'd we do?
13 Adam- (as writes) We put green in straw, we put red in straw... it turned clear.

Lisa and Adam quickly fell into a routine that reflected shared understanding of the nature of the task, and shared responsibility for completing it. However, this shared responsibility was accomplished by turn-taking rather than by equally distributed joint responsibility for each test. Lisa's first statement above (move 1) was a restatement of an observation from the previous test that Adam had just run.

She repeated this as she wrote it down, signaling the end of a trial. Adam then gave her the materials, and coached her into using the dropper (3). She invented a test in an *ad hoc* fashion, squirting the colors together (4). He then mouthed an observation statement, checking it with her before recording it (5). Clearly, this pair followed a tightly proscribed routine in which the person manipulating the liquids had control over the test to be run and the results to be reported. This was a shared version of the exploring task, in which turns alternated and Adam took responsibility for teaching Lisa basic use of the equipment so that she could fulfill her part of the task.

While completing the task, Adam and Lisa recorded the following information in their logbooks:

*1-19-93*

*Adam*

*Colored Solutions*

| *Techniques: What I Did* | *Observations: Things I Saw* |
|---|---|
| *1. Put clear into vial: put two eye-droppers of red into it* | *1. The red liquid didn't mix with the clear liquid* |
| *2. Put green in vial; 1 eye-dropper full of clear; 2 eye-droppers full of red* | *2. They all mixed and stayed the color of green.* |
| *3. Put 3 eye-droppers full of green in vial; 3 eye-droppers full of clear in vial' 3 eye-droppers full of red in vial.* | *3. It turned an olive green color.* |
| *4. 2 eye-droppers full red in vial; 2 eye-droppers full of clear in vial; 2 eye-droppers full of green in vial.* | *4. Each time we put a color in it changed that color.* |
| *5. Put green in straw, put red in straw and put in vial.* | *5. It turned clear.* |
| *6. Put red in straw, put clear in straw, put green in straw.* | *6. The stacked and did not mix. Red on top, clear in middle, green on bottom.* |
| *7. Same test as number 6.* | *7. Same results as number 6.* |

*1/19/93*

| *Lisa C.* | *Color solutions* |
|---|---|
| *Techniques: (What I Did)* | *Observations: (Things I Saw)* |

| | |
|---|---|
| *1. Put clear into vial: put two eye-droppers of red into it* | *1. The red liquid didn't mix with the clear liquid* |
| *2. Put green in vial; 1 eye-dropper full of clear; 2 eye-droppers full of red 1/20/93* | *2. They all mixed and stayed the color of green.* |
| *3. 3 eye-droppers of green, clear, and red.* | *3. It turned a olive green color.* |
| *4. We put 2 eyedroppers of red, clear and green* | *4. Each color we put in it turned that color.* |
| *5. Put green in straw, put red in straw and put in vial.* | *5. It turned clear.* |
| *6. Red in straw, put clear in straw, put green in straw.* | *6. They stacked and did not mix.* |

**Note: For both Adam and Lisa, trial #1 is a record of the class demonstration done by the teacher; student work begins with #2.*

There was a very close correlation between the entries in the Observations columns of these two students. This correlation resulted, at least partly, from the joint view of nature and purposes of the task that these two students held, and the routine that they worked out to get it done. For them, while making a stack was clearly a bonus, carefully recorded attempts were the name of the game, and shared (but not necessarily equal) responsibility was also a basic feature of their work. Both of these students made accurate and detailed recordings in their logbooks, especially in terms of techniques. Their records differed from one another in seemingly small ways.

Analysis Notes:

- *When they were working with the solutions, Adam announced an observation, and Lisa wrote it down. This kind of "making by naming" may be related to the process of social validation that Latour & Woolgar [Latour, 1986 #1141] noted.*
- *In their logbooks, much of what they wrote also mirrored each other, since much of the time they "made by naming" their observations and techniques.*

Chet and Donnie worked in a pair, and were members of Group 2. As they explored the solutions, they interacted with Emma, whose partner, Amy, had been absent the previous day and was copying from Emma's notebook into her own during this time.

1 Chet: Alright, now, I'm gonna try and put white on the top of red and see what happens.
2 Emma: It doesn't do anything.
3 Chet: It doesn't?
4 Donnie: That's what I'm trying to do. It just turns it light.
5 Chet: It does?
6 Emma: Oh! So, if you put white on top of something, it mixes. (She writes in logbook).
7 Chet: It doesn't mix (looking at his vial).
8 Donnie: (looking at Chet's vial) See? Oh, I should have mixed red... (he has clear in the vial first)
9 Emma: yes it does.
10 Donnie: not with red!
11 Chet: (shakes head no) Look, it's all on the top (shows to Emma and Donnie)
12 Emma: Put more white on. I can't...I really, I truly can't see.
13 Donnie: Oh, it does work with red

Moves 1 and 4 show that Chet and Donnie were working in parallel and clearly separate ways, with each student taking ownership of his work ("I'm gonna try....", and "That's what I'm trying to do."). This parallel pattern, which extended to their larger group of four, included showing results to others, and cross-talk about intentions and findings. In move 12, Emma suggested that Chet add more white (Clear) solution to make the effect more visible. Chet took this as a challenge, as illustrated below.

14 Chet: (adds more clear)
15 Emma: You need to put more in.
16 Donnie: Yo, let me borrow some red.
17 Emma: Let me see it again (Chet still adding to it).
18 Chet: (holding up vial) You see it? You see it now?
19 Emma: Mmm hmm.
20 Donnie: Here, let me borrow some red. (gets from Chet, squirts it into clear in his vial)
21 Chet: (watching Donnie) It mixes.
22 Donnie: Ah, it mixes.
23 Chet: You squirted it too fast. Squirt it slowly. You squirted it in and it went all the way down... yeah, it does mix.
24 Chet: Hey, what do I do when I'm done? Do I dump it into this big thing right here? Do I dump it into this big thing?

25 Donnie: Yeah. OH, COOL! (Chet looks at Donnie's vial intently, Donnie reaches over and gets more red) (to Chet) A bunch of bubbles come to the top. (Squirts it into mixture) See it?

In move 15, Emma continued to push Chet to make the visual effect easier to see. Chet finally finished this in move 18, getting Emma's validation in doing so. Donnie's trial then interested Chet (move 21), who made a judgment about his technique. Finally, in move 25, Donnie bid for Chet's attention, but to show off a visual effect other than a stack.

As noted above, Chet and Donnie did not develop a jointly held routine, instead taking the task as individually exploring with a shared set of materials. This was the case for three of the four students in this group. Amy just watched as Emma and the two boys explored, choosing to join in after ten minutes or so. During this exploratory phase of activity, all of the group members were involved in running their own trials, and dropping in and out of the conversation. Most of the talk in this group was loud and demonstrative. Both Chet and Donnie explored for several minutes without recording trials in their logbooks.

In this exploration, these students appeared to have the goal of making interesting things happen with the liquids, and showing them to others in their group. There was a competitive and hurried nature to their work, which stood in stark contrast to the work of the students in Group 1. Logbook entries for Donnie and Chet are reproduced below:

*1-19-92* *Colored Solutions* *Donnie*

| *Techniques (What did)* | *Observation (Thing I saw)* |
|---|---|
| *Put clear into vial; put 2 eye-droppers of red into it.* | *The red didn't mix with the clear liquid.* |
| *1-20-93* | |
| *Put the red, then he put the clear on the top* | *The red didn't mix with the green.* |

*Colored Solutions*

| *1-19-93* | *What did Techniques* | *Things I saw Observations* | *Chet R.* |
|---|---|---|---|
| | *1) ~~Put a dropper full of red into the clear~~* | *1) The red didn't mix with the clear liquid.* | |
| | *1) Put clear into vial; put 2 eye-droppers of red in it.* | *2) they mixed* | |
| *1-20-93* | | | |
| | *2) Put drops of clear into vial of red* | | |
| | | **3) they mix* | |
| | **3) Put clear into straw then put red into straw* | *4) Red gathers on sides of vial* | |
| | *4) Put drops of red into vial of white* | | |
| | *5)* | | |

Beyond the first trial (which was a record of the demonstration done by Mr. V), the Technique and Observation statements of these students differ markedly. As mentioned above, these students worked independently, and thus did not share trials or results with each other, beyond showing interesting visual effects to one another. While making stacks was clearly a goal for these students, each brought a competitive edge to his work, appearing to try to outdo one another in visual effect. One interesting result of this approach was the attention each paid to carefully examining the results of any trial (even those conducted by other group members). During one such examination, Chet happened to look down through a vial containing Red and Clear (see trial 4). He observed that the Red solution appeared to have moved to the edges of the vial. While this observation was not supported by any reasoning or other trials, he quickly showed it to others. Upon showing it to Mr. V, Chet asked "why does it do that?". The teacher explained that the illusion was caused by the refraction of light by the sides of the vial. Chet's move to show his vial to others typified his approach to working with the solutions, as well as Donnie's.

<u>Analysis Notes:</u>

*When Chet and Donnie (and Emma) were working in pairs, they worked side-by-side, but each chose what to do next. Emma was nearby, working without a partner, and was skeptical of their work, so she served as an interloper as they tried to show each other 'neat stuff'; theirs was a competitive approach as they tried to outdo each other. They did very little recording as they went, wrote some things down at the end.*

- *"Seeing is believing" was the norm here. However, some casualness in working with the solutions was noted. Emma pushed several times for using more liquid, in order to make the visual effect more easily seen. This is interesting in that she refused to accept "soft" pictures of the layers, where there may have been some mixing in a zone between the solutions, and since small amounts were used, she may not have seen a "pure" layer. She pushed the bounds of acceptability here.*
- *Chet and Donnie had as their goal showing each other interesting things they got the solutions to do. They went from trial to trial quickly, but examine the results of each trial very closely. This has been described as an "engineering approach" by Schauble, et al.*(Schauble, Klopfer & Raghavan, 1991) *(as opposed to the "scientific approach" they describe, which is seeking to understand how the system works).*

Thresholds for acceptability seemed to be established in these ways:

1. Both students looked at it and decided what was there and what to call it, as illustrated by Adam & Lisa.
2. One got a visual effect that was interesting to him, and showed it to the others in attempting to gain their recognition of it, naming it as he did so. Two possible results seen:
   - Accepted by the other, verbally and with visual verification, as demonstrated by Donnie
   - Other pushed for more clarity in effect (add more of each solution) as demonstrated by Emma

Note: Acceptable data was assiduously recorded by both partners in one pair (Adam & Lisa). Acceptable data was only recorded by Emma, an interloper into Chet & Donnie's work, during the investigation in the other group. Chet and Donnie were seen to write several things down <u>after</u> the investigation, but their records were shorter, and more variation was seen between them. Claims from data later would result from their memory of the events.

B.N.: the differences in approach between these two groups of students can be characterized, in Ballenger's (1994) terms, as *populating the task with their* own goals, a phrase that she borrowed from Bakhtin. Adam and Lisa might be characterized as having transformed the goal of exploring the system of solutions into producing a series of tightly constrained tests in a repetitive mode that ensured consistency between their observed results and their records. Donnie and Chet, in juxtaposition, saw the goal as making interesting things happen and showing them to each other.

In terms of the idea of student-centeredness, this initial exploration phase resulted in products that were generated solely by the students, and in fact varied in form and completeness as the students' approach to the task varied. However, pairs of students owned their products, and they were the only ones who were invested in them. engagement was high, at this point, as students were involved in the tasks of trying to make stacks. Connections to canonical scientific knowledge had not been made at this point.

Student work in groups of 4

On the beginning of the third day, Mr. V asked the students to set up a table (following) on a page in their logbooks to record group and class data.

| STACKS WE MADE | STACKS WE COULDN'T MAKE |
|---|---|
| | |

Mr. V wanted students to collect data in an organized way from each of the two pairs comprising their group of 4. The students then worked in their groups to compile their data, with most groups appearing to take this task as simply an additive process in which all claims made by anyone within the group were to be recorded. Students then moved their desks back into rows for the whole-class data gathering session.

*Analysis Notes:*

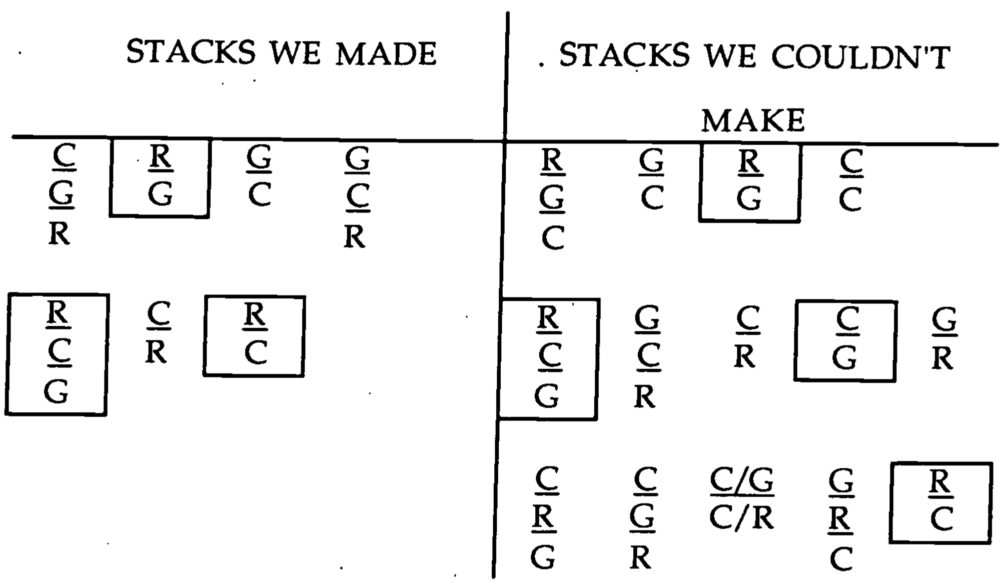
- *No cases of students challenging or not accepting data from another pair were observed. Instead, the process appeared to be additive, and students took interest in seeing that their claims were recorded by others.*

- *Every member of the groups was supposed to end up with a list of all of the claims in that group. In terms of ownership, all students in these two groups were still involved and interested, and in fact Chet & Donnie actually acted charitably towards Emma in this phase.*

Thresholds for acceptability seemed to hinge on verbal claims; some students worked solely from their written claims in their logbooks, while others voiced agreeing claims and new claims from memory. No validation processes had yet taken place, and no challenges were observed (even from Emma).

Students report claims in the whole-class setting

To initiate the reporting process, Mr. V began by asking students to nominate stacks from their data. He recorded all verbally made claims on an overhead transparency. Students were instructed, at the same time, to record all claims in their logbooks. The result was a table with claims about stacks on it (shown below).




Of the 7 stacks claimed as "made" in the class, only 3 are possible (i.e. "correct") based on the density of the solutions (possible stacks are boxed in the figure). All 7 of these stacks also appear among the 14 claims identifying stacks students couldn't make. 10 are indeed impossible ("correct"), although a claim of not being able to make a particular stack could be a correct claim, depending on technique. Notable in this data set are the 4 "STACKS WE MADE" claims which indicate that students made stacks that are physically impossible to make. This feature, and the appearance of 3 of the 4 possible stacks on both sides of the table, led Mr. V to ask the students what to do next.

<u>Analysis Notes:</u>

- *During the reporting of group data, some students (notably, Donnie was among them) objected to claims made by other students. Mr. V's response was to quiet the objections, and record the claims.*
- *Every member of the class was supposed to end up with a list of all of the claims for the class. In terms of ownership, some students were enthusiastic about nominating claims, but the picture is less clear in terms of their claims now being reported by someone else, and being "common" to larger sets of students. My hunch is that students generally stayed with this because it was a short, moderately interesting task that was easy to do. Some may have had vested interest in particular claims at this point, too.*

<u>Thresholds for acceptability</u> seemed to hinge on verbal claims, but Mr. V took over deciding what was acceptable by refusing to debate claims at this point; it is also clear that, during the reporting process, some students were disturbed by some claims that they apparently had tried, or figured out were impossible. Since Mr. V did not follow up on these objections, it is not possible to say upon what grounds they were made.

### Students find a strategy for separating data from noise

Once the data had been recorded in tabular form, Mr. V turned their attention to the quality of the data that they had recorded. In doing so, he wanted to mirror similar events in scientific working groups, where often a data set would be examined collectively by members working on the same or related projects. This process has been characterized as one of separating the real data, the stuff that has value, from the "noise", the stuff that has no value in relation to the investigation (see (Vellom, Anderson & Palincsar, 1993)).

In the interchange below, the students' responses tell us much about what they regarded as salient to the behavior of the solutions at this point.

1 Mr. V: There's a lot of combinations up here. Would you look at that data. Any comments?
2 Jeannie: Some people made stacks that other people couldn't make. Like, someone made red over green. And then someone else couldn't make it.
3 Mr. V: How about that. Anybody else?
4 Shane: I don't think we should have clear over clear, 'cause how could you tell?
5 Mr. V: That's interesting. Here's a question, if you have two different clear solutions, how could you tell if the things stacked or not?

Beginning with the data, Jeannie and Shane pointed out discrepancies that they saw. Mr. V scaffolded the discussion that ensued by reflecting their ideas back in the form of questions and statements. For example, Shane began with an opinion (move #4) in which he suggested a new threshold for acceptable data. Mr. V's response was to formulate a question (move 5), to which Jeannie responded,

6 Jeannie: Well, if you had clear over clear you couldn't really tell because one is clear and the other one is clear and they both come from the same place...
7 Mr. V: I agree. It's generally not productive to talk about red over red, green over green, etc. What about this problem of some people claiming that they made stacks and other people not getting it to work. How do you think that happened, or what do you have to say about that?

Mr. V accepted Jeannie's reasoning, carrying it further by making a general statement in which he privileged claims of stacks of different solutions over those which claimed to have a stack of two samples of the same liquid (7).

Then he went back to Jeannie's earlier observation, formulating a question from it. Other students suggested ideas:

8 Sherrie: They may have used different amounts.
9 Mick: They may have put them in in different orders.
10 Rex: They coulda had it previously mixed.
11 Jeannie: Like Sherrie said, a big amount of clear and a little bit of red, or a little bit of clear and a big amount of red....
12 Mr. V: Are there other things that you can think of that might cause people to get...besides the order they put 'em in and the amount, are there other things that you can think of that might cause people to get different stacks, that other people might not be able to get?
13 Jeannie: How long you waited. Sometimes it will settle and it won't be stacked any more.

Each of these students suggests aspects of technique that could result in errors or in anomalous data. Sherrie's suggestion (8) indicated, as did Mick's (9), that these students were not fully aware of the pattern that ultimately they would discover. So, essentially they were focusing on what they knew about, issues of technique that would turn out, in the end, not to be important. Jeannie's final statement (move 13) finally focused on the solutions themselves, as well as observational technique. Mr. V then refocused attention on the appearance of the whole data set.

14 Mr. V: So, there are a lot of possibilities here. What do we as a group do now? We gathered data. What does t he data look like to you?
15 Mick: Jumbled
16 Mr. V: Jumbled? What do we do? I mean, put yourself in this situation. We're a group of scientists that's been hired to figure out these solutions for somebody. They're gonna pay us when we give them good data. What do we do?
17 Shane: Run the tests again...
18 Mr. V: Run the tests again and come up with....?

19 Sherrie: Well, um, we could take the ones that are on both sides and run those tests again.

20 Mr. V: The ones that some people could and some people couldn't, run those again.

Mr. V's final response solidified and privileged Sherrie's suggestion, confirming for students what an appropriate course of action would be. Class ended with Mr. V telling students that the next day they would use Sherrie's suggestion to retest those claims over which there was disagreement. At the beginning of class the following day, Mr. V showed the class data table, with the seven pairs of conflicting claims marked clearly. He directed students to set up a clean logbook page in two-column format as before, and to write Technique statements for each of the tests they were to perform.

Then Mr. V reminded students that for scientists, proof of data is necessary. He explained that one must be able to show the records made as the investigation proceeded, or be able to take someone into the lab and perform the investigation again so that they can see it. In either case, having good records of the investigation and data is the accepted way to prove something to your colleagues in the scientific community.

Once pairs of students had recorded the tests they were going to run, they were encouraged to get a tray of materials and begin the retesting process. They were also encouraged to work closely in pairs, to show each other results, and to decide what to write down together, before recording it.

Analysis Notes:

- *During this activity, some students were able to propose reasoning and argue about what was important in the way the solutions stacked. While a majority of those who spoke were incorrect about the important features, providing a place for them to argue from their own understanding seemed to 'up the ante' in engagement. These students, and some others, acted in focused ways; some of their actions may have been competitive bids, but they seemed also to be reasoning from experience.*
- *This whole discussion was about thresholds for acceptable data, as well as trying to explain how the system worked.*

- *In terms of ownership, I see the negotiation of process as confused with other claims about the veracity of data, as well as technique. It is difficult to say what effect this discussion had on non-speakers (the majority of the class). None were reluctant to test conflicting claims, which comes next; this may just be because working with the liquids was seen as fun and interesting.*

Students test conflicting claims in pairs

Once all of the tests were recorded in their logbooks, each pair of students began the retesting procedure, using the common list of seven tests. Adam and Lisa began work:

1 Lisa: I'll go first.
2 Adam: I'll go first.
3 Lisa: Okay, let's take turns. (*Adam opens jars. Tries green in straw first, then red. Dumps.*)
4 Adam: Yep they mix. Don't you think so?
5 Lisa: The observation is they mix?
6 Adam: Um, hm. (*They write. Adam uses towel to wipe up small spill, smiles.*) Okay, what's next?

This work session reflected similarities to Adam and Lisa's first two days of investigation, reported earlier. Here again, they ran one test at a time, and this time were explicit about how they would do this (see move 3). They shared both responsibility for each of these tests, and results from them; as they moved carefully forward, they watched each other work and verified observations and wording with each other as they proceeded.

Adam and Lisa report their results in similar terms to those they used in the first phase, e.g. "mixed". However, they clearly took the earlier standard of careful recording of observations to heart, and continued to work in accordance with it here.

The outset of groupwork for Chet and Donnie showed them working in ways similar to their earlier trials:

1 Chet: Alright, now, here we go. I'm gonna try clear, red, green.

2 Donnie: 'Kay, I'm gonna tryyyy......red and green...

3 Chet: ...A little bit of white, let it drip (*Donnie watches*) (*Chet adds red)*

4 Donnie: It mixed. (*Chet dumps it out*) I need that red. (*Chet hands it over*) (*Donnie has green in his, watches.*)

5 Chet: Mixed. (*Donnie dumps his)*

While they did "help" each other out with suggestions, opinions, and ideas, Chet and Donnie operated independently from each other, running tests side by side. Evidence (moves 3 and 4, for example) suggests that each paid attention to their own work as well as the work of their partners and the rest of the group. It is apparent from their talk-aloud behavior as they worked that both Chet and Donnie still held goals of making interesting things happen that each could show to his peers in the group, even though they were working from the discrete list of seven tests

A little later, there was significant discussion about what stacks each of these two had "gotten to work"; this discussion involved other group members, claims, and counterclaims.

34 Chet: OK (*tries again. Donnie is writing in logbook*) That's cool! Red over clear works.

35 Donnie: Yeah, and red over green works.

MR. V COMES BY TO DROP OFF PAPER TOWEL.

36 Donnie: (*to Mr. V*) Red over green works. I got it to work.

37 Mr. V: No! (*mock amazement*)

38 Chet: (*exaggerating*) Red over clear works, too!

39 Donnie and Chet: COOL!

40 Emma: Red over clear. (*to Chet*) You just got red over clear!

41 Chet: Yeah! (*Emma begins to write in logbook*)

A bit later, while they were testing G/R, Donnie claimed that he got a stack , which Chet decided to verify for himself. In choosing this course of action, Chet led them into an evidence-based resolution of the argument:

55 Donnie: Dang. (*Holds it up, examines, dumps it out*) (*to Emma*) When I do it, it works. Well you guys don't be bitin' offa me.

56 Chet: It mixes. It mixes. The first one mixes.

57 Donnie: Nuh uh, I got it to work. (*Chet shakes his head*) Yes I did! Watch! (*gets green solution*)

58 Chet: You're not supposed to use that much!

59 Donnie: (*adds red, holds stack up*) It's red at the top. (*Dumps*)

60 Chet: But it says green over red!

61 Donnie: Oh.

Donnie had initiated his own trial. When this trial didn't result in a stack, (move 57) Donnie stuck with his earlier claim, rather defensively. Meanwhile, Chet had seen both his and Donnie's attempts fail, and concluded that the stack was impossible. Donnie then made a final attempt, which resulted in Red over Green. Chet reminded him that the stack they were attempting to make was Green over Red, and Donnie then dropped his objection.

Significant in these interactions were a couple of indications that thresholds for acceptable data were emerging as a part of what appeared to be a relatively free-wheeling and disordered process. For Chet, "doing it again" appeared important. For all members of both pairs, seeing was believing. This group's practice of showing results to other members, which I believe resulted mainly from the commonly held desire for social status in the group, served to validate results from many tests.

Even so, it is also clear that Chet was quite concerned with the relative amounts of the solutions (moves 54 and 58), a factor that was unrelated to stacking behavior. He and other students were intuitively invested in the idea that a large amount of a given solution could not stack on top of a small amount of another. This was because, in their minds, the smaller amount was lighter and should therefore float. Earlier, we saw evidence of this in Sherrie's suggestion in the whole-class session that different amounts would give different results. Here, we see further evidence that it was still in play in Chet and Donnie's work as well, in spite of the fact that no amounts were specified in any of the seven tests that students ran in the testing conflicting claims portion of their work with solutions.

Analysis Notes:

- *"Making by naming" and "seeing is believing" were norms for acceptable data as in earlier pairs work, but this time there was an added dimension of familiarity with the liquids, and the issue of some stacks being impossible had been broached. It is clear that intuitive understandings, or informal predictions based on them, were in play. This meant that "just any" claim would not fly this time.*
- *Students were again highly engaged, and when disagreements about stacks broke out, argued with passion. Ownership of stacks, and related understandings about technique, was high.*
- *A standard of replicability was seen here with Chet and Donnie, as in earlier work,*

Thresholds for acceptable data had become more complex, but also closer to those held in scientific circles. Careful observation was the norm for Adam & Lisa, who continued their single-test-at-a-time pattern. Chet and Donnie displayed more vibrant sets of strategies, and also challenged each other (and Emma!) more.

Reporting class data, retesting, and refining class data list

Next, Mr. V initiated a whole-class session in which he asked for a show-of-hands tally of results on the tested stacks, one by one. Mr. V hoped to have decisions by consensus at this point, but this was not to be. When he asked about the first stack, Green over Clear, 18 pairs reported they couldn't make it, while 5 pairs claimed to have made it. Mr. V sent one of the pairs that claimed to have made it to the back, asking them to bring the stack up to show the class when they had made it. After several tries, they came forward to report that they had not been able to make the stack. At this point, Mr. V asked if anyone objected to eliminating it as a possible stack. Hearing no objections, he did so. The table below summarizes the disposition of each of the stacks.

| | Claimed Stack | Result |
|---|---|---|
| 1 | G/C | 18 students said no, 5 said yes. Retested by one 'yes' and one 'no'; eliminated when they could not make it. |
| 2 | R/G | All made this. Accepted as true stack. |
| 3 | R/C/G | 14 students said yes, 6 said no. Issue of careful technique discussed. Accepted as true stack. |
| 4 | G/C/R | All except one said no. Eliminated after repeated retesting failed to produce it. |
| 5 | C/R | No group claimed to have made this; eliminated. |
| 6 | C/G/R | No group claimed to have made this; eliminated. |
| 7 | R/C | All made this. Accepted as true stack. |

In each of the cases in which there was not clear consensus, pairs of students were sent to the back counter (where trays of materials were available) to test the claim again, and to show or report results to the class.

Four of the seven claims retested involved stacks that are not possible. In each of these cases, it was the absence of a particular observation (the "stack") that determined the outcome of the retesting process. This meant that, unlike the situation in which a stack was created and could be shown as proof, in these situations issues of technique were possible reasons for the negative result. In the last part of the process, Mr. V's attempts to leave claims untouched until all agreed that they were not possible fell prey to his sense of urgency in completing the task of tallying and passing judgment on each of the stacks in one class period. So, in one situation in which one person claimed to have made the stack, possible discussions of the sources of difficulties were quashed by his tight control over the routine of tallying, retesting if necessary, and passing judgment.

An exception to the tallying routine came near the end of the process, when a student (Chelsea) brought her attempt to make the stack Green over Clear over Red forward. What she showed in the vial was Red over Clear over Green. Asked to explain what she had tried, Chelsea said

> First I tried to put the Green and then the Clear the Red, but it didn't work, so then I just put the Clear in the vial, and I took an eyedropper and stuck it all the way down and let it out slowly, and the Green stayed at the bottom, and I put the Red on top.
>
> This top part of the stack, Red over Clear, is the same stack that those girls were testing and they got it to work.

Chelsea's description was important in two senses. First, it provided a description of the immediate discrepancy between the stack she was supposed to be testing, and the result (which was a different stack). Providing information on the process that she used showed that she had indeed been running the right test, and that her results, while they didn't show the desired stack, were consistent with results that others in the class had gotten in terms of patterns. In a second sense, Chelsea's response demonstrated the importance of technique in getting the liquids to stack or mix. Chelsea was very specific about the techniques that she used to get the stack that she got, and her moving from the failed first attempt to a second in which she modified her technique provided a good example for others in the class. Mr.

V's request for explanation was a response to the first of these two senses; Chelsea's detailed description brought both of them to the center of attention. While Mr. V certainly might have noted that, in addition to these two senses, Chelsea's description moved nicely into pattern-finding, he did not discuss this in the public arena of the classroom at this time.

Instead, with time running out for the day, Mr. V completed the process of gathering reports and making decisions on the remainder of the stacks, and then announced to the students that the next day, they would recopy the chart to eliminate all of the stricken stacks. With that, the class ended.

*Analysis Notes:*

- *During this activity, engagement wavered as Mr. V restricted the process, and set the standards for acceptable data. In juxtaposition to the earlier discussion leading to a process, he here announced what the process would be. His need to constrain the amount of time this activity took drove this decision.*
- *Students still made claims, but this time just by raising hands. This depersonalized their "I did it" claims from before as they became a tic on the tally sheet, reducing ownership. However, some students were observed to shift their focus from individual stacks to getting the most "right" on the tally sheet, shifting to a whole-task focus. They also enjoyed the retesting, and were eager to show and see results from this testing process.*

Thresholds for acceptable data established by Mr. V in this activity. Near-consensus was the standard, and he worked hard to get it. Still, he was able to note and accept that issues of technique and careful attention to detail were still an issue in the class.

**Discussion:**

The lesson sequence is summarized below, in a modification of an earlier table. Added are the students' goals-in-use, indicators of the ways in which the students interpreted each of the activities. These goals-in-use are seen as important indicators of the ways in which students engaged in the processes of exploration and validation.

| Activity | Social setting | Product | Students' goals-in-use |
|---|---|---|---|
| Initial attempts to make stacks | Pairs | Claims about stacks, as well as other visual effects. Some recorded observations. | Exploration of both technique and behavior of solutions, or engineering solutions to get visual effects. |
| Gathering pairs data | Groups of 4 | Compiled data as list of claims | Additive process to include all positive and negative claims; no collective validation |
| Reporting groups' data | Whole class | Verbally reported claims recorded as part of class data | Making claims from compiled set for group; promoting owned claims in competitive setting |
| Finding a strategy to separate data from noise; identifying conflicting claims in class data | Whole class | List of claims to be re-tested | Identification of pairs of claims; promoting owned claims in competitive setting |
| Testing conflicting claims | Pairs | Test result, either stack or no stack | Attempting to make specified stacks; proving/disproving claims from class data |
| Reporting pairs data, accepting/refuting claims; some retesting; modifying class data list | Whole class | List of possible/ impossible stacks | Critical process beginning with reporting of retesting results. Cumulative effect (consensus?) for making decisions. |

Results are discussed below in terms of each of the research questions.

Question 1: Students working in pairs exhibited a number of mechanisms for making decisions, including those noted above. High levels of engagement and ownership were noted in pairs work for virtually every student.

When pairs findings were brought into groups of four, and then reported to the whole class, ownership and engagement remained high as students bid to get their claims on the lists. Variation was noted in the kinds of goals that these students owned as they investigated and argued, and in what features of the system they understood as important as they examined and described phenomena.

Question 2: As findings from groups of four were brought into the whole-class arena, teacher privileging was seen to play a central role in determining what data was valued. However, ambiguous or contradictory data led to further validation efforts. While the teacher did guide students in determining how this validation would proceed, he was able to maintain high levels of engagement by reverting to work in pairs to solve data-related problems.

Even so, case materials illustrate the delicate balance that this teacher maintained while privileging some students' ideas and claims over others. In this study, as thresholds for acceptable data grew to include claims backed by written evidence, the teacher's voice about what counted became less important, right up until the end. However, the teacher still played a key role in providing direction as the class explored the system and phenomena. And in the end, his need to get the job done led him to impose a process and new thresholds. It is unclear how drastically these affected student engagement, but what stands out is the students' shift from a focus on ownership of individual products (claims, stacks) to a focus on the result of the process (getting the most "right" on the final list). Had this shift towards an imposed process and thresholds occurred earlier in the sequence, a dramatic loss of the ownership that drove engagement may have resulted.

**Importance of the Study:**

This study illustrates how decisions are made and knowledge is generated and accepted in pairs and groups of students within the developing discourse community of the classroom. As the students worked to explore and understand the system of Colored Solutions, individuals' strategies and ideas were either valued or not, in different social configurations. The study illustrates a range of mechanisms at play in student decision-making, and eventually under the direction of the teacher in the whole-class setting.

Cognitive and sociocultural research traditions are brought together in this study, with the latter foregrounded. Thus, analyzing language and related action while attending to indicators of cognition was the ultimate purpose. Moving from students working in pairs to larger groups and back again, we get pictures of the kinds of science different students experienced. From these pictures, we are enabled by our further understanding of the complexities of classroom interactions, in our quest to teach 'science for all'.

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