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Giving Students the Power to Engage with Learning

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Abstract This critical discourse analysis study identifies and describes power relationships in elementary classrooms that support science engagement by providing students time to think, ask questions, and find their voices to talk about subject matter. The first analyses involved identification and description of classroom episodes showing high levels of student power and engagement associated with learning science. Classroom episodes were grouped into seven *power patterns*: use of questions, teacher sharing authority, giving students credit for knowledge, legitimate digressions, enhanced feedback, and writing opportunities. The second analyses documented the manner in which these patterns formed more complex classroom engagement processes called *power clusters*. These examples further our understanding of the dynamics of classroom discourse and the relationships between student power and engagement in subject matter.

Keywords Classroom discourse · Student power · Questioning · Student engagement in science

As tasks unfold in the classroom, discourse and power relationships between students and teachers emerge (Fairclough 1989; van Dijk 1996). These power relationships can be described at societal, political, and cultural levels (Rogers 2004), but they also can be related directly to issues of learning (Gee 2004). Furthermore, teachers can directly control the empowerment of students through their teaching strategies (Wertsch 1998).

In this study, we use a critical discourse lens (Rogers 2004) and view the classroom as a microcosm of broader societal power struggles. We view learners and teachers as negotiators of power relationships, and see the effective classroom as one in which learners are empowered to engage with subject matter, science in this case. We assert that a good teacher creates contexts in which students construct their interpretations and understandings of science through classroom discourse (Lemke 1990; Block-Gandy 2001) and legitimate participation

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(Lave and Wenger 1991; Tobin and Tippins 1993). The purpose of this study was to evaluate power dynamics within three elementary classrooms in order to understand how cycles of classroom discourse support student engagement and learning.

Theoretical Framework

To acquire deep understandings, learners must have the opportunity to be reflective (Dewey 1938). Learner reflection enhances high level thinking and occurs when classroom interactions support student engagement and active development, discussion, and defense of ideas (Engle and Conant 2002; Herrenkohl and Guerra 1998). Good teaching strategies, like those advocated in inquiry instruction in science, provide opportunities for interactions and engagement with subject matter content, peers, and teachers (Lemke 1990; Tobin et al. 1990; Tobin and Tippins 1993). These strategies also allow for learners to create connections between two types of classroom discourse, exploratory (everyday/vernacular) talk and scientific (presentation/social language) talk (Barnes 2008; Gee 2004; Scott 2008). Moreover, this talk is interactive and dialogic and represents a "culture of talk" created in effective classrooms (Alexander 2008; Peirce and Gilles 2008; Scott 2008). It is this transition or inter-connection from exploratory talk to scientific talk that is the essence of academic science learning. This is especially the case at the elementary level, as students are developing skills in the culture of educational discourse (Lemke 1990; Tudge 1990). In order for these connections to be constructed by learners, they must be allotted the power to accomplish this task. Thus, in educational discourse, power is defined as the state of having or exerting control over the actions and thoughts of others (Fairclough 1989; van Dijk 2003). What happens in the classroom from moment to moment is literally the crux of this power. In our studies, we show classroom power to be present in a wide variety of ways as tasks and activities for learning unfold. As learning opportunities develop, it becomes more apparent where students are empowered to engage and participate. In previous work, we have defined power through five categories of classroom interactions; both teachers and students wield control and influence through *conventional power*, *organizational power*, *individual voice power*, *group powe*r, and *subject matter power* (Reinsvold and Cochran 2011, 2013, Cochran et al. 2014). Power codes are presented in bold and full definitions and examples are presented in Appendix 1.

Conventional Power (CON)

The first power category, *conventional power*, represents the typical power structure that classrooms are expected to show in traditional U.S. schools. Examples of conventional power include enforcement of typical rules and conventions such as raising hands to ask questions, behavioral reminders, and student responsibilities for passing out papers. It also includes choral responses when students respond in unison to a teacher question.

Organizational Power (OR)

In order to differentiate between conventional power (which is not related to curriculum or content) and classroom structures that are directly related to subject matter, we identified the latter as *organizational power*. This category allows for the control of tasks that are specific to science learning such as writing in science notebooks, rules for manipulating science materials, and cleaning up conventions. The components of this power category would differ across various subject matter areas, e.g., mathematics, reading, or social studies.

Individual Voice Power (IV)

Another category of power, *individual voice power*, is denoted by the use of "I" statements, either by individual students or the teacher. This power represents the ability of an individual to express an opinion or idea related to the subject matter.

Group Power (GR)

We separated the individual source of power above from a collective source of power, *group power*. Group power is characterized by use of terms such as "we" or "our" or implications of a group-level consensus. This type of power is expected to be found in small group work, particularly in inquiry settings (Reinsvold and Cochran 2011), but it also includes choral responses when students respond in unison to a question.

Subject Matter Power (SM)

Finally, *subject matter power* is identified as the direct use of disciplinary terms and processes in the classroom discourse context. We consider this type of power to be the clearest indication of student subject matter engagement. It is indicative of students' making connections between exploratory and scientific classroom talk and shows the integration of subject matter concepts across time.

Open-Ended (OE), Task-Oriented (TO), and Closed-Ended (CE) Questions

The other major component of classroom dialogical dynamics we have investigated is questioning. Our previous work (Reinsvold and Cochran 2011, 2013) has focused on the five power categories described above and their relationships to the use of open-ended, closed-ended, and task-oriented questions (see Appendix 2). We have found that teachers' use of power and questions varies considerably across classrooms and classroom sessions, and that when students have more access to power and questions of all types, they use that power for more frequent and more effective engagement with subject matter. In this study, power and questioning have now been combined to create more comprehensive patterns and clusters of power relationships that are related to student subject matter engagement.

Research Questions

In this study, we identify and describe classroom power relationships supporting students' ability to learn elementary science beyond our previous work. We focused on positive teacher-student interactions that allow student engagement; enhance interest; and support learning by providing students with time to think, ask questions, and find their science voices as learners. The research questions follow:

1. What types of teacher-student dynamic power patterns give students power to learn in elementary science classrooms?
2. What do these power patterns look like and how do they engage students with science subject matter?

Method

Participant Selection

This study occurred in the classrooms of three European-American elementary teachers in a suburban setting. Purposeful sampling (Creswell 2007) was used to select three teachers in consultation with the district-level Science Coordinator, who identified the teachers as interested in actively enhancing their science teaching strategies; teaching science at least 2 days weekly; involved in district-level science professional development; and using hands-on inquiry-based curricula. The classrooms are described below.

First Grade

The first-grade classroom included 22 students; 16 European-American, three Latina/o, one Iranian-American, one Asian-American, and one diagnosed with Down syndrome. The students studied geology from the *Pebbles, Sand and Silt* investigation from the FOSS curriculum (Regents of the University of California, 2005). Two classroom sessions (53 and 58 min long) were observed 1 week apart. The lesson goals were to compare and contrast rocks, build vocabulary using a word wall, investigate rocks with hand lenses and by touching and rubbing them together, and write in a science journal. Ms. Smith expressed interest in higher level questioning via Bloom's taxonomy (due to her training in gifted education) and the 5Es inquiry instructional model (Engage, Explore, Explain, Extend, Evaluate) from BSCS (Bybee et al. 2006). She had 32 years of elementary teaching experience, 50 hours of professional development in science, and a master's degree in gifted and talented education. She worked with district staff and teachers to select and organize science curricula.

Third Grade

The third-grade classroom had 21 students, 13 European-Americans and eight Latina/o; all the Latina/o students were English Language Learners (ELLs). All ELL students had previously attained the required district-level third-grade literacy benchmarks. The students studied magnetism, electricity, and circuits from the FOSS curriculum (Regents of the University of California 2005). These classroom observations occurred about a week apart (40 and 42 min). The teacher, Ms. Jones, had had only six science sessions with this group because in her school, students completed their science curriculum using a rotation system and this was the fourth and last science group for the year. She stated that she wanted the students to be inquisitive and to ask *why* questions. She used small-group teaching strategies and was assisting students to learn group roles such as the *getter*, the *communicator*, and the *tracker*. Ms. Jones also based her teaching partly on the BSCS 5Es system (Bybee et al., 2006) and was particularly interested in developing science vocabulary skills. She had taught for

26 years, possessed a master's degree in elementary education, and had 30 hours of professional development in science education. She worked with Ms. Smith to plan elementary science teaching.

Fourth Grade

The Grade 4 classroom had 23 students. Thirteen were European-American, nine Latino, and one Malaysian; the families of five of the Latino students did not speak or read English. Half of the students qualified for free or reduced lunch funding and two had Individualized Education Plans. Two class sessions were observed (49 and 43 min) and the curriculum included investigations of mammal pelts and tracks in the Rocky Mountains (Block-Gandy 2001). Students were involved in reading clue cards, and comparing and contrasting animal characteristics to identify pelts on the first day and tracks on the next day. Ms. Allen had an elementary education degree, and was beginning her seventh year teaching, and had 12 hours of science and science education professional development. She met monthly with other district elementary teachers to discuss curriculum and student science achievement. Like the other teachers, Ms. Allen based her teaching on the BSCS 5E model (Bybee et al. 2006); she intentionally structured large and small group settings to allow students to explain their science thinking.

Data Collection and Analysis

Each classroom was observed twice and field notes were collected; for each observation, an iPod was used as an audio-recorder and was attached to the teacher's waist, thus capturing all teacher-student verbal interactions.

All verbal interactions in the six classroom sessions were transcribed. Transcription conventions were adapted from Adger (2003) and are described in more detail in Reinsvold and Cochran (2013). The transcriptions were then coded using NVIVO (version 10) software (QSR International 2012) into a previously developed matrix (Reinsvold and Cochran 2011, 2013). Examples and descriptions of the power codes and question codes are provided in Appendices 1 and 2, and a transcript example in Appendix 3. All codes are in bold, and **T** precedes teacher codes and student codes by **S**. Codes not denoted with a **T** or **S**, such as **CE** (closed-ended questions) and **OE** (open-ended questions), refer to both teachers and students.

Results

All coding was first conducted by each individual researcher (achieving an agreement rate of about 85 %); all inconsistencies were then resolved by consensus. We began our analyses with preliminary frequency data, which showed teacher discourse to be more frequent than student discourse overall, but that types of power and question dimensions varied substantially across classrooms (see Tables 1 and 2).

Both the questioning data and the power data showed the Grade 4 classroom to be more balanced than the other classrooms with respect to teacher and student discourse overall. Along with the higher student use of subject matter power (SSM), this suggests that the

Table 1 Distribution of question types across grade levels

	Grade 1		Grade 3		Grade 4	
	Students(s)	Teacher	Students(s)	Teacher	Students(s)	Teacher
Question type						
Closed-ended freq. (%)	11 (7 %)	148 (93 %)	14 (47 %)	16 (53 %)	104 (33 %)	214 (67 %)
Task-oriented freq. (%)	7 (6 %)	112 (94 %)	10 (7 %)	130 (93 %)	25 (28 %)	64 (72 %)
Open-ended freq. (%)	1 (1 %)	162 (99 %)	2 (3 %)	61 (97 %)	32 (27 %)	88 (73 %)
Totals (%)	19 (4 %)	422 (96 %)	26 (7 %)	365 (93 %)	284 (44 %)	366 (56 %)

Percentages compare students vs. teachers at each grade level

students were more engaged in science in this setting. Moreover, the frequencies of student individual power (the combination of SIV, SSIV, and TSIV codes) were also higher. When we charted the classroom dialog across time, the instances where students specifically showed high engagement through their use of power and closed- and open-ended questions led us to a more in-depth identification of the types of dynamic relationships between power and questions.

Task-oriented questions showed very few relationships with student engagement, so this component was not further analyzed. While enhancing the flow of classroom processes in general, these questions did not directly enhance student power.

Our main results are reported in two sections. These sections address our two research questions by describing and illustrating teacher-student interactions that provide students with power to engage in the science subject matter. First, the relationships between teacher questions and student power are revealed as seven *power patterns* that support student engagement by providing students with time to think, ask questions, and find their voices as science learners. Second, we show our investigation of the relationships between these power patterns that reveal larger dynamics labeled *power clusters*.

Table 2 Distribution of power dimension codes across grade levels

	Grade 1		Grade 3		Grade 4	
	Student(s)	Teacher	Student(s)	Teacher	Student(s)	Teacher
Power type						
Conventionality freq. (%)	18 (5 %)	365 (95 %)	30 (15 %)	176 (85 %)	71 (19 %)	307 (81 %)
Group freq. (%)	37 (29 %)	91 (71 %)	83 (58 %)	60 (42 %)	105 (36 %)	190 (64 %)
Individual voice freq. (%)[a]	558 (96 %)	22 (4 %)	251 (91 %)	25 (9 %)	935 (90 %)	101 (10 %)
SIV (student)	269		162		761	
SSIV (student-student)	4		0		23	
TSIV (teacher-student)	285		89		101	
Organizational freq. (%)	46 (8 %)	549 (92 %)	44 (13 %)	308 (87 %)	122 (24 %)	378 (76 %)
Subject matter freq. (%)	184 (31 %)	420 (69 %)	137 (32 %)	288 (68 %)	442 (53 %)	398 (47 %)
Total freq. (%)	843 (37 %)	1447 (63 %)	545 (39 %)	857 (61 %)	1675 (55 %)	1374 (45 %)

Percentages compare students vs. teachers at each grade level

[a] Individual voice power is the sum of SIV, SSIV, and TSIV codes

Power Patterns

We identified and analyzed seven patterns of power dynamics in the classrooms that were connected with strong student engagement shown by high levels of student power. These seven power patterns were labeled as *use of question sequences*, *teacher sharing authority*, *giving students credit for knowledge*, *legitimate digressions*, *enhanced feedback*, *conceptual integration*, and *writing opportunities*. Explanations and examples of each power pattern follow.

Use of Question Sequences

Teacher and student questions were coded into the categories of closed-ended, task-oriented, and open-ended questions. See Appendix 2 for full descriptions of labels and examples. We found that a sequential unfolding of content ideas through questioning, both closed-ended (**CE**) and open-ended (**OE**) questions, engaged students in subject matter talk not only with the teacher but also with each other. This Grade 3 example shows the teacher's question sequence using both closed-ended and open-ended questions and how this sequence is related to student power.

S1: (Female) I was right! We put the compass there and it was like…chrrrm and then it went soft… **(SIV, SGR, SSM)**
T: And then what? **(TSIV, TOR, TOE)**
S1: And then um… and then…[inaud] the red needle went up **(SIV, SSM)**
T: What? What did you say about the red needle? What part? What did it do? **(TOE, TSIV, TOR, TSM, TCE)**
S1: It went up. **(SIV, SSM)**
T: It went up? **(TCE, TSIV, TOR, TSM)**
S1: Yea. **(SIV)**
T: What about the other end? **(TOE, TSM, TOR, TSIV)**
S1: It went down. **(SIV, SSM)**
S2: Down?↑↓ **(SCE, SSM)**
S1: It was down… **(SIV, SSM)**
S2: It's like [inaud]… the magnet…the compass thing [inaud] **(SIV, SSM)**
S: Oo, cool. **(SIV)**
T: Now remember that when you write your words down. **(TOR, TCON)**
S1: …I think it's the force. It's repelling this but it's attracting to this…because the magnets… in a different way so this one is repelling and one's attracting. **(SIV, SSM)**
(GR3 OBS1, 24:11–25:00)

We found that task-oriented questions from both teachers and students, though certainly necessary for enhancing the flow of the activity, were less likely to be related to student subject matter engagement or other student power, and were omitted from further analyses.

Teacher Sharing Authority

Giving students choices allows students more power. Thus, when teachers allow students to make decisions about where the investigation should go next, the conversation is furthered by more engagement, action, and/or discussion and the students used more student individual voice power **(SIV)**, organizational power (**SOR**), and subject matter power (**SSM**). In this Grade 4 example, the class was identifying numbered molds of animal tracks and determining whether they showed paws (P), claws (C), or hooves (H).

T: Now… what should we do next on these? How can we narrow it down now? … Which are the least? The Ps or the Cs? What do you think Adam? **(TOE, TCE, TSM, TOR, TGR, TSIV)**
Adam: Um the claws. **(SIV, SSM, SOR)**
T: Claws okay = **(TSM, TCON)**

Later, the teacher provided more opportunity for student choice and shared her own indecisiveness, giving students a less authoritarian and a more authentic inquiry experience. In this segment, the teacher's three open-ended questions facilitated this process as well, fostering student engagement.

T: Alright, so which would be the easiest to classify do you think first? Mark? (**TOE, TSIV, TOR, TSM)**
Mark: The eagle. **(SIV, SSM)**
T: The eagle. **(TSM)**
T: So which one do you think is the eagle, Barbara? (**TOE, TSM, TSIV)**
Barbara: Um the biggest one. **(SIV, SSM)**
T: The biggest one. So if you agree with us on seventeen let's write the eagle. Seventeen, eagle. Is what I think. **(TSM, TOR, TIV, TGR)**
S3: Seventeen, eagle. **(SIV, SSM)**
T: Good thing I don't know these very well. It is kind of fun. (laughs) Okay, next…
(GR4 OBS2, 28:08–28:30)

Giving Students Credit for Knowledge

For the third power pattern, allowing students to connect classroom topics with their own knowledge was found to be related to subject-matter engagement and other student power. This pattern shows students having the freedom to use both their own words and their own prior knowledge. The teacher became aware of students' content-related language and validated it as legitimate participation (Lave and Wenger 1991). Furthermore, the dialogic nature of the student-to-student conversation here allows students to make sense of content in their own words and build understanding through "exploratory talk" (Mercer and Dawes 2008; Scott et al. 2006). In this example, the teacher and students are discussing ways in which they can determine the presence of animals, in preparation for a visit to a nature center:

T: This is what we're going to try to look for when we're there. Now we need to be a little more prepared than just we're going to look for them, because when I find them what am I going to do? Okay so let me get a few of these questions out of the way and then we'll continue on. [Ss raising hands] Juli? **(TOE, TGR, TSIV, TOR)**
Juli: Well I have another one that we can look for… **(SIV, SOR, SSM)**
T: What's that? (**TOE, TSIV)**

J: Is that we can look for their… ah… like you know how beavers have like a… thing **(SIV, SOR, SSM)**
S2: Home **(SIV, SSM)**
T: ↑Oh their home. Their lodge. **(TSM)**
J: And then = **(SIV, SOR)**
Kara: =We can see if they… if there're dams in the lakes. **(SIV, SOR, SSM)**
Ed: We could, we could see if trees fell. **(SIV, SSM, SOR)**
J: Yeah, And then we can see if something is over there and stuff. **(SIV, SOR)**
T: Excellent. I like that idea. **(TIV, TCON)** (GR4 OB2, 7:35–8:09)

In this example, the teacher is unsure if the questions are directly related to her planned discussion on finding evidence of animals, but the students are given the opportunity to control the discussion nevertheless.

Legitimate Digressions

Legitimate digressions occur when the conversation diverges slightly to another topic not directly connected with the concepts under study. The teacher allows the digression to occur as a mechanism to enhance engagement and creates an opportunity for the students to use science terms. In Grade 1, the teacher allows and builds on the concept of "molecule" initiated by a student in a discussion of types of rocks. The teacher broadens the dialog to the whole class and validates the students' attempt at understanding. This example also shows students' use of their group power **(SGR)**, indicated by their use of the term "we."

S1: Ms Smith we decided to put molecule, [but] **(SGR, SOR, SSM)**
S2: [but] we don't know how to spell it. **(SGR, SSM)**
T: [to the whole class] They decided to put molecule, but they did not know how to spell it… I ↑ haven't used that word all year = **(TIV, TSM)**

In a second example, the same teacher has students recall a previous reading.

T: =Mmm, would you guys think back to what we read. We read the very first section. Do you remember we saw pictures of El Capitan that gigantic rock? (**TCE, TGR, TSM, TOR)**
Ss: (deep breaths) Mmmm
T: And then we saw something else. We saw what was blowing. Gloria do you remember? (**TOE, TGR, TSM, TSIV)**
G: Umm, sand is rocks **(SIV, SSM)**
T: Sand is [just rocks too] but different… **(TSM)**
G: Just little **(SIV, SSM)**
Ss: ↑↑ah, little, aw (lots of responses, students anxious to talk), rub together **(SIV, SSM)**
T: size, pebbles **(TSM)**
S: They rub together. **(SIV, SSM)**
T: (deep breath) What do you mean they rub together? (**TOE, TSM, TSIV)**
S: They rub together so they could make littler rocks **(SIV, SSM)**
*T: So are you saying to me that the sand is littler—was a bigger rock at one time (child says yes) that got rubbed together and became littler rocks? (***TCE, TSM, TOR)**
S: yes **(SIV)**
T: Wow, that's excellent. **(TCON)** (GR1, OBS1, 46:11–46:48)

Enhanced Feedback

Teacher feedback occurs often in classrooms, and it can be quite brief in more traditional, authoritative settings, but it has great potential for improving learning (Hattie and Gan 2011). In inquiry classrooms, feedback takes many forms (Chin 2006). Like Mortimer and Scott (2003), we found that feedback that furthered the conversation with the students was followed by more in-depth student engagement, such as a student question, prompt, or response. In this example, Zeke asked a question about a pelt in two pieces (a porcupine), and the second and third teacher responses here show enhanced feedback. This exchange results in Zeke's hypothesis that the pelt is a wolf.

> *T: Zeke?* **(TOE, TSIV)**
> *Zeke: Ah, kind of notice. I noticed something. This specific animal, its, um been hooked because it probably got teared* [torn] *right?* **(SCE, SOR, SSM)**
> *Teacher: Well, actually, this specific animal is another part of their body.* **(TSM, TOR)**
> *Z: It is?* **(SCE, SIV)**
> *Teacher: This is the main body, this is something else. So you are going to have to think about that.* **(TSIV, TS, TOR)**
> *Z: It sort of looks like a wolf.* **(SIV, SSM)** (GR4, OBS1, 13:13:25–13:45)

Conceptual Integration

When curriculum is connected across time and/or subject matter (either by a teacher or a student), engagement occurs. This example of conceptual integration occurred in Grade 1. During the science lesson, Ms. Smith reminded students of their reading conversations and how they compared and contrasted different versions of Johnny Appleseed.

> *T: Boys and girls. The reading this morning we talked about a… compare and contrast different versions of Johnny Appleseed. So we are going to talk about comparing and contrasting some rocks today and looking at them. Now it was pretty easy to do it when they were gray and red and white. Okay that was pretty easy. What if they looked almost the same? What if they really looked almost the same, how are we going to compare and contrast them? What do you think might work? Tom?* (**TOE, TGR, TOR, TSIV, TSM)**
> *Tom: You got to have a microscope [inaudible] and see the teeny details on the rock.* **(SIV, SOR, SSM)**
> *T: A microscope and some… some teeny details. Good.* **(TSM, TOR)**
> *T: Now I only have one little microscope. So what could we use instead if you are in small groups?* (**TOE, TSM, TGR)**
> *S1: Huh? (student is raising hand and seeking attention)* **(SIV)**
> *T: Not quite as good, but…* **(TOR)**
> *S2: The magnifying glass.* **(SIV, SSM)**
> *T: The magnifying glass. We can use the hand lens. Good.* **(TSM, TCON, TGR)** (GR1 OBS 2, 3:25–4:21)

Writing Opportunities

We also observed connections between writing opportunities and the engagement of students in science subject matter, sometimes initiated by students themselves, as in the example below:

The Grade 4 teacher used writing throughout the activities of identifying pelts and footprints, and was attempting to get the students thinking about the use of science notebooks.

> *T: Almost just like flippers you guys. Cause when you are in the water and you try to swim, if you claw, that is why we cup our hands to make it a solid so it'll go through the water when we swim. Okay? But if we went like this we would flail and wouldn't get very far. Well um, aquatic animals then they have this like thin skin between each=* **(TSM, TOR, TGR)**
> *S: Ohhh, so they have extra skin (inaud).* **(SIV, SSM)**
> *T: =toe or whatever and then it makes it more solid so they can swim better. It is almost like the fins you wear when you swim.* **(TSM)**
> *S: Turtles have them.* **(SIV, SSM)**
> *T: Yeah, Yeah, okay.* **(TCON)**
> *S: Can we write W equals= ?* **(SIV, SOR, SSM)**
> *T: Oh yeah. W equals web. Excellent. Got to keep that key current. Excellent job.* **(TSM, TCON)**
> *T: Okay black bear. Write it down.* **(TSM, TOR)**
> *S: Can we do everything by ourselves?* **(SIV, SOR)**
> *T: Do everything by yourself really quick, and then I'll go over it in a second.* **(TOR, TIV)**
> *T: What do you think? Do all of them.* **(TOE, TSM, TOR)** (GR4 OBS 2, 16:00–16:51)

This example also shows the teacher creating conceptual integration by relating the information to swimming, sharing authority with students, and giving them credit for knowledge.

In the first-grade classroom, students used science notebooks to capture their observations about rocks and their reasoning about what they observed.

> *T: You all know how to date your page. So go ahead and put your date on… And the first thing we are going to do boys and girls because we are starting a new unit, is we are going to label our unit so we are just going to put, we are going to make this simple, we're going to say "Rocks" at the top… and the date so we know when we started. And that is the first thing we are going to do. And boys and girls, on the first several pages all we really done so far is observe the rocks. So let's write a capital O here, Observations. Rocks (As she is speaking she is writing on the board with chalk)… And boys and girls we are going to use a semi-colon right there {writing on the board). And while I am helping Marsha get started, would you write down two things—two things you've noticed about the rocks so far?* **(TOE, TGR, TOR)**
> *T: (Teacher is walking around to each table of students and reading what they are writing) (28 seconds later) And I will give you about 2 minutes… to write down 2 observations and if you want to draw something to go with one of your observations you can.* **(TIR, TIV)**
> *T: That looks just fine sweetie.* **(TCON)**
> *T: Sh. You just need to write down the word "Observations".* **(TOR, TSM, TCON)**
> *T: (to class) Now boys and girls… then you go ahead write that. Matt that was a great thought, go ahead and get it in your notebook. Are all rocks shiny Matt?* **(TCE, TSIV, TOR)**
> *S: Some* **(SIV)**

S: No **(SIV)**
T: Are all rocks shiny? **(TCE, TSM, TOR)**
S: No **(SIV)**
T: No **(TCON)**
T: So what word would… might be better than "rocks are shiny"? **(TCE, TSM, TOR)**
S: Some rocks. **(SIV, SSM)**
T: Some rocks are shiny. That's good. **(TSM, TCON)**
T: I am seeing some pretty good first sentences. **(TIV, TCON)** (Grade 1, OBS1, 12:25–15:36)

The teacher used her observations of student writing to guide their use of the terms "all" and "some" when describing the characteristics of rocks. She also incorporated enhanced feedback into this process as well.

The Temporal Flow of Power Patterns: Power Clusters

The next phase of our analysis resulted in the identification of larger scale structures showing the flow of classroom power patterns during each class session. Charting the seven power patterns across time revealed another set of structures that we have labeled *power clusters.* Between the power clusters are lulls in student engagement and student power use; the teachers show more control and is often the sole discourse participant during these periods.

Power clusters show connections and integrations between power patterns and the increased student engagement that is embedded within them. In Grade 4 for example, six clusters were identified, four in one class session and two in the other. In the power cluster described in Table 3, Tom reveals that he thinks turtles are both reptiles and amphibians. This cluster occurs just after the teacher gives introductory instructions for the classroom activity of pelt identification. It seems to be triggered by the teacher making reference to another student having brought a fire belly toad to class. The students are excited.

In the power cluster above, the components of questioning and power interweave and create a reciprocal dynamic that reveals there is no simple cause and effect relationship between the teacher's questions and the students' responses. These cycles ebb and flow as the class progresses and the interactions mesh with each other, creating a better setting for dialogic talk (Scott 2008).

In the Grade 3 classroom, four power clusters were observed, one in one class session and three in the other. In the example below, the teacher is asking the students to predict how they might find magnets taped inside a small sealed cardboard box (see Table 4).

In the Grade 1 classroom, nine power clusters were observed in the two class sessions. Most were quite brief compared to the two examples given above, but still showed coherent use of student power. This example is one of several short power clusters that the teacher initiates. Each student had been asked to write down something new that they had observed in their science notebooks, and the teacher is asking students to share their observations (see Table 5).

Individual Teacher Power Patterns

We also found power clusters in both small group discussions and in whole group discussions, but there were no clear-cut patterns discernable within these contexts. It is logical that individual children would have greater opportunities for science subject-matter engagement

Table 3 Grade 4 power cluster

Conversation	Power patterns and teacher questions	Student engagement
T: … Cathy is going to bring a reptile. …You had an amphibian. We had a mammal yesterday. Um we had… which was the turtle? Is what also?	*Start of question sequence* **TCE, TOE**	
S1: I think that was a reptile too.		**SIV, SSM**
Tom: It's… kinda both.		**SIV, SSM**
T: What do you guys think?	*Teacher sharing authority Legitimate digression* **TOE**	
S: No it's a reptile.		**SIV, SSM**
S: Yeah.		**SIV**
Tom: I think it's kind of both.		**SIV, SSM**
T: Okay tell me both. Let's think about that Tom.		
Tom: Um, like some turtles… like like the … a pretty de…deep pool and some of them like land like amphibians and some of them just only like land like reptiles.		**SSM**
T: Okay so you think, okay you think turtles could be amphibians and reptiles?	*Giving students credit for knowledge* **TCE**	
[Tom is looking at teacher and nodding his head, other students raising hands.]		
S: Oh, I know.		**SIV**
T: Okay. So let's think about, can someone tell him um… the… characteristics or maybe Tom you can tell me what are the characteristics of a reptile again? They have to have what?	**TCE**	
Tom: Umm… they have to have like a shell or scales?		**SIV, SSM SCE**
T: Hmm which one?	**TCE**	
Tom: Scales.		**SIV, SSM**
T: Scales. Okay		
T: Because there… I think there might be some reptiles that don't have shells. Remember that station we talked about and we are going to go over it a little more? So let's think about that. So they have scales. What type of skin do amphibians have Tom?	*Conceptual integration* **TCE, TOE**	
Tom: Slippery smooth skin.		**SIV, SSM**
T: Smooth, slippery skin.		
T: So let's think about turtles. What did we say turtles have? What kind of skin?	**TCE**	
Tom: Scales.		**SIV, SSM**
T: So are they ever an amphibian? [Tom is shaking his head no]	**TCE**	
T: No. Did you just kind of get that straight in your mind?	**TCE**	
Tom: Uh huh.		**SIV**
T: That is so cool.	*End question sequence*	
T: I love when I do that kind of stuff. I'm like now wait a minute. I'm thinking this and then all of sudden I'm like ↑oh wait a minute I know I'm going to think through this a little more. So that's what I want. Tom is a perfect example of what I want you to be doing with vertebrates. You are going to get it straight in your mind where they fit. That's why we look at the characteristics.	*Giving students credit for knowledge*	

Table 4 Grade 3 power cluster

Conversation	Power patterns and teacher questions	Student engagement
T: There's two magnets in this box. And the question is can you figure out where the two magnets are taped in the box without looking?	*Start of question sequence* **TOE**	
T: OK, Foster how would you do it?	*Teacher sharing authority* **TOE**	
Foster: umm… could we like get another magnet and.		**SGR, SOR, SSM, SGR**
S: [and put it all over the place]		**SIV, SOR, SSM**
S:…put it on the bottom and move it around?		**SCE, SIV, SOR, SSM**
S:[and when it sticks that's where it is]		**SIV, SOR, SSM**
T: Wow, that is really terrific.		
T:…you could get another magnet… and put it around and see where it sticks, right? OK is there another way that maybe we could detect the magnets where they are in the box without looking… see where the force is?	*Giving students credit for knowledge* **TCE, TOE**	
Ss:(whispers)		
T: How would you know where the force is at?	**TOE**	
Ss:(inaudible)		
T: That's what Foster said. A magnet (would) attract another magnet?	*Giving students credit for knowledge* *Teacher sharing authority* **TCE**	
T: Harry, do you have an idea?	**TOE**	
Harry: This one is very simple. Just shake the box.		**SIV, SOR, SSM**
T: Just shake the box=	*Giving students credit for knowledge*	
T: (shakes the box)…oh, I can't tell where they're at in the box.		
Harry: …you have to shake it a lot.		**SIV, SOR, SSM**
T: [shake it up and down] (interrupting) Can't do that either. Can't do that.		
Come on, let's think up some more. Jerry, you look like you're thinking of something. Do you have any idea? Cause I promise you I am not tricking you. Not today. There are two magnets in here and they are taped somewhere in the box. If I wanted to find out where they were taped, I could, one, Foster said you could use a magnet.	*Giving students credit for knowledge* **TOE**	
[sounds of students raising hands]		
T: What else could I use? Ted.	*Teacher sharing authority* **TOE**	
Ted: Use like another magnet except there's a repelling side?		**SIV, SOR, SSM**
T: Another magnet except the repelling side…		
T: hmm what would be… What else?	**TOE**	
Think, think, think, think. Think about our… um… Jane, what do you think?	*Teacher sharing authority* **TOE**	

Table 4 (continued)

Conversation	Power patterns and teacher questions	Student engagement
Jane: Um you could get something that would stick to a magnet and put it there and then the magnet would attract to that thing.		**SIV, SOR, SSM**
T: What do you think about that one?	**TOE**	
S: Ah, yea		
T: [Did we do that the first time you were in this classroom?]	**TCE**	
Ss: uhuh Um hmm		
T: We wanted to see our testing objects? We could use a testing object couldn't we?	**TCE**	
T: Excellent idea.		
T: I hadn't even thought of that one. I hadn't thought about the magnet one either… because I've just been thinking about these two devices… that I've been using, OK?	*End of Question Sequence*	

and teachers might provide enhanced feedback in small groups, but our methods do not allow analyses of these dynamics. Specific audio analyses of data collected within small groups would make this possible.

However, each of the three teachers showed an individualized characteristic approach in the class sessions we observed, and these characteristics included use of small group and large group processes and transitions. Charting the seven power patterns and broader clusters across time revealed these approaches. The Grade 1 teacher used power clusters in short bursts throughout the class sessions, each focused on a specific topic. This strategy is possibly due to the teacher's belief about the developmental abilities of the student, for example their age level and/or attention span. Teacher beliefs have been shown to influence their classroom instruction, the quality of interactions in the classroom (Kagan 1992), and whether the teacher

Table 5 Grade 1 power cluster

Conversation	Power patterns and teacher questions	Student engagement
T: Mary what did you write down as your observation?	*Start of question sequence* **TCE**	
M: The red has more dust.		**SIV, SSM**
T: What word did she use that we really haven't talked about much?	**TOE**	
T: [[deep breath]] The red has more dust. You just used a really good word too.	*Giving students credit for knowledge* *Enhanced feedback*	
Ss: (choral) Dust		**SGR, SSM**
T: Dust, good listening.		

perceives the student's role as more active or passive in relation to learning (Minor et al. 2002). It is also possibly due to her stated interest in the BSCS 5E model (Bybee et al. 2006) and her intention to initiate engagement, followed by student exploration and explanation stimulated by open-ended questioning, which is then followed by feedback (evaluation). The Grade 1 example above showing the power pattern of legitimate digression (the example regarding El Capitan) is also a power cluster and reflects this structure.

In Grade 4, the teacher showed a repeated tendency to approach the small groups working on pelt identifications by starting a question sequence, letting students explain their thinking, and then using a final comment such as "figure it out" or "you decide" before moving on to the next group. Her use of small and large group activities was less clear cut and she facilitated large group discussions even when the students were working in small groups. Students' subject matter power and engagement in science were nearly evenly spread across all classroom activities, except for a reminder speech about appropriate behavior that occurred at the end of Observation 2. Overall, the frequencies of student power codings were higher for this teacher than for the other two in this study (see Table 2), showing a more even balance between teacher and student power.

In Grade 3, the teacher's tendency was to focus on closely supervising students' tasks and activities, and to assure that students were using appropriate science vocabulary from a word wall in the classroom. Her distinct separation and alternation between small and large group activities was clear. This strategy resulted in repeated closed-ended questions from students and a lower number of questions overall (see Table 1).

While the sources of these characteristic approaches are not addressed in our study, we know of no other research that describes them. They are certainly worthy of future study. We are curious as to the extent of the teachers' awareness of these patterns and the ways that teachers' reflections on these dynamics would enhance the facilitation of student power and engagement in classrooms.

Summary

To address our first research question regarding types of teacher-students dynamics power pattern that give students power to learn science, our analyses show that there are at least seven types of teacher-student dynamic power patterns that give students power to learn in elementary science classrooms. These patterns are associated with *both* open-ended and closed-ended teacher questions (but not with task-oriented questions) and with a balance between teacher and student power. The analyses also address our second research question regarding what these power patterns look like and how they engage students with science subject matter. The power patterns occur in clusters where the level of teacher-student interaction ebbs and flows, creating more complex dynamics where students are provided opportunities to explore and explain subject matter. Moreover, teachers' habitual strategies show differences that can be revealed and characterized, and that some teachers create opportunities for student engagement more frequently, even based on the similar curricular assumptions, in this case the BSCS 5E model (Bybee et al. 2006) or the use of FOSS kits (Regents of the University of California 2005).

Implications

There are many examples of the empowerment of students as learners in classrooms, and we argue that it is important to be able to show teachers specific examples of effective classroom interactions that support student learning in subject matter areas like science. Vague recommendations to teachers to such as "ask more open-ended questions," "give students more choices," "use authentic tasks," or "create active learning" do not readily translate into classroom practice (Barnes 2008), either for teacher candidates or for experienced teachers. This is particularly true when teachers are pressured to cover material, increase the frequency of assessment without time for effective feedback, and assure that students meet standards, all within very limited time frames. We are concerned that these pressures reduce student access to many of these power opportunities.

In addition, it is important to make the concept of power more accessible to teacher candidates and teachers so they can connect the idea of power with their own experiences, pre-service, and in-service training. We can facilitate teachers' use of power in ways that are appropriate for their settings, subject matter content, student characteristics, and with their previously developed skills and expertise. By collecting and analyzing examples of student power and its relationships with student engagement in subject matter discourse, we can provide more specific recommendations for teacher educators and educational researchers to identify teaching practices, skills, and knowledge that encourage student engagement and student learning. Moreover, these skills are directly in alignment with the Next Generation Science Standards' Science and Engineering Practices that outline the strengthening of specific student activities such as asking questions, constructing explanation, and formulating arguments (National Science Teachers Association 2014). One of the authors (Cochran) has used some of these examples in undergraduate teacher preparation courses and in graduate courses with experienced teachers, resulting in informal evidence that teachers quite easily recognize and can become aware of these patterns. We recommend that future research focus on helping teacher candidates and experienced teachers to discern, consider, and use these ideas in classroom planning and reflection. This power analysis provides a tool to understand the cognitive, social, and cultural dimensions of discourse that illuminates classroom learning interactions (Kelly 2007).

We do not assume that the forms of power documented here are the only possibilities. It is likely that there are other forms of student power that occur in different contexts, such as special education or English language classrooms, science laboratory settings, or across different educational levels (high school, community college, or college) or disciplines (e.g., mathematics, science, history). Individual differences between learners of various cultures and ethnicities, gender, socio-economic levels, or in teacher-centered or learner-centered classrooms are also likely to show important variations in relationships between teacher-student power dynamics and clusters of power use. Our findings support others that show that in learner-centered classrooms, more student power increases motivation and engagement (Brown 2003; Lambert and McCombs 1998; McCombs and Whisler 1997). Identifying ways teachers can engage students in science, organize instruction, and develop learner-centered classrooms will increase awareness of the effective use of power in classrooms and examples for modeling exemplary practices (Cornelius-White 2007; Schwarz 2009). It is important that all learners have equitable access to classroom subject matter content and the power to engage with that content.

Appendix 1

Table 6 Power codes with definitions and examples

Category	Definition	Forms	Examples
Conventionality power	These indicate control supporting the conventions and rules (procedural and non-subject matter) in the classroom, including behavioral reminders, feedback, reinforcements, and punishments.	Teacher Conventionality Power **(TCON)**—Includes behavioral reminders. Student Conventionality Power **(SCON)**—Shows "buy in" to conventional classrooms rules—Includes choral/unison responses.	T: Marsha, Fred, and Jeff, you will be in this group… **(TCON)** S: Can I pass out the hand lenses? **(SCON)**
Organizational Power	These indicate control of subject-matter procedures in the classroom activities or recall of a previous activity	Teacher Organizational Power **(TOR)** Student Organizational Power **(SOR)**	T: We want to be scientists and make careful observations. **(TOR)** S: We should write our conclusions so we don't forget. **(SOR)**
Individual Voice Power	The use of I; or the indication of an individual having an opportunity to speak; or referring to a specific person's idea, conception or contribution.	Student Individual Voice **(SIV)** Teacher Individual Voice **(TIV)** Teacher-Student Individual Voice **(TSIV)** - The teacher acknowledges a student's voice, usually by name or in the context of a specific conversation, including a small group. Does not include behavioral reminders. Student-Student Individual Voice **(SSIV)**—A student acknowledges what another student by name in the context of a specific conversation within a small group or large group.	S: I never thought of that. **(SIV)** T: I need to look up the meaning of radioactive. **(TIV)** T: Mark what do you think? What did your group decide? **(TSIV)** S: Susan said that the compass arrow went up when it was placed near a magnet. **(SSIV)**
Group Power	Explicit or implicit use of a "we" perspective or acknowledges a group-level or consensus idea(s).	Teacher Group Power **(TGR)**—Includes addressing the classroom as a whole. Student Group Power **(SGR)**—Includes choral responses.	T: We looked at force on Friday. **(TGR)** S: Our group thinks so too. **(SGR)**
Subject Matter Power	Speakers use the discipline as an authority of knowledge, to explain subject matter, using science terms, and shows owner-ship of subject matter ideas.	Teacher Subject Matter Power **(TSM)** Student Subject Matter Power **(SSM)**	T: When we make a prediction we are stating a hypothesis. **(TSM)** S: The rock is red, so it must be an asteroid. **(SSM)**

Appendix 2

Table 7 Question codes with definitions and examples

Question Type	Definitions	Examples
Closed-ended questions (CE)	Request a decision between two options, fills in the blank or completes a definition, determines attributes of an object or situation.	Do we get them now? How many categories can we use to sort our rocks? Magnetism is what kind of…?
Open-ended questions (OE)		
1. Definition **(OED)**	Ask for or determines meaning of a concept.	What is size?
2. Interpretation **(OEI)**	Seeks a description of what can be inferred from pattern of data. Often includes a "How do you know?" type of question.	How would we describe a size that is between small and big?
3. Causal antecedent **(OECA)**	Seeks an explanation of what state led to the current state.	What caused the motor to turn on?
4. Causal consequence **(OECC)**	Seeks an explanation of the consequence of an event.	What would happen to the layer of silt in the water if we shook the bottle?
5. Enablement **(OEE)**	Seeks an explanation of process that allows a person to perform an action. Can include referencing a learner by name.	How would you figure out where the magnets are inside the box?
6. Expectational **(OEEX)**	Seeks expectations or predictions.	Before you connect the wires to the motor, what will happen to the motor when you close the switch?
7. Judgmental **(OEJ)**	Seeks a value placed on idea, advice, or plan.	What do you think about their plan to find the magnet?
8. Process **(OEP)**	Seeks an explanation of a process that allows a person to perform an action	How would you figure out where the magnets are inside the box?
Task-oriented questions (TO)	Checking on progress of a task, seeks clarification of a statement or confirmation, request a specific action or a response.	I am going to put some circles over here on the board, okay? Can you help her think of how size can be described?

Sub-types of open-ended questions are not included in the present analysis (see Reinsvold and Cochran 2013)

Appendix 3

Table 8 Transcript example with codings

TIME	INITIATION	RESPONSE 1	PROMPT	RESPONSE 2	FEEDBACK	RESPONSE 3
27:11	S: We got it with the switch. **(SSM/SIV)**					
27:16					T: Did you? **(TCON/TCE)**	
27:17			T: OK, open it. OK close it. Open. Close it. {{motor going on & off}} **(TOR/TSM)**			
			T: What do you guys think? **(TSIV/TOE)**			
					T: =Is that pretty cool? **(TCON/TCE)**	
27:33			T: OK show me…open the circuit…{{inaud}} show me the electricity flow… show me the electricity flow. how is the electricity moving. **(TOR/TSM)**			
				S:{{inaud}} this one {{inaud}} then this goes through this {{inaud}} onto this because that's right there and it connects to {{inaud}}..**(SSM)**		
			T: OK so you are saying it starts here with the D cell, it follows this wire… **(TSIV/TSM)**			
				S: yah, yah **(SIV)**		
			T: It makes the receiver what?… do something… and then it comes out… out of the receiver into the switch? **(TSIV/TOR/TCE/TSM)**			
				S: uhuh, and then the switch needs to go over here and then it goes… **(SSM)**		
28:23			T: OK why is this not connected? **(TOE/TSIV/TSM)**			
				S: {{inaud}}		
			T: You need to have that connected… OK close it… **(TOR/TSM)**			

Table 8 (continued)

TIME	INITIATION	RESPONSE 1	PROMPT	RESPONSE 2	FEEDBACK	RESPONSE 3
					T: Cool. Alright, very good. **(TOR)**	
28:55			T: OK show me… show me the electricity flow. If I could be a piece of electricity, how would I travel? **(TOR/TOE/TSIV/TSM)**			
				S: you would travel, you would… {{inaud}} the battery… S2: D cell **(SSM)**		
			T: what is this called? **(TOR/TCE/TSIV)**			
				S: D cell **(SSM)**		
				S: and hook it up to all of these **(SSM)**		
			T: but which way… what you think? How do you think it moves? Use your fingers. **(TOR/TOE/TSIV/TSM)**			
29:21					T: There you go! **(TCON)**	
				S: {{inaudible}} most of the power will go around… **(SSM)**		
			T: What does this do? **(TOR/TCE/TOEC/TSIV)**			
				S: It turns it on and off **(SSM)**		

Codes are not exclusive

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