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ORIGINAL ARTICLE

A sociocultural perspective on mediated activity in third grade science

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Abstract This ethnographic study of a third grade classroom examined elementary school science learning as a sociocultural accomplishment. The research focused on how a teacher helped his students acquire psychological tools for learning to think and engage in scientific practices as locally defined. Analyses of classroom discourse examined both how the teacher used mediational strategies to frame disciplinary knowledge in science as well as how students internalized and appropriated ways of knowing in science. The study documented and analyzed how students came to appropriate scientific knowledge as their own in an ongoing manner tied to their identities as student scientists. Implications for sociocultural theory in science education research are discussed.

Keywords Psychological tools · Science educator · Discourse analysis · Activity theory · sociocultural studies

This paper reports findings from an ethnographic study of a third grade classroom in a public elementary school focusing on a teacher's mediation of student science learning. We examined how the disciplinary knowledge of science was mediated by the teacher and the extent to which this mediation helped students see themselves as "inquirers of science." An important aspect of this mediation was the use of psychological tools. *Psychological tools* (Kozulin, 2003), are referred to by us as the forms of conscious and interactive perceptions that participants in a setting make use of in order to understand the "who," "when," "what," "why," and "how" that ground their goals and shared actions in a setting. In more abstract terms in

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the classroom, these tools are the symbolic artifacts of the class such as signs, symbols, texts, formulae, graphic organizers, and particular discourse practices that arise in the classroom as students and teachers go about their work. As we show in this paper, the psychological tools introduced by this teacher became symbolic mediators of students' conceptual understanding as they utilized these symbolic tools to appropriate their own scientific understanding.

The objectives of this study were to (a) identify specific strategies used by the teacher to mediate students, learning of psychological tools and (b) to examine the consequences of the application of these psychological tools for student learning of science. Through the study of classroom practices across the year, we examined both the ways the teacher introduced particular psychological tools for learning science as well as the ways students internalized such tools to construct their own understanding. Through this process we consider the value of sociocultural theory for understanding the activities of elementary science classrooms.

Theoretical underpinning

Sociocultural theory and science learning

Our theoretical perspective draws from sociocultural theory (Leontiev, 1978; Vygotsky, 1978) and research on science learning (Lemke, 1990). From a sociocultural perspective (e.g., Wertsch, 1998), students and teachers are viewed as constructing educational contexts over time within activity systems that draw on psychological tools and practices, as developed and used by members of the community.[1] The situated and constructed nature of learning proposes that these psychological tools frame collective cognition in which members' understanding is shaped and acquired within the social context (Vygotsky, 1986). Furthermore, sociocultural psychology suggests learning within an activity system is constructed through interaction of members of a community. This implies that issues of student learning need to be examined over time (Cole, 1996), as a specified community jointly constructs ways of speaking, acting, and being. Fundamental to this view is the importance of the framing of learning experiences by a human (cultural) mediator (Mortimer & Scott, 2003).

How might students acquire specific subject matter knowledge and how to use it with expertise? Domain and context specificity of mediation have been identified as relevant research issues (Kozulin, 2003). Ways that psychological tools are enacted, internalized, and subsequently appropriated by students in different subject domains has yet to be fully investigated. A focus on activity in subject matter learning requires consideration of multiple interconnected dimensions of activity. Engeström & Miettinen (1999) propose that the unit of analysis for such investigations consist of: "object-oriented, collective, and culturally mediated human activity, or activity system" (p. 9). This suggests that relevant factors in understanding student learning include the ways that roles are established and positioned, the norms and expectations developed through concerted activity, the mediating artifacts, and the local history of sociocultural practices enacted in learning subject matter. How does this point of view affect thinking about science learning from a sociocultural perspective?

Several issues need consideration. First, teaching and learning occur through human interaction bound up in the social context of the classroom. An empirical focus on the ways

[1] Our use of the term "psychological tool" in this paper follows the usage of Kozulin (2003). By "psychological" we do not mean "only arising in the mind of a single individual." Our meaning of "psychological" is more akin to Wertsch's (1998) notion of "mind as activity." In the sense we intend, "psychological" refers to shared interpretations and understandings that make human action possible as a collaborative enterprise.

psychological tools contribute to learning is essential for developing theories of practice for science education. Second, framed in terms of activity theory, student access to science is accomplished through engagement in the everyday life of the classroom, which includes the norms and expectations, roles and relationships, sociocultural practices and mediating tools for learning (Kelly & Green, 1998). Issues of understanding, appropriating, affiliating, and developing understanding for participating in the practices of a locally-defined science classroom can be understood through the study of the activity system in which it takes place. Third, scientific disciplinary knowledge is constructed, communicated, and assessed through language. Thus, understanding the language spoken within a classroom context as the "tool of tools" that shapes intellectual development (Cole, 1996; Vygotsky, 1997) serves as a base for understanding ways to make science accessible to students. Fourth, until recently, science education research has focused heavily on individual cognition (Lawson, 1982) and students' individual conceptions (Pfundt, and Duit, 1991) of science and science content, typically from a conceptual change point of view (Tyson et al., 1997). While this research has made valuable contributions to our understanding of how individual students conceptualize scientific ideas, it has not examined the social processes that support this learning mediated by cultural means, tools, and signs in the context of everyday classroom activities (Leontiev, 1978).

We continue our theoretical review by addressing two areas of focus in our study, (a) human and symbolic mediation of science and (b) the development and use of psychological tools for learning. In doing so, we regard human and symbolic mediation as locally constructed, contingent, and central to student science learning. Additionally, we consider ways that psychological tools are locally constituted, made public, developed, and appropriated. We then examine the expressive potential of viewing science learning from this point of view. This empirical study thus considers contributions made by an activity theoretic analysis to ongoing sociocultural research in science education (Lemke, 2001).

Human and symbolic mediation of science

In taking a sociocultural view of learning science from a psychological tools perspective, understanding human and symbolic mediation is considered central because the sociocultural study of learning science requires tracing how abstract-thinking skills are learned during the process of engagement with more knowing others, such as a teacher (Tudge, 1990). A child's higher mental functioning is dependent upon mediating agents (human or symbolic) that the child comes into contact with during her or his interaction in social contexts (Vygotsky, 1978). Researching science classrooms as social contexts in which the student's cognition is shaped and reshaped by human and symbolic mediators requires an emphasis on science learning as being situated within the activity system of the classroom. The socially relevant and locally recognized scientific knowledge learned by students, therefore, is contingent upon many intervening factors. These factors impact and affect the ways students come to participate in science during their interaction with human (i.e., their teacher, other students, teacher's aids, and so forth) and symbolic (language, charts, graphical organizers, signs, symbols, texts, formulae, and so on) mediators. Such a view places emphasis on the ways knowledge is co-constructed by students and teacher within recurrent activity systems tied to mutual understandings about the who, when, why, what, and how they are used to make sense of events that make up classroom time.

From this perspective, learning science is viewed as changes in ways of interpreting and interacting with others in the world, rather than say a change in cognitive structure (Edwards, 1993). Engaging in discourse processes situates learners in an interpretative system focused on sense making, exploring, and persuading, rather than uses of language for transmission of information (Sutton, 1996). This view of learning science treats language (as evoked in discourse processes, parole), not as processing representations (of putative cognitive structures), but rather as an "active molder of experience" (Roth & Duit, 2005, p. 870) where ways of talking, being, and valuing actively constitute self, others, and the experienced world. Thus, the emerging ways of talking and being are shared cognitive processes, mediated through various signs, symbols, and discursive practices. Our focus in this research, then, is on how mediation occurs in situated conversations about science and how psychological tools are specified and re-specified through social interaction within particular classroom events and over time.

Psychological tools

According to sociocultural theory—once internalized and appropriated – psychological tools assist a person in mastering her or his own psychological functioning in the social as well as individual sense (Kozulin, 1998). Thus, in the process of learning to appropriate internalized psychological tools, the individual develops metacognitive abilities that contribute to their own higher order cognitive functioning and how to interact with others in a learning setting (Kozulin, 2003). Such a view suggests that psychological tools are developed through learning activities that aim to initiate students into particular ways of inquiring into their world as ongoing social processes. These tools transcend disciplinary frameworks, as students come to understand ways of investigating across disciplines. Because psychological tools must be internalized (i.e., transformation of externally introduced tools into internal ones), and because psychological tools must also be appropriated through social-interactional processes, such tools are introduced by other people who have made use of the tools in question at an earlier time. The internalization and appropriation of symbolic tools are construction and transmission processes that overwhelmingly occur during social interaction and not in solitude (Vygotsky & Luria, 1930/1993). Moreover, the psychological tools are continually shaped and reshaped by the recurrent social and cultural context where their use takes place. In this way, the psychological tools are created and transformed during the development and transformation of learning activities over time; earlier learning builds the roots for new learning and the new learning in turn builds the roots for further learning (Vygotsky, 1997). Therefore, the use of psychological tools is a recursive means for the interactive transmission, accumulation, and transformation of knowledge. It influences the nature, not only of external behavior, of the mental and intermental functioning of individuals within the collective (Kozulin, 1998).

In our study, we identified those psychological tools shared with students by the teacher that contributed to student learning across subject matter domains and specifically within the domain of science. Since the teacher in this classroom was the primary human mediator of student science learning, and since he engaged students in co-constructing content knowledge emphasizing their use of psychological tools to guide their learning, our study highlights the systematic teaching practices employed by the teacher. These teaching practices themselves can be considered psychological tools to teach other psychological tools. Students in the classroom we investigated not only had to learn psychological tools for thinking as scientists and about scientific concepts, they also had to understand the teachers' systematic use of psychological tools to guide their learning in his role of expert and their roles as learner-collaborators. Thus, the subject matter of our study involves the careful examination of teaching and learning science through a sociocultural lens. Viewing science as praxis of teaching and learning where community knowledge is a culturally mediated, collective

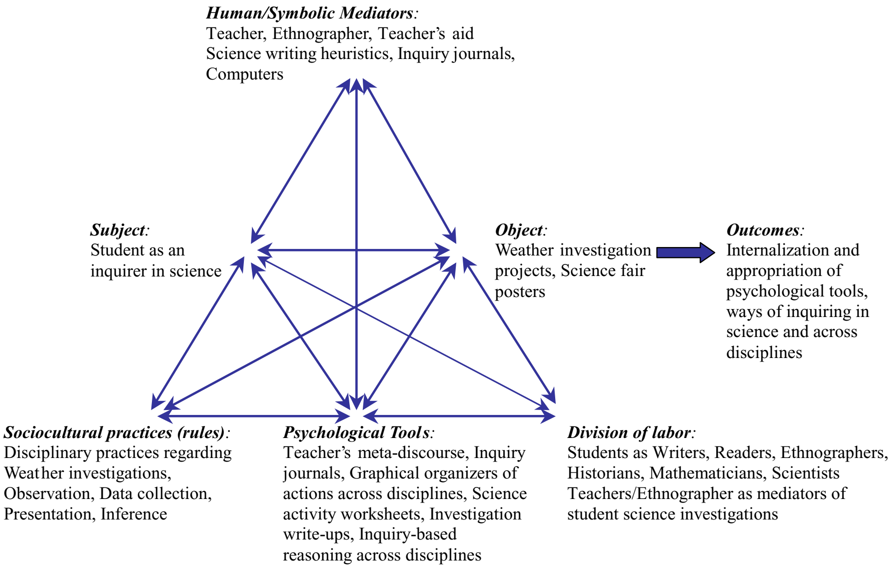

Fig. 1 Interactive model of activity system leading to the internalization and appropriation of scientific inquiry practices

human activity, addresses scholars' recommendations for studies of this kind (Engeström & Miettinen, 1999).

A model for viewing science learning as an activity system

Our guiding theoretical framework situates students and teachers as active agents within a general activity system making up the classroom as a cultural and social space with many nested activities, each with interactive processes facilitating the co-construction of content knowledge – the teacher sharing new knowledge, the students appropriating this knowledge through interaction with the teacher and each other. For this reason, (before presenting our data analysis) we discuss a generalized model of the activity system of the classroom. Figure 1 represents a graphical depiction of the interactive process of science learning that took place in this classroom. The interactive model is adapted from Engeström's expanded model of mediation and activity as depicted in Cole (1996, Figure 5.3, p. 140). In the top triangle of Figure 1, a student as an inquirer in science is represented as the *subject*. The teacher, ethnographer, teacher's aid, science writing heuristics, inquiry journals, and computers are all depicted as human and symbolic *mediators*. The *object* as depicted in the figure represents the weather investigation projects and science fair posters accomplished by students. Thus, the subject-mediator-object relationship emphasizes the dialectic nature of the activity system by which the subject "transforms the object in the process of acting upon it" (Cole, 1996, p. 140). Viewed from this lens, the interactive relationship between subject-mediator-object is also impacted by the *sociocultural practices*, *psychological tools*, and *division of labor* within the classroom context (see Wertsch, 1998 for a similar perspective). These elements are represented at the bottom of the triangle. They encompass the notion that all of the elements within an activity system are in constant connection with one another. In Figure 1, the sociocultural practices we are referring to are the disciplinary practices in science that members of the classroom engaged in throughout the school year. Lastly, the psychological tools indicate specific tools that the teacher introduced to students during their science learning and the division of labor, refers to the "object-oriented" actions among members of the community (Cole, 1996).

Educational setting and data source

The setting for this study takes place in an elementary classroom in a public elementary school located in a small city in southern California. The school had served as a district magnet bilingual school (Spanish/English) prior to the elimination of bilingual education in California public schools. Although no longer designated a bilingual school at the time of the study, the school still served many bilingual children from Spanish speaking families who were bused into the neighborhood of the school. The school had a student population that was 62% Hispanic, and 32% white. Roughly half the student population was designated English Learners.

The data sources were drawn from an extensive yearlong ethnographic study. As a participant-observer, the first author (referred to in the class as "Mr. Reveles") collected ethnographic data across the entire school year in order to gain an insider perspective of what it meant to learn science within the classroom context. Data collection began with extensive, day-long observations during the first two weeks of the academic year and continued with selected visits throughout the year. Data sources included videotaped records of classroom interaction (approximately 120 h of video data, recorded on 40 days, spanning 9 months), digital photographs of student products (notebooks, projects, journals), fieldnotes, and interviews with teachers and students. The primary data source collected during the school year was in the form of videotaped records. These videotaped data provided a comprehensive account of classroom interactions. Collecting video data of the classroom discourse and activity allowed us to revisit salient episodes of students/teacher interaction that were essential to understanding how scientific meaning was discursively constructed in this classroom community. The data were analyzed to examine the ways that the activity system was constructed across different units of analysis (interactional, meso, ontogenetic) following Lemke (2000) and Wortham (2003).

Teacher participant

The teacher (Mr. Cordova) in this study engaged in teaching and learning practices that draw upon an ethnographic perspective. Mr. Cordova is a member of a teacher-researcher collaborative research group (Santa Barbara Classroom Discourse Group) that examines teaching practices across the content areas in monolingual and bilingual classrooms. He is also a leader in the South Coast Writing Project (SCWriP), National Writing Project (NWP), and the National Council of Teachers of English (NCTE). This teacher is an instructor within the University of California at Santa Barbara's Graduate School of Education, Teacher Education Program, has over 10 years of teaching experience, and has recently completed his Ph.D. in Education.

Mr. Cordova was both a teacher educator and an elementary classroom teacher during the year of this study. His teaching goals included providing students ways of interacting with and learning from academic content. In doing so, he sought to provide his students opportunities to develop understandings of situated academic practices. In his teaching, Mr. Cordova attempted to develop students' academic identity by providing opportunities for understanding how disciplinary knowledge is framed as he mediated student interaction with him, with each other, and the academic content across the year. The classroom provided him with examples supporting his work as a teacher educator and he opened his teaching to student teacher observers who regularly visited.

Participants

The third grade classroom from which the data were selected was comprised of 17 students. However, at the beginning of the school year the class had 18 students, one of which was transferred to a sheltered English immersion classroom because she was new to the United States and spoke virtually no English. The student population in this third grade class was comprised of primarily of two ethnic groups, defined by the district as “White” (56%) and “Hispanic” (39%), with smaller percentage of one other ethnic group “Asian-American” (5%). The students in this classroom ranged in age from eight to nine years of age with 8 females and 9 males. The students’ cumulative records of previous years academic performances were not analyzed for the purposes of this study because we did not wish to form preconceived notions regarding students’ ability or inability to learn science content. Rather, we entered the classroom seeking to understand what students were able to accomplish through the collective activities of its members.

Research methods

Discourse-oriented studies of science classrooms examine the nature of scientific knowledge and practices as students and teachers engage in specific activity (Kelly et al., 1998). Our approach combines the attention to the accomplishment of everyday life through discourse with the study of the local cultures from an ethnographic perspective. Using an ethnographic approach we examined ways the teacher at this research cite framed science activities and how these activities were part of a larger set of concerted actions of the classroom. In the following sections, we present our methodological orientation and evidentiary data as analyzed through a psychological tool theoretic lens. The research methods employed in this study followed micro-ethnographic techniques (Erickson, 1992; Reveles, Cordova & Kelly, 2004). As such, three levels of analyses were conducted: (a) video analysis of classroom life, (b) discourse analysis of interaction, (c) artifact analysis of student products. These analyses were conducted to provide ethnographic evidence gathered throughout the study and to exemplify science teaching and learning within an activity system.

Video analysis

Following the video analysis methods described by Erickson (1992), we first conducted a review of the video and audio taped records of classroom activities. Notes were taken and compared to the other records such as the student science interviews, fieldnotes, and artifacts of the classroom science activities across the entire year in this classroom. After the initial review of the data, event timelines were developed to identify individual events, their duration, and sequences of events for each day recorded. Changes in events and the make-up of events were identified by a shift in purpose, type of activity, and topic (Kelly & Chen, 1999). These events and their timelines made visible the connection of human and symbolic mediation orchestrated by teacher, and the subsequent appropriation of internalized psychological tools by students.

Transcript analysis of classroom discourse

The next level of video analysis examined the ways that the events of the classroom were interactionally accomplished through discourse processes. This sociolinguistic analysis examined the construction of sequences of activity and subactivity, and ways activity was interactionally accomplished (Duran & Szymanski, 1995). The discourse analysis techniques considered the contextualization cues such as pause structures, pitch variation and intonation, stress, proxemic distance, and eye gaze (Gumperz, 1992). Subsequently, transcripts of key events were constructed to examine in detail how the teacher mediated science and students appropriated certain aspects of the science made available in the classroom. Using sociolinguistic features of the discursive interchanges taking place within the classroom culture allowed us to examine the ways that specific scientific practices were introduced, developed, and became "common knowledge" (Edwards & Mercer, 1987; Gee, 1999). Analyses of the transcripts of classroom interaction were completed to identify scientific practices made available in the public space of the classroom.

Artifact analysis of student science work

The artifact analysis consisted of examining a range of student products arising from different instructional units (e.g., watermelon investigation, weather instruments, weather channel show, plant adaptation and experiments, and science fair posters). For each artifact, a domain analysis (Spradley, 1980) was conducted to classify student responses to the tasks required in units into categories. Subsequently discourse analyses examined the scientific practices engaged in by students as they appropriated particular practices introduced earlier through group activity making up a current unit of instruction or an earlier unit. Through our artifact analysis, we discovered that the process of appropriation of scientific practices into ongoing psychological tools was different than the process of learning the content itself as a one-time accomplishment. The difference was indicated by the fact that as students were drawing on scientific practices that they had internalized (i.e., utilizing psychological tools previously introduced by their teacher), some students appropriated certain science practices and others did not for re-use in new contexts. Conversely, some of the science practices introduced by the teacher early on were evident in all of the student artifacts analyzed. These differences in student appropriation are interesting to note and will be addressed in subsequent sections of the paper.

Analysis of spoken and written classroom discourse

In the following section we present the analysis of several dialogic interchanges. These dialogues focus on specific teaching strategies, themselves psychological tools used to mediate student learning by introducing new, particular psychological tools for understanding science. Additionally, we examined the ways that these latter tools were internalized and appropriated by students in order to construct scientific knowledge during investigations conducted as part of new units of instruction. The interactive dialogues we selected for analysis were purposefully sampled to examine the teacher's introduction of specific psychological tools to teach and to share new tools for learning science. The selected transcripts, therefore, indicate specific moments in time during the academic year when this teacher introduced particular psychological tools for learning and engaged his students in developing their own understanding and use of such tools.

In addition to analyzing the pedagogical practices involved in introducing psychological tools, we wanted to understand how students' interaction with the teacher and each other demonstrated their acquisition of psychological tools for learning to think scientifically and learning of science content. Viewing the interchanges analyzed through a sociocultural lens, we offer our interpretations of ways that disciplinary knowledge and understanding were co-constructed in this classroom community. We now proceed to present and discuss examples of the use of prominent psychological tools for learning science as interpreted through our data analysis.

Framing inquiry through introduction of psychological tools

Episode I: The use of meta-discourse to mediate student learning

The first episode pertains to how the teacher introduced a psychological tool to orient students to the learning of science by helping students see themselves in the role of scientist. This episode occurred during the beginning of the academic year (9.04.01). At this time, the teacher was introducing his students to an inquiry project. In this instance, Mr. Cordova (the teacher) mediated common disciplinary practices of inquiry to help students think about their own inquiry from different disciplinary perspectives. This was accomplished through meta-discourse. The term *meta-discourse* refers to the teacher's introduction and continuance of a type of talk taken up with his students that facilitated their thinking about inquiry across disciplines. This meta-discourse was used by the teacher to offer students ways of thinking about how to see themselves as scientists, historians, ethnographers, mathematicians, and so forth. Thus, this was talk about the ways of talking about inquiry.

The meta-discourse helped orient community participants to think about their own inquiry practices. Throughout the school year, he continually oriented students to think about actions of inquirers, and connected these points of view to the past, present, and future classroom events. As such, the meta-discourse tool of the classroom was a general framing tool for the students allowing them to think about their own thinking across different instructional units, across different disciplines, across classroom project investigations, and across time. During this classroom conversation, Mr. Cordova drew upon students' existing knowledge base in order to introduce the idea of taking an interdisciplinary point of view. By utilizing a meta-discourse tool to teach students to observe from various disciplinary perspectives, he was mediating students' thinking about ways that they could come to view themselves as inquirers—a general learning theme a meta-tool in his classroom. The dialogue proceeded as follows:

Line #	Speaker	Talk
1	Mr. C:	we are going to start another project next week sometime
2		in social studies where you are going to do interviews with your families
3		I'm going to ask you to think like historians
4		people who do and write history
5		so we're going to be thinking like different people in this class-room this year
6		we're going to be thinking like mathematicians
7		like readers and writers
8		we're also going to think like scientists

9		we're going to do a lot of science in this classroom
10		we're also going to think like historians
11		we're also going to think like responsible people
12		we will think like lots of different people
13		but today we can think like mathematicians
14		so far we have:
15		they study math, they think hard, they make their own problems, they write,
16		they can write down problems on paper
17		what else?
18	Rosa:	they solve problems
19	Mr. C:	they solve problems

In lines 1–4, he began the classroom dialogue by instructing students that he would be asking them to think like historians. At this points Mr. Cordova made reference to a project requiring an inquiry of a particular sort – ethnographic interviews with family members (lines 2). He immediately followed by telling them that they would be thinking like different people throughout the year (lines 5–12), depending on the subject being studied. Here we see the thematic nature of his use of meta-discourse (*so we're going to be thinking like different people in this classroom this year, we're going to be thinking like mathematicians, like readers and writers, we're also going to think like scientists, we're going to do a lot of science in this classroom*...). The theme of meta-discourse use across the school year was one that was woven into the fabric of daily classroom community life. While Mr. Cordova used meta-discourse as a psychological tool to inform students that they would be thinking like different professionals, he was also teaching them how to be able to think from different disciplinary frames of reference. Thus, the work on building students' identities toward that of inquirer had begun. This groundwork, and the interdisciplinary nature of the inquiry orientation, would surface later in the academic year when students designed their own inquiry investigations. The rest of the transcript continues to exhibit this classroom practice.

Next, Mr. Cordova brought his students back to the topic at hand, thinking and discussing what mathematicians do (lines 13–19). Again, he was using meta-discourse to connect future ways of thinking as different people to present ways of thinking about how particular professionals think (i.e., line 13, *but today we can think like mathematicians*). The teacher introducing and taking up multiple ways of knowing and acting as mathematicians, scientists, historians, and so forth would be a common set of practices throughout the school year. As this conversation concerning what mathematicians do continued, we observe Mr. Cordova as he elicited clarification from Rosa regarding how mathematicians solve problems (lines 20–37).

Line #	Speaker	Talk
20	Mr. C:	what else do mathematicians do?
21	Rosa:	they think of better problems
22	Mr. C:	they think of better problems
23	Rosa:	yeah
24	Mr. C:	say more about that
25	Rosa:	they just like
26		they have problems and then make an answer
27		and then they think of another answer of the same thing
28	Mr. C:	okay so they think of more difficult problems

28		or so if they have an answer
30		then you're saying that a mathematician may come up with another problem
31		okay
32		oh so they come up with different ways to solve problems
33		is that what your saying?
34	Rosa:	Yes
35	Mr. C:	Okay
36		so there is more than one way of solving a problem
37		so they think of a new ways to solve problems

In this interaction between Mr. Cordova and Rosa, Rosa articulated her current level of understanding about what she believed mathematicians do (line 21, *they think of better problems*). In line 24, the teacher prompted Rosa to continue. This demonstrated the ways that the meta-discourse was a co-construction in which students' views were solicited and integrated into the ongoing conversation of the class. The interchange eventually led to an important understanding of one way that mathematicians solve problems (lines 30, 32, and 36) within their own community of practice.

Following this interchange, the actions of mathematicians were recorded as a list on chart paper and was revisited and drawn upon by students during the future science projects. A similar list of the types of activities scientists engage in while doing science was also eventually constructed during another classroom dialogue. The list was also recorded on chart paper by the teacher and was used as a way to highlight commonalities and differences between practices in each of the disciplines. The co-construction of community knowledge within the public space of the classroom afforded students an active role in contributing to the ways that members of the classroom community would eventually understand disciplinary frames of reference. The social construction and public display provided opportunities for this discursive work to gain permanence and serve as a reference in subsequent work.

This example began with the teacher initially engaging his students in a conversation about how to think of themselves as mathematicians, readers, writers, scientists, and historians. He followed by focusing attention on the mediation of students' thinking like mathematicians (line 13). Eventually, one student's statement of what mathematicians do was expanded and built upon during the interchange. By providing his students with the opportunity to understand disciplinary knowledge from the point of view of practitioners, Mr. Cordova was creating a psychological tool that aided students in thinking of themselves in new ways associated with their own actions taken during investigative activity. This conversation indicates the teacher's use of meta-discourse to mediate students' thinking about their own thinking (metacognition). This specific teaching strategy would prove to be an effective mediator of student thinking across disciplines as well as across the school year.

This first transcript example demonstrates how opportunities for student learning are co-constructed by the teacher and students. The psychological tool of meta-discourse can capture complex, dynamic aspects of the mediation of student learning. This can be understood through reference to Figure 1. The beginning of the academic year marked the onset of the use of meta-discourse, which became a psychological tool for student use in their own take of the scientific practices. Mr. Cordova used the psychological tool of meta-discourse to mediate his students' thinking from different disciplinary frames of reference. As students began to internalize and appropriate such perspectives, they would begin to incorporate these disciplinary frames of reference into their own thinking in the classroom across time and across classroom activities – thus the various objects of the educational experiences were influenced by the ways that the inquiry processes were developed. We continue our presentation of purposefully sampled transcript excerpts taken from classroom dialogues demonstrating the interactive use of psychological tools for learning.

Episode II: The psychological tool of learning to observe

The next transcript presented came from a classroom conversation that took place approximately two weeks after (9.17.01) *Episode I*. In this dialogic interchange, students were required to consider how an observation of an everyday event (from an ethnographic perspective) was similar to scientific observations. The dialogue included the teacher, students, and ethnographer. The classroom conversation primarily dealt with the teacher speaking to the students about why he wanted them to develop their own observation skills. The teacher highlighted the importance of such observation skills as being closely tied to preparing their minds to think like different people (mathematicians, ethnographers, scientists, etc.). This episode presents an example of Mr. Cordova and Mr. Reveles – who was working as an ethnographer in the classroom collecting his dissertation data – introducing the psychological tool of "learning to observe" across disciplines. Consider how the classroom conversation ensued:

Line #	Speaker	Talk
38	Mr. C:	I'm going to ask you a very hard question
39		my hard question is this
40		why do you think I am asking you to go home?
41		why do you think I asked you to go home and observe?
42		why do you think I did that?
43		why do you think that I as teacher would think that that's important?
44		it's a hard question I told you
45		there is not a right answer
46		there is no right answer to it
47		so why do you think I asked to you to go home and observe?
48		Luke?
49	Luke:	cause we were learning about actions of mathematicians
50	Mr. C:	right
51		you were learning in class that day what the actions of mathematician were right
52		and you also learned what it is that the ethnographer does back there

In this example (lines 38–43) we see that the teacher was questioning his students as to his rationale for asking them to do a homework assignment in which they were to go home and carefully "observe" an everyday event writing down interesting aspects of what they observed happening. At this point in time, students were already accustomed to the dialogic nature of classroom life in which their teacher would initiate classroom conversations and pose questions to them regarding his reasoning for asking them to think in different ways. In this exchange, not only does Mr. Cordova reiterate the assignment by posing related questions (*why do you think I am asking you to go home? why do you think I asked you to go home and observe? why do you think I did that?*), he also asks students to think about his reasoning for having them complete the homework activity (*why do you think that I as teacher would think that that's important?*). This is a particularly salient example of how students and teacher in the classroom would openly discuss disciplinary ways of thinking about phenomena as related to their own thinking.

Next, we observe the teacher include a student and the ethnographer in the conversation. In lines 49–51 a student (Luke) answered the question and the teacher validated his response. Then, he repeated the answer for the rest of the class to hear. In the very next line (52), the teacher connected the actions taken by mathematicians to the observations of the class ethnographer working in the back of the classroom. This serves to again remind students of related ways osf understanding (*you were learning in class that day what the actions of mathematician were, right*? *and you also learned what it is that the ethnographer does back there*) in relation to current understanding on the topic of "learning to observe". Because learning to observe was a psychological tool that students were being asked to take up in their homework assignment and because learning to observe was a psychological tool that students would engage in across subjects, Mr. Cordova connected past classroom conversations about learning to observe to the ethnographer's observations by inviting him into conversation. By connecting the psychological tool of "learning to observe" in their homework assignment, to actions taken by mathematicians, to observations made by the classroom ethnographer, the teacher helped tie students' use of "learning to observe" in this instance to other types of observations carried out across disciplines. The psychological tool of "learning to observe" was one of the symbolic tools that students would draw on during their future science investigations. The dialogue continued:

Line #	Speaker	Talk
53	Mr. C:	Mr. R let me ask you this question
54		when you are back there Mr. R do you do a lot of watching and looking?
55	Mr. R:	I do Mr. C
56	Mr. C:	and seeing and remembering?
57	Mr. R:	I certainly do
58		I remember a lot of what's happened in the class
59		at the beginning of the year
60		at the very first few days
61		and then I remember
62		and then I look at what's going on now
63		and I observe
64		I think about how you're learning some of the things that Mr. C is teaching you
65		some of the concepts and interesting relationships
66		between what mathematicians do
67		between what ethnographers do
68		between what scientists do
69		it's very interesting to me

In this part of the conversation the teacher asked the ethnographer about the types of observations he made from the back of the classroom (lines 53–56). In this way, Mr. Cordova invited the ethnographer to share his ethnographic perspective relative to different ways of knowing that had been thus far co-constructed between students and teacher. The ethnographer responded (lines 58–69), articulating the relationship that his observations have to other ways students were learning to think. His views on disciplinary ways of thinking reflect a common relationship between students' meta-cognitive ways of understanding across disciplines (learning to observe, in math, science, and language arts) and a mediated understanding across time made explicit (*I remember a lot of what's happened in the class, at the beginning of the year, and then I look at what's going on now, and I observe*). As a community member in the class, Mr. Reveles was able to share his own perspective, mediating student understanding of "learning to observe" in different disciplines (lines 64–69). Next, the teacher publicly weaves together the mediated understanding of "learning to observe" for students to realize.

70	Mr. C:	also observing
71		students today you are going to be asked to do an even harder thing
72		and I know you're going to do it
73		it's harder because it's going to be new
74		and I know you'll be able to figure it out
75		if we're going to start science on Monday
76		we need to have a mind that's prepared
77		remember a little while ago I said we're preparing our minds
78		we're preparing our minds by thinking like mathematicians
79		we're preparing our minds by thinking like ethnographers
80		and ethnographers observe everyday things

In the next line (70), the teacher connected the points expressed to the ethnographer's observing. Lastly, Mr. Cordova continued to explain to his students that they were preparing their minds to begin doing science (lines 75–80) by thinking like different types of observers. This example of meta-discourse made reference to the work already accomplished among members of the classroom, i.e. thinking like mathematicians and ethnographers. The teacher's and ethnographer's mediation of students' "learning to observe" from a particular point of view was an essential psychological tool that we will show was internalized and appropriated by students in later science investigations.

Mediation of student learning and psychological tools

As Mr. Cordova introduced and used a particular psychological tool (such as, learning to observe from disciplinary frames of reference), he was also mediating student learning (using meta-discourse instructional framing tools) while the tool itself was shaped and reshaped by community interaction (i.e., between the teacher, ethnographer, and students). Thus, analyzing this classroom interaction as an integrated activity system allowed us to view the human and symbolic mediation of student learning using specific teaching psychological tool strategies for introducing and using other psychological tools tied to learning general ways of thinking and acting as a scientist associated with more specific science concepts introduced at various points.

The internalization and appropriation of psychological tools for learning science eventually became common practices engaged in by students as they completed various investigations across the academic year. Therefore, in our discussion we couch the psychological tools appropriated by students as scientific practices engaged in during the science investigations they carried out. In the next section we describe and provide evidence of, "observing from a point of view" as one example of a psychological tool that students internalized and appropriated during a range of science investigations.

Appropriating situated practices: Science posters-in-the-making

In the following subsections, our analysis examines students' ability to use psychological tools for understanding and communicating practices in science. In these examples, we provide evidence of individual student use of internalized psychological tools. In order to be able to appropriate scientific ways of talking and interacting evinced in these episodes, students needed to have internalized the necessary practices to carry out the construction of their science fair posters. From our theoretical perspective, we view these dialogues as key instances demonstrating a culmination of different dimensions of psychological tools use across the year. As a result, these interchanges represent examples of ways that individual students were able to articulate their science fair projects by appropriating collectively co-constructed practices that they had a part in defining.

The following series of conversations took place in May near the end of students' last inquiry based science activity, "The Plant Experiment." At this point in time, the whole class was working on their plant experiment posters for the science fair. Students were writing up and putting together various components (e.g. experiment hypothesis, materials, procedures, findings/conclusions) of their plant experiment posters, to be displayed at the science fair. The ethnographer visited different student table groups as they were working on putting together their poster and asked them to describe, in their own words, the different aspects of their plant experiments. As the ethnographer circulated around the room, he posed a variety of questions to the students. The dialogue participants were four students (Osvaldo, Samuel, Amelia, Rosa), representing each of their respective project groups, the ethnographer (first author, Mr. Reveles), and the classroom teacher (Mr. Cordova).

Dialogue 1: Talking to Osvaldo

In this first dialogue, the ethnographer (referring to student science group projects) initially posed the question *what was yours about?* (line 82) to Samuel, but Osvaldo, a student in a different group, answered within his own perceptions. Osvaldo's group was investigating plant reproduction. Osvaldo was a student whom the teacher had to frequently discipline throughout the school year. While Osvaldo did not have as many behavioral problems in his research group as he usually did in class, he repeatedly tried to disrupt other students when they were working. The "Reproduction" research group was comprised of all boys who at times tolerated his behavior and at other times simply ignored his attempts to interrupt the group. However, Osvaldo was valued because of the insight he brought to the table regarding the group's science fair poster. The interchange with the ethnographer began as follows:

Line #	Speaker	Talk
81	Mr. R:	Samuel
82		what was yours about?
83	Osvaldo:	how does a small seed grow into a big plant?
84	Mr. R:	okay
85		and what did you find?
86		what were your findings?
87	Osvaldo:	Uh?
88	Mr. R:	what were your conclusions?
89	Osvaldo:	a seed is like a package
90		everything a seed needs to grow is inside it
91	Mr. R:	oh, that's good
92	Osvaldo:	it needs shade at first to germinate
93		then it needs soil, water, and sunlight to grow
94		the right conditions the seed will continue to grow
95	Mr. R:	excellent
96		thank you

The interaction between the ethnographer and Osvaldo showed how the student was able to engage with the questions posed. When asked about what his project was about, Osvaldo offered a reasonable summary in the form of a question (line 83, *how does a small seed grow into a big plant?*) – a scientific practice psychological tool introduced earlier in the year. Osvaldo's use of a psychological tool indicates a certain level of internalization and appropriation practice for two reasons. First, Osvaldo's response in the form of his group's research question was an automatic one. As soon as the ethnographer posed the question, Osvaldo immediately offered the research question being investigated by his group as an answer to the ethnographer's query. Second, the question stated was an unsolicited response by Osvaldo. In fact, the ethnographer was initially speaking to Samuel when he asked the question (*what was yours about?*) and Osvaldo took it upon himself to jump into the conversation. Interestingly, when asked about his "findings" (lines 85–86), Osvaldo appeared to be unsure of the question, until the ethnographer reframed the question in the terms employed by the students on their poster, "conclusion" (line 88). The statement made by Osvaldo – once he understood the question from a now familiar scientific frame of reference – again indicated that he had already internalized this understanding and was now easily able to appropriate his knowledge. Osvaldo then offered a candidate for a scientific conclusion (lines 92–94: *it needs shade at first to germinate, then it needs soil, water, and sunlight to grow, the right conditions the seed will continue to grow*).

Dialogue 2: Speaking to Samuel

The second dialogue we present is from Samuel whose group was investigating the structure of plants. Samuel was a shy student during his interactions with other members of the class and was usually quiet unless he was directly called upon to speak. Although, he had no problem offering his opinion or articulating his understanding about investigations he worked on, he just did not seem to enjoy the spotlight as much as other students did. In this case the ethnographer entered the conversation with knowledge of the project and thus posed a specific question regarding the research design (lines 97–99).

Line #	Speaker	Talk
97	Mr. R:	what were you looking at Samuel?
98		I know yours was interesting
99		you had three different conditions right?
100	Samuel:	I was making the
101		I put three plants
102		and then I was giving
103		I was giving one positive feelings
104		and one negative feelings
105		and one without feelings
106		and just gave it water and sunlight
107		the positive is growing real big
108	Mr. R:	the positive feeling seeds are growing larger than the other ones
109		than the
110		negative and the no feelings
111	Samuel:	yeah
112	Mr. R:	excellent
113		good
114		so what did
115		can you read your conclusion for me?
116		yeah, right here
117	Samuel:	do human feelings affect the was plants grow?
118		I know the positive is the first one that is the biggest one to grow
119	Mr. R:	okay
120		alright
121		thanks, Samuel

Samuel explains his project, which entailed treating plants to variations in human feelings (lines 100–107). Samuel's investigation involved two different treatment conditions and one control (*I was giving one positive feelings, and one negative feelings, and one without feelings*). Samuel's ability to articulate the research design of the investigation additionally indicates the internalization and appropriation of locally-defined scientific practices, such as designing research plan, observing from a particular point of view, and pose research questions, that were introduced earlier in the year (see Table 1).

In this case, we observe some of the ways that the teacher provided structure and autonomy for his students – this itself constituting a psychological tool used by the instructor to facilitate students' acquisition of other psychological tools for learning. The research design was built on practices introduced during previous science projects, but unlike those led by the teacher, in this case the choice of key variables was not circumscribed by previous science lessons. The students were afforded autonomy in choosing variables and were not restricted to those with likely scientific plausibility. This issue is important in the on-going identity development of the students (Reveles et al., 2004). When posed the question regarding his conclusion, Samuel proudly announced the improved growth for the plant receiving positive feelings (line 118). The autonomy and structure, as a psychological tool, afforded to students illustrates an interesting point in our study. From our perspective, many of the scientific practices needed to conduct somewhat autonomous science investigations were internalized by these third graders earlier in the school year and were now being employed as psychological tools that were collaboratively re-applied to build science fair posters (See Table 2).

Table 1 Scientific practices introduced across four science projects

Academic school year:	September	October–December	January–February	March–May
Scientific investigations:	Watermelon investigation	Weather experiments	Weather channel show	Plant adaptation/Plant experiments
Student scientific practices:				
Design research plan	√	√	√	√
Observe from a point of view	√	√		√
Pose research questions		√		√
Investigate research questions	√	√		√
Provide estimates	√	√		
Provide evidence for investigation	√	√		√
Write down estimates	√			
Sketch	√		√	√
Complete investigation worksheet	√	√		
Use scientific instruments	√	√	√	
Take measurements	√	√		√
Record actual measurement data	√	√	√	√
Write down research questions for investigation		√		√
Compare estimate with evidence	√	√		
Pose investigation hypothesis		√		√
Carry out investigation step-by-step	√	√	√	√
Record investigation information in table	√	√	√	√
Draw schematic representations of science instruments		√		
Work in collaborative research groups	√	√	√	√
Define disciplinary practices	√	√	√	√
Make scientific instruments	√			
Keep science inquiry journal	√			√

Table 2 Psychological tools introduced by the teacher and evident in project posters

Student research groups:	Structure			Sunlight				Reproduction			Water			Photosynthesis				Plant cures
Student pseudonym	Eduardo	Kathy	Samuel	Emily	Julie	Amelia	Cameron	Osvaldo	Luke	Cody	Yzabel	Alexa	Jade	Rodrigo	Nicholas	Jacob	Juan	Rosa
Student scientific practices evident in posters:																		
Design research plan	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Observe from a point of view	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Pose research questions	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Investigate research questions	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Provide estimates																		
Provide evidence for investigation	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Write down estimates																		
Sketch																		
Complete investigation worksheet	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Use scientific instruments	√	√	√															
Take measurements	√	√	√								√	√	√					
Record actual measurement data	√	√	√								√	√	√					
Write down research questions for investigation	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Compare estimates with evidence																		
Pose investigation hypothesis	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Carry out investigation step-by-step	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Record investigation information in table	√	√	√															
Draw schematic representations of science instruments																		
Work in collaborative research groups	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Define disciplinary practices																		
Make scientific instruments																		
Keep science inquiry journal																		

Viewing this student's articulations and science project as the appropriation of internalized psychological tools reflects the synthesis of a year-long construction of knowledge and understanding engaged in by all members of the community. Thus, Samuel's ability to carry out the science fair project is not merely an achievement in itself. Rather, it encompasses a culmination of the appropriation several different psychological tools introduced and used throughout the school year. These internalized psychological tools were then employed by students during the science fair project and resulted in a specific form of achievement consisting of purposeful, goal-oriented, and socially determined interaction. In our view, the posters produced by students were materialized objects produced through the dynamic interaction in which students as object-oriented subjects autonomously and collectively transformed their ideas into research investigations manifested as science fair projects. The next example illustrates an individual student working within her collective research group.

Dialogue 3: Asking about Amelia's experiment

In this third dialogue, the ethnographer asks Amelia a series of questions related to her group's investigation. Her group was known as the "Sunlight" group. Amelia's role in the sunlight group took on many forms. For instance, once students were separated based on their research interests Amelia helped the group come up with a plausible research question to investigate. Although Amelia did not voluntarily do much public speaking and reporting for the group, other group members frequently referred to her as a resource for describing what they were observing and recording. In this way, other members of the sunlight group were well aware of Amelia's proficiency and relied on her as a resource for their own psychological tool learning.

Line #	Speaker	Talk
122	Mr. R:	Amelia
123		what was your experiment about?
124		what was your question
125		and then your hypothesis
126		and what were your
127		findings?
128	Amelia:	how does artificial lighting help things grow?
129	Mr. R:	how does artificial light affect the plants
130		Okay
131	Amelia:	there was
132		the hypothesis
133	Mr. R:	yeah
134		what did you think?
135		did you
136	Amelia:	I think that the one in sunlight will grow more
137		than the one in artificial light
138		there are some in our classroom that haven't grown much
139	Mr. R:	oh
140		okay
141		and what
142		what were your findings?

143		your conclusions I should say
144	Amelia:	that the
145		that the one in artificial light grew more
146		I think because it is
147		it depends on the plant
148	Mr. R:	oh so you're saying maybe it's the plant
149		the type of plant that's receiving artificial light
150		might have to do more with whether it grew
151		than whether it received
152		artificial light
153	Amelia:	right
154	Mr. R	Okay
155		that's good

This dialogue contained several interesting interchanges between the ethnographer and Amelia. As observed from the onset of this conversation, the ethnographer begins by asking Amelia a series of questions related to her group's science investigation (lines 122–127). Amelia answers the first three questions, *what was your experiment about?* (line 123) *what was your question* (line 124) *and then your hypothesis* (125), without the ethnographer having to repeat or clarify himself. This appears to indicate a familiarity with the group's investigation as well as an ability to easily articulate different elements of the group's investigation. Additionally, Amelia even kept the ethnographer on point by reminding him of her research hypothesis (lines 131 and 132). Next, Amelia goes on to assert her hypothesis as well as reservations she had as to why her group found what they did (lines 136–138 and 146 and 147). Afterwards, the ethnographer paraphrases what he thought Amelia was saying about her research group's findings and she agrees. In this interchange we see Amelia appropriating internalized scientific practices as she described each element of her group's science fair poster, such as designing a research plan, posing questions, and taking measurements.

Dialogue 4: Listening to Rosa's perspective

The last dialogue we report is the most unique. The dialogue participants are the ethnographer, Rosa, and the teacher. Both the teacher and ethnographer are involved in the conversation because the teacher had allowed Rosa to work alone under the condition that he would be a resource for her unique research project. This example is most interesting to us not only because Rosa conducted a non-traditional science investigation but also because Rosa herself came into this classroom labeled as a special education student. The institutional label she carried as a special education student marked Rosa's daily interactions within this classroom community. While other students in this class came to appreciate and value the unique knowledge that Rosa had to offer, they were all well aware of the fact that several times a week she and a few other students were pulled out of the class to work with the resource teacher because they were deemed academically behind other students based on external grade-level expectations set by educational administration. Although Rosa began the school year in such a manner, she finished the year as a student who had gained a unique ability for doing science in creative ways. In our minds, Rosa's example provides a telling case of what is within the realm of possibly when a teacher actively supports all students in learning the value of science in their own lives.

For this investigation, Rosa worked independently and investigated science in ways consistent with the ethnographic perspective offered in the class, but at variance from the traditional ways of investigating plants. However, in her investigation she utilized a psychological tool that consisted of a scientific protocol for hypothesizing, gathering data, and reporting the results of her findings in her science fair poster. Her work entailed researching members of Mexican heritage to learn about the medicinal properties of plants. In her hypothesis she referred to a class assignment earlier in the school year in which students interviewed their parents regarding home remedies and subsequently made retablos. Retablos are derived from a Latino (Mexican) artistic tradition and are small oil paintings on tin, zinc, wood or copper that venerate a multiplicity of Catholic saints.

Line #	Speaker	Talk
156	Mr. R:	Rosa
157		I just
158		I'm asking the kids what their
159		their research question was
160		what their experiment was about
161		what they hypothesize
162		and what they found in their conclusion
163	Rosa:	okay
164		my question was
165		what part of the plant do people use for remedies
166		and
167	Mr. R:	oh
168		that's interesting

In this case, the ethnographer opened in a similar fashion, stating an interest in the headings of the science posters: research question, hypothesis, experiment, and conclusion (lines 156–162). Rosa offered her response beginning with her research questions and indicated an interest in remedies (lines 163–166). Rosa set direction quite different than her classmates by setting people central to her study of science. The ethnographer apparently found this interesting. Rosa continued:

169	Rosa:	and my question was
170		how
171		wait
172		how different
173		how do people use different parts
174		part plants for
175		as remedies
176		and my hypothesize is I think people do use plants for remedies
177		because
178		there are a lot
179		lot of kids in my class whose families use plants
180		plants for remedies in the re
181	Mr. C:	the retablos
182	Rosa:	the retablos
183		use
184		we

185	Mr. R:	we made
186	Rosa:	yeah
187		we made
188	Mr. R:	so
189		so the students made retablos
190		and they
191		in those retablos
192		they reported about ways that their families use plants
193		is that correct?
194	Rosa:	yeah

Rosa decided to examine how people used plants for remedies (176) and offered her rationale based on observations of her classmates' families (177–180). Although Rosa's statement of "hypothesis" in line 176 is not a well-articulated hypothesis from ideological scientistic point of view, i.e., posing a question of nature that could be investigated with empirical means, the divergence served her well and was permitted in the context of this class. She derived this "hypothesis" from careful observations of her classmates' previous "retablos" projects. Rosa was helped by the teacher to remember the word "retablos" (line 181), but clearly had drawn from this cultural experience to derive her interest in her science project. Her position was clarified by the ethnographer (188–193). As the interaction continued, the ethnographer noted that this project was unique in a number of ways and he asked Rosa about the origins of her ideas (lines 195–201).

Line #	Speaker	Talk
195	Mr. R:	okay
196		so your
197		your experiment is a little different
198		and that's very interesting to me
199		what
200		how did you choose this experiment?
201		did you just think of it on your own?
202	Rosa:	yeah
203	Mr. R:	you just wanted to know?
204	Rosa:	yeah
205		I just wanted to know what kind of plants
206		what kind of plants are used for healing
207	Mr. R:	okay
208		that's good
209		and what were some of your conclusions and your findings?
210		what did you find with this experiment that you did?
211	Rosa:	I found that people do use remedies and there's different plants
212		a lot of different plants that they use for like different things
213		like stomach aches
214		so
215		uhm
216		uhm
217		like and sore throats and I uh sick
218		like if you're sick
219		Headaches

220	Mr. R:	wow
221		so they use them for a lot of different things
222		right?
223	Rosa:	yeah
224	Mr. R:	all different plants
225		roots and leaves and different parts of the plants as well
226	Rosa:	yeah
227	Mr. R:	okay
228		good

Rosa explained her research interest (lines 204–206) and, when prompted about her conclusion, she explained her findings regarding the medicinal uses of plants (lines 211–219). Rosa's statement that *I found that people do use remedies and there's different plants* (line 211) identified her research approach: She used research interviewing (a psychological tool learned while taking on the ethnographic point of view) to examine this non-traditional scientific issue.

Line #	Speaker	Talk
229	Mr. R:	and could you read me your conclusion and then that's it?
230	Rosa:	this one?
231	Mr. R:	uhm I think
232		your conclusion
233		right there
234	Rosa:	they do use plants for remedies
235		they use roots
236		stems and grains
237	Mr. C:	gel
238	Mr. R:	gel?
239	Rosa:	gel for
240		from the plants
241		people as-
242		people also
243		people also
244	Mr. R:	Learn
245	Rosa:	learn from each other how to use plants
246	Mr. R:	okay
247		thank you very much
248		Rosa

Continuing, the ethnographer asked about her conclusion (line 229). While initially uncertain (line 231) Rosa stated her two part conclusion. She found that people use roots, stems, grains, and gels from plants for medicinal purposes (lines 234–236, 239–243) and that *they learn from each other how to use plants* (245). The later conclusion is an unlikely candidate for a scientific conclusion in most classrooms. In this case, however, the conclusion stood. It was supported by the evidence Rosa had gathered and, to while it was not derived from a traditional scientific experimental design, Rosa was able to engage in many of the socially negotiated scientific practices of the classroom.

Thus, Rosa posed a question about the medicinal uses of plants, but rather than designing a study with a experimental and control group, or something of that sort as seen in Samuel's and Amelia's projects, she explored – through the uses of her classmates retablos – ways, psychological tools from our perspective, that people reported home remedies derived from plants. Consistent with the "ways of inquiring" approach of the teacher, Rosa was afforded the opportunity to explore the "science" concerned with the medicinal properties of plants and develop a unique research plan of her own. In the process, she was able to provide her evidence and engage in a number of the scientific practices introduced throughout the school year and employed in the service of science.

Discussion

We discuss three related issues derived from the study of this classroom. First, we consider ways that sociocultural theory informs the interpretation of discursive work accomplished in the classroom. Second, we consider the expressive potential of sociocultural theory for science education research, particularly for studies centered on the concerted actions of members of a community. Third, we provide a rationale for the use of the construct of psychological tools to inform our own sense making of the educational events.

Interpreting the discursive work of the classroom

The examples of spoken and written discourse examined in this study, show how science learning activities were accomplished through language and interactional social processes. From a sociocultural perspective, learning to "do science" entails more than simply being a receptor of factual scientific knowledge or acquiring concepts. Rather, it involves developing and transforming students' identities through action and interaction (Brown, 2004; Reveles et al., 2004) and expanding individuals' social repertoire of ways of being in the world. This process involves learning to use psychological tools for constructing new understanding that are developed and shared socially. The social activity of learning science involves students' gradually internalizing scientific practices shared first through interaction with the teacher as a more capable other who can model and guide students' learning. These social practices can be more or less transparent for many science learners, even as those learners engage in concerted activity among members of a group.

The teacher's goals included finding ways to make inquiry practices accessible to his students. He had joined the faculty of the school at a time when the school was a magnet bilingual school with the intent to expand opportunities for all students, but particularly those students from lower income and Spanish speaking families. By viewing and analyzing the classroom as an activity system, the discursive work of the teacher oriented toward developing academic practices and identities can be unpacked into specific pieces of work supporting students' acquisition of specific knowledge and skills associated with the practice of being a scientist. The practices introduced by the teacher were integrated across designated discipline areas. By showing how particular practices can be applied in different contexts, the teacher provided his students with ways of participating as a scientist and being valued as such through engagement in academic science subject matter instruction.

By examining how the students took up these opportunities and appropriated some of the inquiry practices, the study identified the consequences of the teacher's and students' work together around ways of inquiring as scientific practice. The explicitness of the ways of being valued, and the flexible manner in which students were able to engage in these practices, show how access to knowledge can be constructed through social interaction. Mediated by psychological tools associated with acting as a scientist, students were able to achieve curricular goals, and to acquire and jointly build new knowledge for themselves as they interacted with other members of the classroom community during collective activity. Students' use of psychological tools to learn and apply science, scientific concepts, and scientific understanding through the meta-tool role of thinking-as-a-scientist became salient experiences that were drawn on during future science learning. In this way, experiences from the past build current practices from prior learning and build the pathway to new learning through re-enactment and adaptation of new practices in future contexts and settings. Rosa, in particular, was a student who was afforded opportunities to construct a version of science – which drew from the inquiry practices of the classroom – crafted around her unique ways of understanding and investigating. This example demonstrated how what comes to count as science in school may intersect with students' evolving identities as learners of science and how this can have an impact on future learning.

The expressive potential of sociocultural theory for science education research

Sociocultural theory is an important teaching-learning perspective offering an expanded expressive potential for science education research. Recent studies have begun to apply sociocultural theory to learning in science classrooms and other settings (Lemke, 2001; Roth & Lee, 2004). Rather than focusing on individual students' conceptions, sociocultural theory examines how the relationship between human agents and objects within their environment is mediated by cultural means, tools and signs over time and contexts – other forms of psychological tools (Leontiev, 1978). Following the suggested research issues identified by Kozulin (2003), this study examined the type and techniques of human and symbolic mediation, the development of psychological tools, and the appropriation of the disciplinary practices and psychological tools by students. By examining specific strategies used to mediate students' learning of psychological tools and then by examining the internalization and appropriation of these psychological tools by students, we identified how disciplinary knowledge was mediated by the teacher and how these psychological tools were particularly manifest in science learning thus, laying a foundation for practice and new learning. Accordingly, the expressive and generative potential of the research tradition was examined in the context of elementary school science.

Psychological tools as a construct for understanding science-in-the-making

One aspect of the expressive potential of sociocultural theory is the construct of psychological tools. Our emphasis on the interaction between the agents (students, teacher, ethnographer, and so forth) in this study and their environment (i.e., a third grade classroom setting, its artifacts, and cultural practices) helped us explain why the principle of psychological tool mediation was an effective construct for understanding student learning. We came to view psychological tool mediation as a key construct for understanding the co-construction of science in this classroom. Furthermore, understanding psychological tools as forms of symbolic mediators of conceptual understanding that participants made use of facilitated a view of the classroom as an activity system in which teaching and learning were interactively shaped and re-shaped over time. Therefore, we used the theoretical notion of psychological tools (presented at the beginning of this paper) to explain the interactive transmission, accumulation, and transformation of scientific knowledge as situationally-defined in this classroom for several reasons.

First, the psychological tools introduced by the teacher in our study shaped the way students interacted with science. As the teacher and students collectively used psychological tools to understand science content, the tool use framing the public activities of the classroom resulted in shaping students' own understanding of psychological tool use for application in the present and potentially in the future. Second, while the psychological tools introduced initially reflected the teacher's experiences as he used them to teach his students to think across disciplines, eventually they became symbolic tools that students appropriated and used to think across their own classroom science investigations. Moreover, psychological tool use proved to be an effective construct for understanding how students took up the genre of a scientific poster. Third, in viewing this classroom as an activity system affecting the future as well as the present, we were able to track the knowledge required for participation in the on-going activities as it was being co-constructed through the use of the psychological tools internalized and appropriated across the school year. Thus, ways of being a student in the class evolved, as practices derived from inter-psychological activity became resources for intra-psychological cognition. The specific ways externally introduced psychological tools transformed to internally utilized tool use by students was an important discovery for us. Fourth, as students learned to appropriate internalized psychological tools, they learned specific ways of cognitively organizing and learning science content in meaningful ways appropriate to the agentive role of "scientist." Moreover, once these psychological tools for learning science became part of students' own ways of "doing science", they became part their mental and inter-mental functioning within the collective classroom as a science learning community.

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