Differential Participation During Science Conversations: The Interaction of Display Artifacts, Social Configuration, and Physical Arrangements

Wolff-Michael Roth
Faculty of Education
Simon Fraser University
Burnaby, BC, Canada
michael_roth@sfu.ca

Michelle K. McGinn
Faculty of Education
Simon Fraser University
Burnaby, BC, Canada
michelle_mcginn@sfu.ca.

Abstract: This study was designed to investigate how different combinations of artifacts, social configurations, and physical arrangements give rise to different content and form of classroom discourse. Over a 4-month period, we collected data (videotaped activities, interviews, ethnographic observations, artifacts, and photographs) in a Grade 6/7 science class studying a unit on simple machines. This study describes how different artifacts, social configurations, and physical arrangements lead to different interactional spaces and participant roles, and, concomitantly, to different levels of participation in classroom conversations. The artifacts had important functions in the maintenance and sequence of the conversations. Depending on the situation and the role of participants, artifacts served as resources for students' sense making. Each of the different activity structures supported different dimensions of participating in conversations and, for this reason, we conclude that science educators teaching large classes should employ a mixture of these activity structures.

Recent conceptualizations of knowing and learning focus on the degree of participation in the practices of communities [Lave 1988, Lave & Wenger 1991]. Discursive practices are recognized as the most important and characteristic practices in many communities. Over the past 5 years, we have been interested in discursive practices in classrooms that provide learning opportunities resembling those of out-of-school settings. Learning in these classrooms is student-centered, problems are open-ended, and collective learning is encouraged over individual prowess. This study investigated how different artifacts, social configurations, and physical arrangements create different interactional spaces and participant roles, and, concomitantly, different levels of participation in classroom conversations.

1. Theoretical Framework

Our research program is based on recent conceptualizations of knowledge as fundamentally situated and distributed across physical and social contexts [J. S. Brown Collins & Duguid 1989, Lave 1993; Scardamalia & Bereiter 1994]. As such, we have begun to describe what it means to learn as part of a knowledge-building community, particularly in science classrooms [Roth 1996b, Roth & Bowen 1995]. The current study builds from research on sense-making conversations at the classroom level [Orsolini, 1993, Orsolini & Pontecorvo 1992, Théberge 1993] and workplace studies concerning the relationship of discourse with artifacts, social configurations, and physical arrangements [Button 1993, Galegher Kraut & Egido 1990, Lynch & Woolgar 1990]. The science curriculum of the Grade 6/7 class under investigation was built around the notion of learning as participation in a community's practices, especially its discursive practices. However, we assumed that participation in the communicative practices would be mediated by the existing [display] artifacts, social configurations, and physical arrangements of the classroom.

Central to our design was the notion of *participation* in the practices of a community. Participation *is* knowing and learning [Lave 1993]. Our goal, however, was to allow students not only to participate in schooling, but in practices that, at a minimum, resemble those of scientists. Such practices are sometimes referred to as "authentic" [e.g., J. S. Brown et al. 1989]. It is difficult to argue that students participate in the communities of practicing scientists [Traweek 1988]; we therefore considered our community as bounded by the classroom. In part, this classroom community changes in its [discursive] practices through interactions with other, initially foreign, practices introduced by the teacher. *Peripherality* then indicates the possibility to participate to different degrees, that is the "multiple, varied, more- or less-engaged and -inclusive ways of being located in the fields of participation defined by the community" [Lave & Wenger 1991: 36]. In our context, *legitimacy* was achieved not by participating in a community of "little scientists," but by the possibility of belonging to this classroom-bounded community which includes students and teacher [who also belonged to several "scientific" discourse communities].

Legitimate peripheral participation does not only describe the activities in a community of practice, but also the relationship an artifact takes with respect to the members of the community [J. S. Brown & Duguid 1992]. Well-designed artifacts must encourage members of the community to engage and must enable and empower them to increase the depth of their participation in proportion to their competencies. Well-designed artifacts configure the physical layout of workplaces—which in the most general terms are constituted by the whiteboard of a team of AI researchers or the desktop computer system for magazine editors—to allow participation in practices and to become resources for various social configurations in the coordination of practices [Ehn & Kyng 1991]. In a science classroom, artifacts [e.g., overhead transparencies, physical models, computers] have thus to be evaluated in terms of their affordances to students' participation. In the present study, we were mainly interested in students' participation in evolving discourses and these discourses were mediated by the artifacts, social configurations, and physical arrangements of the classroom.

2. Research Design

2.1. Participants

The present study focuses on learning in a Grade 6/7 classroom engaged in a unit on simple machines. Mountain Elementary School [all proper names are pseudonyms] is located in an urban area in Western Canada predominantly serving a middle-class clientele. There were 10 Grade 6 [5 boys, 5 girls] and 16 Grade 7 students [7 boys, 9 girls]. One of the authors, with graduate degrees in physics and science education, taught the unit. He designed and planned all activities with feedback from the homeroom teacher and three other members of the research team.

2.2. Curriculum

The curriculum was based on notions of learning as increasing generation of and participation in tool-related and discursive practices. Our main focus was on developing students' talk related to simple machines. However, we did not want just any talk to emerge, but were interested in fostering a discourse that showed some resemblance to the language in scientific communities on similar topics. We operated under the assumption that any founded language about simple machines had to develop from students' current discourse. By choosing inscriptions and associated physical models that are relevant in other domains of discourse [e.g., physics], we set the stage for producing, maintaining, and developing new discourse that would handle those segments of the world more appropriately.

The simple machines unit lasted from beginning of October to the end of January for a total of 36 lessons and included two 70-minute and one 55-minute lesson per week. There were four types of activities that differed in terms of the social configuration [whole class, small group] and the origin of the central, activity-organizing artifact [teacher-designed, student-designed]:

- whole-class teacher-directed conversations on the topics of simple pulley, block-and-tackle, lever, inclined planes, work, and energy [about 25% of the unit] in the presence of a physical device and its re-presentation on transparency.
- small-group teacher-designed investigations of topics related to simple machines [about 15% of the unit].
- design—which includes conception and construction—of four hand-powered machines in small groups of two or three students [about 30% of the unit].
- presentation of design artifacts to the entire class, and student-led question and answer sessions [about 30% of the unit].

All four activity structures supported students' participation in talking science and engineering design but with different degrees of teacher input and feedback.

2.3. Data Collection.

This study was designed like other studies of knowing and learning in scientific and school communities [A. Brown 1992, McCain 1991, Traweek 1988]. That is, we sought to establish a rich data base to support our development of a theoretical vocabulary for understanding knowing and learning in a community where collective knowledge-building was emphasized. At any one moment, two to four members of the research team were present in the class, recording with two video cameras and one or two tape recorders, taking photographs, collecting ethnographic field notes, conducting interviews with children, and collecting other information from the teachers. Our data base further included children's science notebooks where they kept glossary entries, designs, and photographs of their constructions. After each lesson, the teacher-researcher debriefed with at least one other member of the research team; these debriefings were documented as fieldnotes. Based on these fieldnotes and our experience during transcription and analysis, we prepared theoretical fieldnotes that entered the data base. In addition, all curricular materials and the artifacts used during teaching became part of the data base.

2.4. Data Interpretation

The present interpretations are based on the assumption that reasoning as socially structured and embodied activity can be observed [Suchman & Trigg 1993]. Video tapes and transcripts are natural protocols of students' efforts in making sense of events, structuring of their physical and social environment, or interactions with the teacher. Together with the collected artifacts, protocols provided occasions for construing the conversational and cognitive work done by individuals, groups, and the classroom community. The data analyses were conducted in sessions with two to four members of the research team according to precepts of *Interaction Analysis* on the basis of videotaped data sources [Jordan & Henderson 1995]. We played the videotapes, stopping and replaying them as often as needed and whenever a team member felt something remarkable had happened. When we had isolated an event as significant, we searched the entire database [not just videotapes] to see if the event represented a class of events. In this way, we ascertained that the phenomena reported here were representative of the data base, though illustrated only with excerpts from one whole-class discussion.

After identifying a number of significant categories of events, our analyses were also driven by the search for a language that could describe them in some economical way. We found a theater metaphor involving stage, actors, director, audience, script, and props most fitting. We use this metaphor as a way of talking about the experience in this classroom, not as a mirror of this classroom. Thus, our theatrical metaphor does not imply that science classrooms are theaters with the associated front and backstages, rather the metaphor serves as an efficient way to describe the importance of physical locations, participants' roles, and artifacts in a variety of classroom situations using a discourse familiar to most readers.

3. Findings and Discussion

The following analyses show how different combinations of artifacts, social configurations, and physical arrangements mediated speakers and speaking turns, topic development and cohesion, and type of communication. Our starting point was with the four different activity structures given by the social configuration [whole class, small group] and the origin of the central artifact [teacher-designed, student-designed]. These activity structures afforded different physical arrangements of participants with respect to the artifacts. In the following sections, we use our theater analogy to describe how the different combinations of central artifacts, social configurations, and physical arrangements brought about different interactional spaces, participant roles, and levels of participation in classroom conversations.

3.1. Interactional Spaces and Participant Roles

The interaction of central artifacts (overhead transparency, instruction/summary sheets, models of simple machines), social configurations, and physical arrangements brought about different interactional spaces and participant roles; they defined a *stage* of particular size including a certain number of *actors* and *props*, and a place for the *audience*. Distance and relative position to the artifacts [props] determined participants' *stage presence* and roles [actors, *directors*, *stage hands*, audience]. The teacher's stage presence was a critical determinant for the current *script* [discourse]; when the teacher was *on-stage* and directing conversations, discussion of scientific and technological topics increased. When students were on-stage, they interacted with artifacts and directed conversations.

3.1.1. Whole-Class Activities: One Central Stage

In whole-class activities, the interactional space was ordered along an axis from central artifact to audience. The actors onstage (students or teacher) determined who from the audience should participate in the ongoing conversation. These conversations, thus, were characterized by the actors who dominated the conversation: they *held the stage*. In most situations, every second turn was taken by someone onstage. Those onstage mediated any participation from the audience. This, then, limited the number of students who could actively contribute (and gave rise to opportunities for some students in the audience to engage in other activities).

The physical arrangement of the audience was in part determined by central artifacts, the *props*. Transparencies were projected against the screen or some segment of the wall, and thus visible from most spots in the classroom. When such a transparency was the sole stage prop, students often remained in the seats assigned to them in their other subjects. When the presentations included a model of a simple machine as a prop, visual access was limited so that students, interested in seeing the artifact talked about, pulled up their chairs. Participation here does not necessarily mean contributing to the conversation, but watching demonstrations and listening to presentations and contributions (questions, comments, criticisms) from the audience. Thus, there were students who visibly followed the events, but who did not talk. In both situations, the problematic of the physical arrangement became evident. The actor(s) onstage had physical access to the artifact (prop). Students in the front rows sometimes became *stage hands* by helping out in making measurements or getting the presented artifacts to work. However, most students in the audience, although participating in the conversation, only had visual access. All conversation was mediated from the stage area.

3.1.2. Small-Group Activities: A Stage of Stages

Small-group activities were organized by (a) teacher-prepared models of machines with associated instructions for investigations or worksheets requesting students to describe and explain a physical situation previously discussed in a whole-class discussions or (b) students' design and construction activities. In situations of the first kind, the classroom was like a stage constituted by 8 - 13 smaller stages defined by the location of the artifact and the way students chose to situate themselves with respect to this artifact. During the design and construction of models, the entire classroom became one stage on which a design studio was recreated. During these small-group activities, participation in discursive and tool-related practices was high. Rather than being audience or participant audience, all students were actors. Each student in the group had access to the artifacts—thus opportunities to manipulate the artifacts, participate in the related activities, contribute to the organization of the activity, and co-participate in making sense by drawing on various resources in the environment.

3.2. Artifacts as Scenarios and Records

Our analyses revealed a major role of artifacts in organizing content at the local level, across locations, and across time. Artifacts not only structured the interactional physical space, but also the temporal evolution of activities. They were *scenarios* for actions and unfolding conversations in as far as they determined topics and structured conversations. For example, in whole-class conversations around teacher-designed artifacts, transparencies served as scenarios for the conversation, without specifying the *script*—the specific text to be spoken—ahead of time. Actors (students and teacher) improvised their lines based on the transparency script. At the same time, the structure of the transparencies constrained the evolution of conversations. The transparencies also became *records* of conversations that were stored and posted for future reference. In contrast, students' actions were the least determined during the design and construction of models: students had to script future actions on their own, and decide what courses of actions to follow. While designing and constructing models, much of students' conversation was about planning and converting designs into models, and only partly devoted to "conceptual" talk.

3.3. Artifacts as Mediational Tools

Whenever actors had access to drawings or models, their talk contained increased levels of indexicals, gestures, and pointing; they could draw on the affordances of the artifacts as mediational tools. Others, who did not have access to artifacts [drawings, models] had to verbally explain the situations to which they referred. In those cases, artifacts were resources and mediational tools to a much lesser extent [if at all]. For example, when audience members suggested modifications to designs during whole-class conversations, their verbal descriptions no longer sufficed. Some students entered the stage to indicate the operation or modification they wanted to propose by pointing directly to the transparency, projected image, or model. In contrast, small group work afforded forms of communication not available to most students in whole class situations. Compared to class discussions, students in small groups used increased pointing and gesturing to explain their ideas or to remediate misunderstandings. Access to artifacts afforded means of communication beyond the verbal/propositional, and thus changed discourse in the community.

We found that the artifacts used in this classroom [transparencies, lab instructions, models, students' designs] characteristically defined the interactional space and led to different kind of talk. Across the different teaching-learning situations, the theater analogy provided an efficient description. Artifacts were not only stage props, but defined in important ways the interactional space [stage] for the actors. These artifacts were important resources in that they served as scenarios for action, as backdrops for ongoing conversations, and as referents for indexicals that allowed a situated but efficient language. The teacher's roles were that of actor, director, script writer, stage designer, stage manager, and stage hand. We showed that stage props and social configurations interacted such that there were different interactional spaces with different levels of access to the central artifact, and thus with different affordances for interactions and discourse.

4. Conclusions

In previous studies with smaller classes, we had few whole-class teacher-centered conversations and preferred to interact with students in small groups and according to a cognitive apprenticeship metaphor [Roth, 1995; Roth & Bowen, 1995]. Here, with a class of 26 students, we included whole-class and small-group conversations around student- and teacher-designed artifacts. We found that each of these activity structures afforded something particular to students' development of a new language so that we recommend all four activity structures to teachers. First, small-group conversations about student-designed artifacts [which started each cycle through the four activity structures] allowed students to begin instruction with their "native" language, on topics of their interest, mostly at their own pace, and to communicate as much as they wanted with their partners and other groups in the community. Their proximity [inherent in the physical arrangements] afforded sense-making over and about the artifacts. However, other than through the initial constraints on the artifacts to be produced, there was little guarantee that the talk would include canonical concerns regarding the design of machines. Small-group conversations over teacher-designed artifacts had the same affordances to sense-making that arise from proximity in the physical arrangement, but conversational topics were constrained by the canonical concerns embedded in the artifacts. Whole-class conversations about student-designed artifacts focused again on students concerns and interests, but often included canonical concerns when addressed by teacher questions. Whole-class conversations around teacher-designed artifacts provided the greatest control in terms of topic development, and content and form of argument, but also provided the least amount of time per student to talk science. Both whole-class activities limited the contributions from the student-audience and were dominated by those onstage.

It is naive to assume that children will spontaneously engage in or develop canonical discursive or tool-related practices [Cobb 1993, Roth 1995]. The activity structures presented here provide students with a range of opportunities to develop and practice new ways of talking about simple machines. Depending on the designer of the conversation's central artifact, the issues raised followed canonical concerns or students' interests [not necessarily the same as the teachers]. The activity structures allowed students to choose the level of their participation according to their preferences and confidence.

However, even if we fostered changes in the language in this classroom community, students may not use their new discourses in different situations in and out of school. If we view classrooms like other communities of practice where discourses are not necessarily continuous across situations [Star 1989], we must admit the possibility that students employ language games in, for the theoretician, inconsistent ways across situations and settings. Thus, the best we can strive for are language games consistent across situations in one school setting. In the classroom under investigation, opportunities were provided for students to employ new discourses in different situations. The notion of peripheral participation also forces us to accept that students choose to participate to different degrees, and even refuse to participate at all. We found that the different situations encouraged students to participate differentially. There were several students whose participation in the whole-class discussions had to be curbed because they had the tendency to monopolize; others contributed little or not at all to ongoing conversations. During the design and construction lessons, the levels of participation appeared to be reversed. We found a high level of participation among the latter students, but almost disinterest in the activities by the former three students.

This study has allowed us to develop ways of talking about affordances of artifacts, social configuration, and physical arrangement to participation in a community's discourse. We provided descriptions of the roles of various participants, and the differential effects of an actor's physical location on participation in an on-going conversation; and we described how artifacts functioned as resources to content and form of conversations. While our study has provided a good understanding of the present situation, it raises new questions about classroom communities that are structured around computer technology as described by Scardamalia and Bereiter [1994], Harel [1991], or A. Brown [1992]. We already know that the introduction of tools into a community can influence the physical arrangements, social configurations, and the artifacts available to members [Roth, in press]. The open questions are, however, "How do computers change the classroom in terms of the physical arrangements and social configurations?," "How do such changes influence the discourses in the classroom?," and "How do the roles of participants change with the introduction of computer technology?"

5. Implications: Designing for Changing Language Games

Planners of science learning environments designed to bring about changes in students' language games can learn from the experiences of computer systems designers. Systems which force users to radically change their practices (including their language games) are often doomed to fail, while those designs which draw on the users' language games prior to the new system are particularly successful. This point is beautifully illustrated by the success of the Xerox-Macintosh interface which uses icons based on traditional office practices, desk top, trash cans, file folders, paper stacks, and documents (Ehn 1992, Ehn & Kyng 1991, A. Henderson & Kyng 1991). The present study showed how the interaction of artifacts and social arrangement created different conditions for supporting changes in students' interactions and language games about simple machines.

During whole-class conversations, the levels of individual participation from those in the audience are lower than in small group work, the access to artifacts is limited with concomitant limitations on the affordances as mediational devices. On the other hand, the possibilities for controlling the creation of and changes in language games are high, as are the possibilities for feedback. During small-group conversations, the possibilities for individual participation are high, as are the opportunities for creating and exploring new ways of talking away from the watchful eyes of the teacher. In these situations, especially during open design and construction, students have experiences on which they can later draw as resources for more formal discussions. However, it is unlikely that students would evolve the language games of canonical science were they to work in an unassisted way, even in the presence of artifacts that have specific meanings in the scientific community. The interpretive flexibility inherently associated with artifacts affords different language games so that it would be naive to expect students to redevelop those of existing scientific communities (Roth 1995 1996a).

Once changes in the public forum of the community become available, individual members need to have avenues perceived as safe by those individuals who contribute little to whole class conversation; here, they can use changed language games in practice through active participation. In our case, these opportunities existed in the small-group structured investigations and unstructured design and construction activities. Only through the perpetuation of the changes by many members can it be expected that the community's language game changes. The levels of participation in the ongoing conversation also contributes to the rate of change. During design and construction, we often found high levels of interaction within and between groups and an associated rapid spread of language games (how to use an elastic to drive a vehicle on wheels, a boat, examples of inclines). On the other hand, in spite of repeated discussions about pulleys and mechanical advantage, there were students who maintained the claims that "pulling down is easier than pulling up" even if the effort is twice as great as in the first case. This finding confirms that made in another classroom which showed rapid changes in language games when they were initiated by students, but much slower or negligible change when they were initiated by the teacher (Roth 1996b); and there is similar, anecdotal evidence that, where the circulation of knowledge among peers and near peers is possible, it spreads rapidly and effectively (Lave & Wenger 1991).

There are two constraints on learning new language games which underscore why the Lave and Wenger (1991) formulation of legitimate peripheral participation is not directly applicable to school situations. First, the new language game has to emerge as much as possible out of the other ones we know and understand; second, to participate in specific language games, one needs to participate in the very communities where those language games are part of meaningful practices (Ehn 1992). School science, however, cannot be viewed as a legitimate peripheral participation in or enculturation to canonical science because the usual mechanisms of participation are not maintained. We thus view science classrooms as communities which are provided with opportunities to change their language games about specific objects. Here we have shown how artifacts and concomitant social configurations and physical arrangements afford different levels of participation, feedback, control, and access.

As classroom teachers, we operate under the constraint of our mandate: to teach a subject. This implies that we do not encourage the development of just any language game, but those which show some family resemblance with that of the scientific community. Artifacts that invite and support students' participation constitute an important part of the development of language games. Well-designed artifacts must encourage the members of the community to engage and enable and empower them to increase the depth of their participation in proportion to their competencies (J. S. Brown & Duguid 1992). We showed here how communicative practices not only depend on the artifact but that the interaction of artifact, social configuration, and physical arrangement create differential affordances for participation.

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