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From dialogue to monologue and back: Middle spaces in computer-mediated learning

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Abstract The authors develop a framework for the design of tools to mediate collaboration intended to lead to learning. We identify two categories of media that are common in computer-supported collaborative learning and software in general: communication media and information media. These two types of media are then mapped onto two types of social activities in which learning is grounded: dialogue and monologue. Drawing on literature in learning theory, we suggest the need for interfaces that help students to transition from dialogue to monologue and back again. We examine in detail two cases of students participating in a computer-mediated science learning activity that involved technologies designed to support this transition, and suggest ways that the "middle space" can be supported with software and activities that transcend some of the traditional tradeoffs associated with information and communication interfaces.

Q1 **Keywords** Dialogue · Middle space · Monologue

To better understand and design more effective tools to support computer-mediated collaborative learning, we must understand both the ways in which media mediate certain types of interactions and the way it mediates the process by which people are able to construct and negotiate meaning through interaction and collaborative activity. In this paper, we begin with the assumption that all computer-based media are to some extent

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collaborative, since all media presume some sort of audience, even if the audience is oneself (Eco, 1994). Based on this assumption, we fuse a human–computer interface design perspective with a social interaction and social learning perspective.

In this paper, we first describe two types of computer-based media genres: information genres and communication genres. We then examine an interesting parallelism between these two types of technologies and theoretical notions about monologue and dialogue in learning. We examine two case studies of students engaging sequentially with different models of collaboration supported by different computer technologies. From our developmental and historical account of learning in these two case studies, we propose a learning principle for how to promote effective learning trajectories. This principle recognizes the dialectical relationship and complementary functions of engaging in a back-and-forth dialogue with one's peers and reflectively reorganizing that dialogue into a monologic text for public presentation. We advocate abandoning the forced dichotomy between two genres of collaboration tools and call for more CSCL tools that begin to fill out the "middle spaces" between information and communication interfaces. We recommend doing so by designing progressive tools and activities that offer more structured dialogues, more open monologues, and semiotic pivots to help students quickly move back and forth between different modes of collaboration.

Interface design: From information to communication

In this section, we describe two stereotypically different types of computer media: information interfaces and communication interfaces. These types of interfaces differ in the primary goals that drive their design (and as a result differ in the types of activities for which they are used). Information interfaces are designed primarily around individual access, manipulation, synthesis and analysis of information. In contrast, communication interfaces are designed to support interactions between people (generally communication between individuals or small groups). Information interfaces might be thought of as functional extensions of libraries and filing cabinets, mediating an individual's interaction with his/her culture's historically constituted knowledge base and ways of thinking. Communication interfaces are often viewed as extensions of messaging systems, such as postal mail or telephones, mediating a group of individuals' interactions with each other and coordinating their joint activity.

Generally, these two types of interfaces are seen as separate. A number of researchers have pointed out the differences in design constraints for "groupware" interfaces as opposed to informational interfaces designed for individuals (Grudin, 1994; Shneiderman & Maes, 1997; Winograd, 1988, 1989). One reason they are seen as different is that information interfaces tend to be data-centric, meaning they take much of their structure from the form of the information they contain. For instance, a computer-aided design tool is highly specialized to represent abstracted three dimensional data, while calendar management software is highly specialized for representing appointments, lists of tasks to do, etc. Information interfaces often deal with issues of search and retrieval, or perhaps information presentation and visualization. Information interfaces also tend to be more context-independent, presenting information intended for any user in idealized or generic contexts. In contrast, communication interfaces tend to be more domain-general and process-focused. They take their form more from interaction processes than from the content of the domain, often striving for verisimilitude to offline interactions, such as face-to-face discourse or group work. Communication systems frequently include explicit

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support for social features such as authorship, privacy, and turn taking. These interfaces also tend to present information that is highly contextualized. For instance, an e-mail message might make sense only to its intended audience, the addressees, in the context of an assumed shared understanding of the particular topic, history, norms and vocabulary of the electronic conversation.

The reciprocality of monologue and dialogue in learning

A parallel can be made between these different genres of interfaces and media, and sociocultural learning theory. Sociocultural perspectives (Cole, 1996; Wertsch, 1985) have argued that learning occurs as a result of first participating in activities with others who scaffold the process (i.e., a type of structured dialogue), leading to an appropriation of the tools, rules, and practices of the activities (i.e., enabling monologic and independent activity). Communication interfaces are aimed squarely at the first aspect of this process while information interfaces seem better suited to the expression of appropriated knowledge. Is there a middle path between "personal computing" and "interpersonal computing" when it comes to learning?

One way to frame the design of learning environments (especially collaborative learning environments) is to explicitly specify the types of social interaction and communication they support. We argue that one important dimension of social interaction to consider is the difference between dialogic and monologic discourse.

By *dialogue*, we mean an interaction in which participation is distributed across individuals, and where the production of meaning is dynamically negotiated within and dependent on the current context. Dialogic forms of communication stress that the meaning of a message is negotiated in interaction and only partly determined by its semantics. Additionally, according to Bakhtin's theory of dialogism, the listener is assumed to take an active attitude towards the text or another person's utterance, and it is not until an utterance is responded to that it is understood (Holquist, 1990). In fact, one of the often-cited educational advantages to engaging in dialogue is the interpenetration of multiple contexts brought to bear by the different interlocutors, especially when they are engaging in argumentation (Bell, 1997, 2002; Means & Voss, 1996; Pontecorvo, 1993; Sandoval, 2003; Wegerif, 2006).

On the other hand, in a monologue the meaning of the "text" is, at least at first glance, more coherent, organized, self-contained and maximally explicit. Consider the examples of a book, or a student's essay exam. Roughly, monologic discourse appears to speak with one voice and carry within it more of the context that makes it comprehensible. The message of a monologue is not typically debated nor negotiated with its intended audience during its production. In monologue, meaning is not seen as the product of interaction but the expression of one person's ordering of experience (Coutler, 1999). Because monologue lacks a shared communicative context, it requires the text to be maximally explicit in its linguistic formulation. Further, monologic forms of communication assume that the objective semantics of the message itself are adequate to convey the text's meaning, and they do not provide a means for refining or extending this meaning. From this perspective, one can see that relying solely on monologic forms of collaboration embodied in informational interfaces can reproduce many of the faults and limitations of the much criticized transmission model of communication and instruction (Pea, 1993).

However, on close examination the appearance of one voice in a monologue is in fact produced by the control and organization of multiple voices. One critical factor in determining

what is monologue and what is dialogue is not the number of participants involved—even a monologue theoretically involves both a speaker and a listener. Rather, the critical factor that distinguishes a dialogue from a monologue is "the degree to which both parties participate in a concrete speech setting to produce a text" (Yakubisnkii, 1923, 1979). As Bakhtin pointed out, even a single person's utterance or monologic text is dialogic and multivocal and filled with "dialogic overtones" (Bahktin, 1984, p. 92). That is, in constructing an utterance the speaker borrows and weaves together the words and voices of others while populating them with their own intentions and subjectivity. These voices interact and inter-animate each other, juxtaposing the different frames that people use to organize experience in productive ways (Eco, 1994). However, this interanimation does not depend on the immediacies and contingencies of interaction in the same way a dialogue does.

We propose that the production of a monologue can be seen as an activity in which the object is to consolidate or recapitulate a previous (possibly inner) dialogue. From this perspective, monologues can be seen as second-order dialogs that differ from first-order dialogs in the degree of reorganization and reflection that is involved during the activity. Further, monologues are second-order dialogs in the sense that they are internalized, or as in our data, external, representations of dialogues. That is, we focus on the intent or purpose of the communicative context to define it. Monologic representations (henceforth monologues) may well be produced by multiple people via a dialog, but when the intent of the interaction is to create a stand alone text, we refer to it as a monologue. Finally, while a monologue is constructed with an audience in mind (much the same as a dialogue), the audience is an idealization who is imagined to have a certain background and is anticipated to react to the monologue in particular ways. In this way, monologic texts are "calculated to be responded to in turn" (Bakhtin, 1986, p. 72; as quoted in Holquist, 1990), but this imagined interaction occurs within a single subject.

Integrating dialogue and monologue in education through progressive discourse

In our formulation of learning through social interaction, we see the value of both dialogue and monologue. Following Wells (1999) and Bereiter (1994), we advocate designs that support *progressive discourse*. Progressive discourse is characterized by the joint construction of a shared body of knowledge. The discourse progresses as individuals take up what is said by others, compare it to their own understandings and respond to these ideas, pushing the collective discourse forward and at the same time extending one's own thinking. In progressive discourse, learning is a byproduct of participation in a series of linked dialogs and monologues (see Enyedy, 2003, 2005 for other examples of learning through progressive discourse).

We wish to specify a particular type of progressive discourse in which there is a progression within the collective discourse from dialogue to monologue and back again. In our formulation of these cycles of progressive discourse, it is not only the encountering of other's ideas that is important, but the continual re-organization and reflection that occurs when one attempts to take the multiple voices of a dialogue and wrestle them into a coherent story that, in turn, can be the object of the community's future dialogue.

Two qualities of dialogic speech seem especially fitted for the early stages of a student's participation within a community oriented towards the production of knowledge. First, because dialogic speech occurs within a shared communicative context requiring less explicit linguistic formulation, students may find it easier to articulate their emerging understanding of the domain. Students' abilities to verbally describe a concept has been

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shown to often lag behind their conceptualization (Crowder, 1996; Crowder & Newman, 1993; Roth & Welzel, 2001). Helping students to publicly articulate and "make visible" one's initial and emerging understanding within a medium that is tolerant of implicit and informal articulations is a critical aspect of active learning (Bell, 1997; Enyedy, 2003; Koschmann, Myers, Feltovich, & Barrows, 1994).

Second, once a student's thinking is made "visible" it is available to others for comment, criticism and negotiation. Different meanings, stemming from different histories for the same words, come together in interaction. When these differences and conflicts come to light in a dialogue, there is the opportunity for meanings (and people) to shift to and appropriate the words and ideas of others. Dialogic interaction allows for interlocutors to give each other timely feedback on each other's ideas, leading to the iterative refinement of partial meanings and the construction of increasingly sophisticated approximations of normative concepts (Roschelle, 1992).

Monologues also have educational value. While the consumption of monologues as the primary activity of students has been roundly criticized, many researchers and theorists see value in having students produce monologues as part of the learning activity. One advantage stems from the fact that in schooling, monologic forms are the hallmark of individual competence and accountability and are one of the primary measures of expertise in learning assessment. Student monologues, such as essays or test responses, are used to judge students' competence and are often used to identify experts long after formal schooling. Second, monologic communication provides a more ordered presentation of the information and can be particularly persuasive and helpful when the goal is to establish a consensus. Given the emphasis on argumentation in the pedagogy of mathematics, science and social studies, the ability to produce an organized monologue is an important tool in the toolbox of academic discourse. Third, the explicitness of monologic expression represents a significant intellectual challenge and the value of concise and concrete expression of one's ideas for one's own learning has been well documented in psychology (Chi, de Leeuw, Chiu, & LaVancher, 1991, 1994).

Tools designed to facilitate monologues can lead to dramatically different participation structures and interactions than the tools that are designed to facilitate dialogue.[1] Dialogue shares many of the features of communication media, with a more distributed locus of control, more inclusive participation, and a focus on interaction and co-construction of meaning. Monologue, on the other hand, shares many of the features of information-centric media: more context-independence (i.e., assumes a limited role of the context in establishing the meaning of the text), lack of social cues and a focus on the structures of the domain (as opposed to the structure of human interlocution. In addition, the two types of tools make differential assumptions about the nature of "meaning" and how it is created and communicated: information interfaces tend to use a storage–transmission–retrieval metaphor, while communication interfaces use a discursive metaphor (see Table 1). This is important because the affordances and constraints of these tools reflect epistemological assumptions about the nature of meaning and the nature of participating in a community of practice. These assumptions may be communicated to students when they interact with the tools.

[1] While we recognize that the features of a technology do not determine how that technology evolves and/or is used in practice, what a technology supports, constrains, and makes easy does influence the negotiation process.

Table 1 Summary of constraints of information and communication interfaces t1.1

	Information interface	Communication interface	
Constraints on the process of interaction	Information is transmitted and passively received	Information is actively negotiated	t1.3
Constraints on the product of interaction	Information is structured conceptually	Information is structured sequentially or hierarchically	t1.4
	Monologue	Dialogue	t1.5
Constraints on the process of interaction	Meaning is assumed to be self evident, maximally explicit, and context independent	Meaning is negotiated, indexical, and context dependent	t1.6
Constraints on the product of interaction	The "text" is an expression of an individual's (or group's) ordering of experience	The text emerges and reflects the bi-directional, reciprocal unfolding of the conversation	t1.7

We adopt a dynamic and relative view that begins from the assumption that learning is not a single, monolithic event, but is comprised of a series of separate, interrelated activities. Further, we assume that a learning trajectory is likely to include a number of different contexts, some of which may be best supported by dialogic, communication interfaces and some of which may best be supported by monologic, informational interfaces. While the specific relationships between monologues and dialogs may vary with the situation, tasks and individuals, we believe the tools—what types of interactions they afford and constrain—will play a major role in how the relationship is resolved in any instance. The point is to endeavor to offer the right tool to the student, at the right time, along the student's learning trajectory. Better still, it forces us to consider the progression of discourse and to prompt and support shifts from dialogue to monologue and vice versa. In short, it suggests we design progressive discourse tools and activities that offer more structured dialogues, more open monologues, and ways to quickly move back and forth between different modes of collaboration, in which students will be able to use the tools in a manner supportive of their learning wherever they happen to be in their learning trajectory. This represents a somewhat radical departure from the previously existing dichotomy of interfaces that either support individual, content-specific computing and those that support direct communication (such as computer-mediated communication tools, or CMCs).

Creating middle spaces for science learning

Here we explore an example of how dialogue and monologue were mediated by a set of tools designed to create a middle space for learning. First, we describe the research setting and the tools and activities with which students engaged, including some information about the intended properties of the tools. Special attention is given to an activity that allowed students to use a conceptual organization tool to construct a monologue-oriented artifact directly from posts in a dialogical threaded discussion system. Next, we discuss two case studies of students who used monologue and dialogue in different ways in this activity.

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Methods: Tools, activities, context, and data collection

Research context: The Knowledge Integration Environment

The Knowledge Integration Environment (KIE) (Bell, Davis, & Linn, 1995; Hoadley & Bell, 1996; Linn, Bell, & His, 1998; Linn, Davis, & Bell, 2004) was a research project created in the early era of the Internet that studied K-12 science learning via deep engagement with Internet-based tools. This research team developed a series of project-based science learning units in a variety of subject areas and tested them in a suburban partner classroom. Each KIE unit exemplified a different type of science project using the Internet: critique projects, theory comparison or debate projects, and design projects. The prototype design project was entitled *Houses in the Desert* and served as a capstone activity for the semester-long curriculum on light energy and heat energy-specifically, the concepts of heat capacity, thermal inertia, and insulation (Hoadley, 2004). The classroom studied was a heavily technology-supported environment. Students generally worked in dyads, with one Internet-connected computer per dyad. Generally, students would log in to the KIE system in pairs, and the software would manage students' participation though the steps of the activity and the types of software tools available to them at each stage. Two tools, the SpeakEasy and SenseMaker tools, are important to our analysis and are discussed below.

SpeakEasy: A communication interface for dialogue

SpeakEasy (see Fig. 1) was designed squarely in the paradigm of a communication interface and promoted dialogue. SpeakEasy was an early Web-based threaded discussion tool (Hoadley, Hsi, & Berman, 1995). However, because it was designed specifically for education, there are a few differences when compared to the general purpose tools available today. First, SpeakEasy provided two screens for postings: an *opinion area* with one comment per person that could be revised over time, and a *discussion area* with collapsible threaded discussion. Second, postings in the discussion area were categorized by the poster with labels from a fixed list such as *and, i.e., or,* and *but*. These link labels established a relational context between contributions. Not only were related contributions located together spatially (as opposed to being in the order the messages were sent, which is the norm for many discussion tools), but because of the labels the students could see discursive features at a glance, such as whether or not the second message was intended to disagree or add on to the first. These structuring features helped the students use SpeakEasy to establish a temporally and topically coherent discussion, which is a major problem with many of the existing asynchronous discussion tools (Herring, 1999). Lastly, comments were always attached to a face icon representing the poster, or to a generic face icon when students chose to post anonymously. See Hoadley (2004) for a more complete discussion of the evolution of attribution and anonymity in the tool.

In this classroom, the SpeakEasy was used for an extended (2–3 weeks) asynchronous discussions of scientific phenomena, and (unlike the typical classroom situation where student-run dialogues are rare, Gutierrez, Rimes, & Larson, 1995) the SpeakEasy discussions would typically be seeded by a number of comments from adults and then open solely to participation by students for the duration of the discussion. Students were placed in discussion groups of 15 people from their school; typically these groups included only a few other students from the same science period, and usually the discussion groups did not include a student's lab partner. Some discussions were homework, meaning they

Fig. 1 SpeakEasy opinion area

were not yoked to in-class activities, while others were done during class, at specific points during an in-class project. (Hoadley, 1999). In this study, the SpeakEasy tool is analyzed in terms of the dialogue it facilitated.

SenseMaker: An information interface for producing monologues

The SenseMaker tool (Bell & Linn, 2000) was an information interface designed to support the *production of monologues*. SenseMaker was created to help students prepare presentations that addressed important debates raised by the KIE projects. Thus, while the students were collaborating and interacting with each other, their intent was to produce a monologue. The tool provided students with a graphical organization space in which hyper-links could be dragged into nestable boxes called "claim frames" using the space on the computer monitor to organize claims and evidence. Initially, links began in a box labeled "to be categorized" and the students would create boxes representing claims. They could then drag the links into the boxes to show support for the particular claim. The students could create overlapping boxes or make copies of the bookmarks if they wanted to use the same evidence to support of multiple claims. Nested boxes were used to indicate either subcategories of support or chains of reasoning.

In this classroom, the SenseMaker tool was used during in-class online activities to help students substantiate scientific claims about light and heat energy. For instance, during a debate project created graphical "arguments" (box diagrams) with their lab partner in which "evidence" (bookmarks) such as websites, lab results from classroom experiments, or

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personal experience would be dragged into claim frames to help identify chains of reasoning. Follow-on activities included pairs of dyads meeting to explain and critique each other's SenseMaker diagrams, and then using a graphical display of their "argument" as a conversational prop during the whole-class debate. Thus, these representations were jointly constructed by dyads of students, but later became objects of wider discussion. Typically, these representations were not jointly constructed by the entire class, although they might be presented to everyone.

In this study, the SenseMaker tool is analyzed in terms of the way in which it supported the production of a monologue from dialogic utterances.

Houses in the Desert: A middle spaces unit to support progressive discourse

The *Houses in the Desert* unit was designed to help students integrate their understanding of heat flow, insulation and conduction, specific heat and thermal mass and the conversion of light energy into heat energy through absorption. The context for learning was a challenge to design a house that would passively maintain a comfortable temperature in the hot days and cold nights of the desert climate. The *Houses* project took approximately 3 weeks of classroom time at the end of the term. Students coming into this project had been primarily studying the relationship between heat energy and heat flow, and especially phenomena related to thermal conductivity. They had also done a number of units on light energy, with one lab on the absorption of light and its conversion to heat by dark materials. Although students had been exposed in one lab activity to the notion of specific heat and thermal mass, this was not the primary focus of the curriculum.

This activity consisted of several phases, listed below in Table 2. These descriptions are taken directly from the checklist and associated help files seen by the students during the project. A more extensive description of the design of this activity and the rationale for the activity sequence is available in Hoadley (2004). A number of monologic and dialogic activities were included in the intended activity structure for the unit. Students co-created the primary team artifact, the house design, and refined this at least once by creating an initial design and then editing this to create a final design (a monologue). Students were verbally encouraged to edit or refine their designs as often as needed. They also "digested" the monologues of others, both during the "Survey Evidence" phase of the activity, in which they read pre-selected websites, and during the "Gather Evidence" phase of the activity, in which students used a guided search tool that accessed a much larger set of websites related to heat, temperature, light, and building design. Dialogue in the project included whole-class discussion, teacher-led discussion (such as the initial problem definition discussion about desert climates), within-dyad interactions, team-to-team discussion (as during the project critique phase), and student-to-student discourse in the SpeakEasy.

Students entered the SpeakEasy to find a number of seed comments to which they responded with their own posts (for examples see the comments by ChrisH and AlexC in Figs. 3 and 4). Next, students were asked to use SenseMaker to reorganize these seed comments in the "Organize Ideas" phase of the unit. The students were asked to organize the seed comment postings as if each one were a separate piece of "evidence" for a particular point of view. The intent was for students to explicitly reflect on the ideas presented in a prior dialogue and consolidate them, making the SpeakEasy to SenseMaker activity a "middle space" for students. The students were then given another opportunity to engage in an online discussion using the SpeakEasy tool before finally going on to produce their final design. For the purpose of this study, the *Houses* project is analyzed as an activity

Table 2 Houses in the Desert activity sequence

Project step	Activities	Artifacts produced
Define problem	Participate in class introduction	Initial survey/pretest (monologue)
	Do survey about heating and cooling (handed out in class)	
Initial design	Think about what problems you are trying to solve	Initial design (monologue)
	Do one or more initial house designs.	
Survey evidence	Survey each piece of evidence	
	Desert climate biome	
	Enertia site	
	Heat capacity—comparing different materials	
	R-values	
	How building materials reflect light	
Discuss and refine	Read all SpeakEasy comments	SpeakEasy discussion (dialogue)
	Take the SpeakEasy quiz	
	Add your own comments	SpeakEasy quiz (monologue)
Organize ideas	Organize the ideas from SpeakEasy in the SenseMaker	SenseMaker argument (monologue)
Gather evidence	Use the design library	
	Look at science topics	
	Look at other house designs	
Critique and refine	Critique student house designs in class	
Final report	Write up your design report in Mildred	Report (monologue)
	Print out your evidence notes and turn in your worksheets	Survey (monologue)
	Take final survey	

structure that created a middle space by connecting otherwise isolated dialogic/communication and monologic/information activities/tools.

Data sources and analytic method

The *Houses in the Desert* project was developed in the paradigm of design-based research and its precursor, design experiments in which iterative refinement of the activity is used to inform theory (e.g., Brown, 1992; Design-Based Research Collective, 2003; Hoadley, 2004; Kelly, 2003). In particular, the unit was intended as a way of exploring *knowledge integration* as both a psychological theory of learning and as a design framework for instruction via the scaffolded knowledge integration (SKI) framework (Linn, 1995; Linn et al., 1998; Linn et al., 2004; Linn & Hsi, 2000). Importantly, design-based research allows implementation issues to help drive and refine both theory and questions, and this study is a perfect example of how rich data collected to inform one theory might be examined with a different theoretical lens (Design-Based Research Collective, 2003; Hoadley, 2002; Joseph, 2004).

Approximately 90 students participated in the activity. Each student completed a pretest after the initial class discussion of the nature of the problem and the desert climate. A final posttest was completed after final reports were turned in. In addition, students took a quiz

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on their recall of seed comments from the SpeakEasy. Generally, the student dyads moved through the activity at their own pace (and the classroom culture encouraged students to use after-school or lunchtime to work on projects if needed to meet project deadlines, so the variability in progress could be quite large), but the SpeakEasy quiz was administered to each period as a whole midway through the activity, constituting an intermediate checkpoint on their progress. In addition, their computer-based work (SpeakEasy comments, SenseMaker maps, final reports) was stored electronically. These four data sources—pre-test, post-test, SpeakEasy quiz, and digital artifacts—constitute the corpus we drew on for the analysis below.

While we came to the extant data for the present analysis with the lens of dialogue and monologue as our initial theoretical framework, we were less than sure of how to operationalize each category, especially as they occurred in some very new media (much as was the case early in the use of email; see Duranti, 1986). Obviously, the particular tools and activities could be analyzed with respect to their designed intention of supporting monologue or dialogue. Instead, we chose to take a modified grounded theory approach (Charmaz, 1983) and the first half of that process is reported below, namely our attempt to derive categories of discourse or domain ideas that appeared to have monologic or dialogic characteristics, or that facilitated transitions between them. Thus, although our lens of monologue and dialogue was specified a priori, the categorization of frames of discourse was emergent, and we let the data tell us where the boundaries between these two types of discourse might be drawn. The level of detail of the data is somewhat coarse, essentially sampling on the order of materials produced every few days in the activity. This produced considerable variability in how much might have occurred between data elements, but was an appropriate grain size to trace the development and the history of ideas. We consider generating these traces as a preliminary analysis aimed at theory building. As such, it is a precursor to uncovering stable activity patterns of learning and appropriation. Our aim is to use this sample of data to generate a framework that can inform a more complete and systematic coding of this corpus, or other data of computer-mediated learning, by advancing our theories of how the ebb and flow of monologue and dialogue contribute to the student learning in "middle-spaces."

Student cases in Houses in the Desert

In the sections below, we explore two cases of students who participated in this activity. Since the students worked in dyads, their partners' work is referenced as well. We selected two cases from the data corpus of more than 90 students based on the grade they received on their final design, choosing one group that received an exceptional mark of "A" and one that received a more typical "B" mark (on the typical American grading scale from A to F). The two cases show a striking difference in their use of the SpeakEasy to SenseMaker activity, and more generally the relationship between monologue and dialogue for these two students seems tellingly different.

Taken collectively, these two cases illustrate several claims about how dialogues and monologues worked together to at times support and at times limit the students' learning trajectories. First, many of the aspects of what the students learned can be traced historically through their interactions (usually with its initial origins in a dialogic interaction). Second, engaging in a dialogue alone did not seem to effectively support learning. Third, in transforming a dialogue into a monologic text, the students demonstrated a fair amount of

reflection about their own understandings of the content. Fourth, the production of a monologue was often the impetus for further dialogue.

Case 1: Detours and roadblocks in progressive discourse—Jordan

Jordan began this activity with some existing scientifically normative intuitions about heat capacity and thermal inertia. In the pre-test he described how the earth "takes longer to heat up"[2] than air. However, his initial responses to the pretest also showed some confusion about the role of insulation, equating insulation with keeping a house cool, but not with keeping it warm. His final post-test showed a similar attitude towards thermal inertia, namely, that it is easier to heat air than ground. Further, he showed continued, but different, difficulties with the notion of insulation. While he no longer equated insulation only with coolness, he did retain non-normative ideas about the transfer of heat (see Fig. 2). Jordan and his partner received a B on their final design grade. In this report, he and his partner pursued a heat storage/thermal inertia strategy, building a house half-buried in the ground, made of mud and adobe bricks, with double-paned windows.

The question that guided our analysis was: can we trace aspects of this design and student learning back to Jordan and his partner's participation in ostensibly dialogic and monologic activities during the project? Because this was a "less successful" example, we hoped to trace problems in the final outcomes back to problems and omissions in Jordan's participation in a progressive discourse.

Preliminary dialog: Seed comments and recall

As noted in the methods section, the SpeakEasy activity began with seed comments that represented two scientifically normative design strategies, insulation and thermal storage. While we do not have any clear record of the verbal dialogue within the dyad, we have some evidence that Jordan attended closely to this initial dialogue in the form of a quiz midway through the unit. In Jordan's post SpeakEasy quiz, he correctly paraphrases the reasons suggested by the seed comments for choosing either insulative or high heat capacity materials, but displays a problematic understanding of R-value as "thickness" of a material rather than a measure of insulation. Additionally, he correctly identifies materials such as water and earth as having a high heat capacity. Engaging in a dialogue around the issue of heat transfer, thermal inertia, and insulation impacted Jordan's thinking, but as expected, engaging in a dialogue alone did not lead to a full understanding of these issues or clear up all his misconceptions.

Producing an online monologue from dialogue

Jordan's team participates in the SpeakEasy (dialogue) to SenseMaker (monologue)[3] activity by preserving the dialogic structure of the seed comments. Initially, the comments are in the "to be categorized" box and arranged according to the threading structure of the discussion. Jordan's team does not re-organize these comments conceptually. Instead, they merely create categories for each of the top-level discussion threads (See Fig. 3) and for the

[2] To avoid distracting the reader, we have corrected spelling and grammatical errors of quotes provided throughout this paper.

[3] Recall, monologues may be produced interactively.

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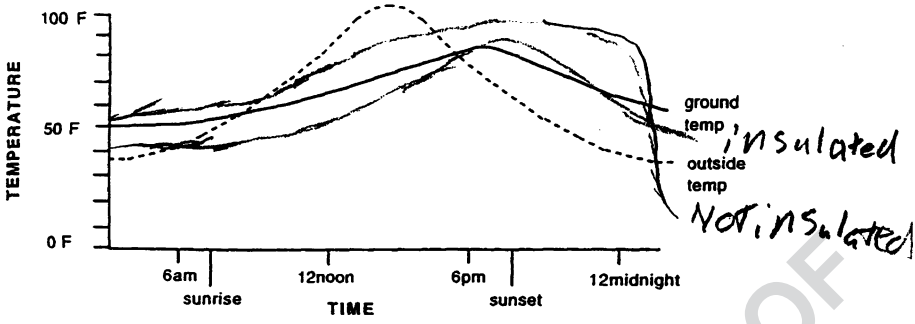
2. The graph below has the outside and ground temperatures drawn for you.



2a. Draw a line that shows what you think the temperature will be for a **well-insulated house**. Label it **INSULATED.**

2b. Is the line you drew for the **well-insulated house** closer to the **(circle one)**:

A. ground temperatue
B. outside temperature
C. none of the above

2c. Can you explain why?

because I think that it would keep up like the ground

2d. Draw another line that shows what you think the temperature will be for a **poorly-insulated house**. Label it **NOT INSULATED.**

2e. Is the line your drew for the **poorly-insulated house** closer to the **(circle one)**:

A. ground temperatue
B. outside temperature
C. none of the above

2f. Can you explain why?

because I thingk that it wloud look defer inT,

Fig. 2 Portion of Jordan's post-test worksheet

opinion area comments. Although the tool and activity were designed to support a conceptual organization rather than a discursive organization, it appears in this case that Jordan's team did not take advantage of this opportunity. This lack of reflection and re-organization contributed to the problems they have with their final design and limited what they learn from the experience overall.

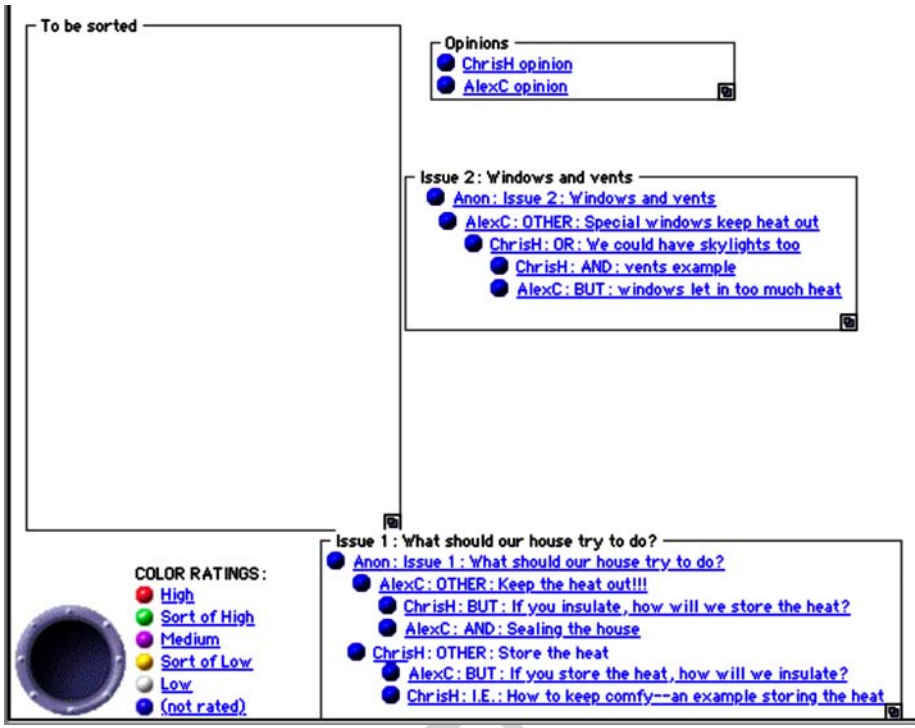


Fig. 3 Jordan and Ann's SenseMaker

Online dialogic participation

Jordan was an active participant in the second SpeakEasy-based dialogue (Table 3). He made six posts, twice as many as required. Effective dialogue involves both listening to the ideas of others and contributing one's own ideas to the conversation. Jordan's posts are split between these two functions, with four referencing and depending on other posts and two that—while they are within threads—stand alone in contributing a new idea. The four responses are clearly related to and locally coherent with their predecessor comments and are difficult to understand out of context. All of Jordan's posts are substantive, as opposed to simple "I agree" type posts used for conversational maintenance. For instance, when he agrees with someone on the subject of insulation, he qualifies his agreement with a proposal inviting response: "I agree, but shouldn't any house even on the desert have some kind of windows?" Jordan's participation in SpeakEasy relates to several science concepts; he explores the practicality of water as a building material, the relationship of windows and vents to the temperature of the house, and some ideas about roof color and reflection of solar energy. Thus, it is here in the second dialogic activity that Jordan's team begins to make some progress towards their design.

Links between online dialogue and final design.

Jordan's online discourse is linked to his team's design—a second monologue. Jordan's team's final report shows a design with three primary features: the structure

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Table 3 Jordan's SpeakEasy postings

Preceding post(s)	Selection of Jordan's posts
Keep the heat out (seed) I think we should try to keep the heat out by insulating with bad conductors (like Styrofoam or wool) Heat flows more slowly through insulators than it does through good conductors, which we learned in the coke and potatoes lab.	*I agree but:* I agree, but shouldn't any house even on the desert have some kind of windows?
Windows let in too much heat (seed) When the problem is keeping the house cool, heat from windows is greater than heat from roofs. The article talks about putting windows high on the walls to allow in light but keep the sun's heat out. I need to understand how this works because it seems related to the insulation strategy.	*But:* I agree with your statement, but you can use special windows to prevent heat from getting in.
Houses in the desert (seed) How can we design an energy efficient house for the desert? It should stay cool during the day and warm at night. Support your decisions with evidence and examples.	*House in the desert:* To design an energy-efficient home in the desert you must put some of the house underground to keep it at a moderate temperature day and night. But you still must put [on] a good insulator such as Styrofoam. The roof will [be] one side facing the East where the sun rises and the other side of the roof facing west where the sun sets. The roof would be a mirror to reflect the sun.
What should our house try to do? (seed) What should our house try to do? What kind of heat flow do we want?	*Our house should:* Our houses should stay the same temperature through dark and the light. We would do this by insulating the walls with good insulators, but bad conductors. The windows would be triple-paned to help prevent heat from getting in. Our roof would be all solar panels.

was four feet underground, it was constructed of adobe bricks and mud, and it had heavily insulated windows. This design picked up on the ideas discussed in the second SpeakEasy dialogue. In the case of windows, the idea was introduced into the discussion by another person, and appropriated by Jordan and his partner. In the case of the underground building strategy, Jordan introduces this idea into the SpeakEasy dialogue. The idea is picked up by another student in SpeakEasy and extended to a two-story strategy (one story underground, one above ground) and connected to the use of bricks for thermal storage. In their final report, Jordan's team adds the idea of bricks for thermal storage to their prior underground building strategy, and they explicitly mention having considered but rejected a two-story design strategy. In contrast, several design elements that Jordan proposed in SpeakEasy such as vents, solar panels, Styrofoam insulation, and building orientation were not carried through into the final design (despite the fact that in at least one case Jordan explicitly states in SpeakEasy that this strategy will be used in the final design). Nor were they mentioned as ideas considered and rejected when the final report template explicitly prompted for such alternative ideas. Thus, all of the elements of this team's final

design can be traced back to comments in Jordan's SpeakEasy dialogue, although not all of the key elements of Jordan's dialogue can be traced forward to the final design report.

Interactions within the dyad

The influence of Jordan's partner Ann is noticeably absent. Ann's pre- and post-test both show a focus on insulation concepts and a relative ignoring of thermal inertia concepts. When prompted to explain the delayed and dampened thermal shifts in the ground temperature when compared to the air temperature, Ann uses the concept of insulation to explain this on both pre- and post-tests. Her recall from the SpeakEasy seed comments similarly focuses on the role of insulation: she fails to summarize any of the seed comments related to thermal inertia, but correctly summarizes the seed comments that mention an insulation strategy. She characterizes the seed comment conversation solely in terms of insulation, saying, "[they] disagreed on whether or not they should have the house insulated or not, and why they think so." Recall that it was the concept of insulation where Jordan had the most conceptual difficulty. Yet, two of the three core features of their team's final design are related to thermal mass; only the windows are related to an insulative strategy for the design. More importantly, Ann did not contribute at all to the class' SpeakEasy dialogue where the majority of ideas for the final design originated. While we cannot be sure, it seems reasonable to assume that Ann did not have a major voice in the final design decisions, since this design hardly reflects her understanding of the domain, nor does she herself exhibit change in her thinking as a result of her interaction with her lab partner.

Summary: Connections between monologue and dialogue.

In this case, we have seen that Jordan engaged in a lively online dialogue, which in turn influenced the team's final design. However, evidence of dialogic influence from Jordan's partner Ann is missing and Jordan appears to have missed the opportunity for a conceptual transition from a dialogic to a monologic structure in the SpeakEasy to SenseMaker activity. Since we have no record of the student's face-to-face interactions, it is impossible to tell what the full range of monologic and dialogic activities that they engaged in were. However, it would appear that this is not an ideal case of leveraging the affordances of the tools provided for transitions from dialogue to monologue and back. The complete lack of dialogue from half the team (i.e., Ann) and the relative lack of monologic/reflective activity by both students can be seen as missed opportunities that interfered with the students design process and ultimately their conceptual change.

Case 2: Successful progressive discourse—Connor

Our second case is similar to the case of Jordan in terms of what the initial dialogue looked like, but has some important differences with respect to transitions between dialogue and monologue. Connor worked in a team with a more active partner, Tom. Connor's initial conceptions reflect an understanding of insulation, but are not entirely scientifically normative for thermal mass. With respect to thermal mass, he incorrectly states that ground temperature lags air temperature because "sand does not hold the heat very well." On the other hand, Connor appears to have a normative understanding of insulation and its relationship to surface area. Connor's post-test shows more elaboration than his pre-test, and there is some evidence of increased understanding of the relationship between thermal mass and conduction when he describes how a poorly insulated house "might absorb the

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heat better" than the earth. These concepts are still in transition though, as his post-test graph of insulated and non-insulated house temperatures show a non-normative view. Connor's partner, Tom, likewise mentions both thermal mass and insulation/conduction phenomena; he correctly graphs insulated and non-insulated house temperatures on both pre- and post-tests, and in the post-test even describes the role of solar energy in driving daily swings both in air and ground temperature. His post-test, however, non-normatively states that earth is a better insulator than air, although he correctly describes how this system would function if that were true.

The two boys received an "A" on their final house design, which used a combination of thermal insulation and thermal inertia strategies by insulating the house well and by including an indoor basement swimming pool connected to an exterior, passive solar water heater. They also describe a system for managing the absorption of light energy and its conversion to heat at different times of day using a combination of color, materials, orientation, and awnings/screens.

Preliminary dialog: Seed comments and recall

On the quiz mid-way through the unit, Connor correctly recalls and paraphrases all of the building materials mentioned in the seed comments, and in the case of insulating materials such as Styrofoam and wool, he links the material to the heat flow mechanism. Connor also correctly associates both water and earth with the concept of heat storage. This implies that, as was the case for Jordan, after the initial dialogue in the SpeakEasy Connor's thinking had already started to change.

Producing an online monologue from dialogue

In the SenseMaker activity in which the team is supposed to construct a preliminary monologue, Connor's team performs differently from Jordan and Ann's (see Fig. 4). Connor and Tom take the seed comments and reorganize them, changing them from a discursive structure that reflected only the order in which they were presented to a conceptual structure with four main categories. Two of the categories correspond to the major instructional objectives of the unit: thermal insulation and heat storage (i.e., thermal mass). The labels for these categories also explicitly linked design strategy to scientific mechanism: "use a good insulator, to keep the heat out" and "use thermal mass, storing the heat." The content for these conceptual headings were copied directly from the various threads of the discussion to form each of these two primary categories, and corresponded to the two strands of ideas in the seed comments.

Two additional categories were created that integrated comments from both seed contributors. First was a category on "heating," that contained two subcategories related to passive vs. active heat transfer, labeled "natural heating" and "artificial heating." This category contained comments that did not discuss an insulation or thermal inertia strategy, but rather contained information about windows and vents and their impact on passive or active movement of energy into and out of the house.

The second category they added was labeled "questions." This category held three comments that helped frame the entire discussion. First was a comment asking about what kinds of windows and vents the house needed. Second was a comment titled, "What should our house try to do?" which explicitly asks what type of heat flow is desirable in this project. Third was a seed comment titled, "If you store heat, how will we insulate" which

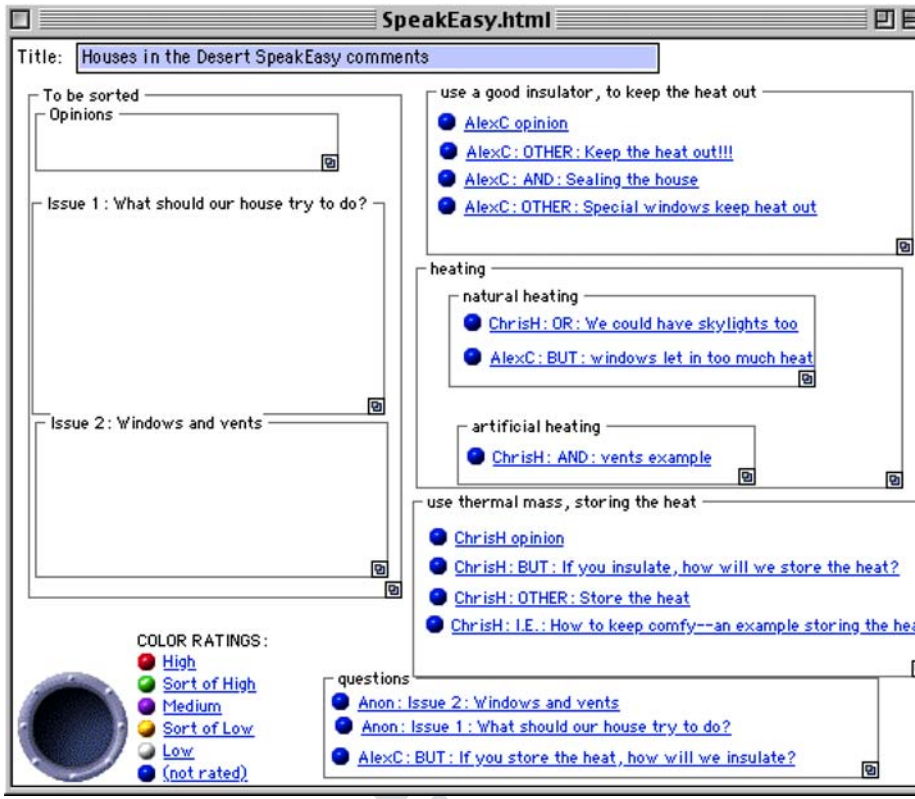

Fig. 4 Connor and Tom's SenseMaker

questions the insulation properties of water. These questions capture some of the most important design decisions faced in the project.

The SenseMaker activity was a significant event in the students' learning trajectories. In constructing a monologue for presentation, the students engaged in a significant amount of reflection and re-organization of their thinking. Perhaps the most significant aspect of this activity is that it led the students to recognize that they still had several questions that they did not know how to answer. These questions drove much of their subsequent dialogic activity.

Online dialogic participation

Connor participated in the online discussion with five contributions (Table 4). Unlike Jordan, where each post was either a "listening" post or a "talking" post, each of Connor's posts both referenced a prior comment and contributed a new idea to the discussion. Three times he built on prior comments and elaborated them, and twice he questioned someone else's idea. These comments were also well connected to three of the four new questions they developed in the SpeakEasy to SenseMaker activity. Taken together, these posts address both major design approaches—thermal inertia and insulation strategies—as well as the inclusion of windows/vents. For instance, Connor asks another student who had wanted to include windows in his/her house "Windows are fine; they might heat the house up a

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Table 4 Connor's SpeakEasy posts

Preceding post(s)	Selection of Connor's posts
Keep the heat out (seed) I think we should try to keep the heat out by insulating with bad conductors (like Styrofoam or wool) Heat flows more slowly through insulators than it does through good conductors, which we learned in the coke and potatoes lab.	*That would keep the heat in:* If you wrap the house in a good insulator it will not only keep the cold air out, but it will keep the heat in, which will not let the air circulate.
Store the heat (seed) I think we should use water to store the heat. The pulsing lab showed it takes a lot of heat energy to warm water up, and we should use it to get heat in the day and save it for night.	*How could you store the water:* How could you store the water so that it stores the heat for night but doesn't heat up the house at the daytime?
Windows let in too much heat (seed) When the problem is keeping the house cool, heat from windows is greater than heat from roofs. The article talks about putting windows high on the walls to allow in light but keep the sun's heat out. I need to understand how this works because it seems related to the insulation strategy.	*Windows are fine:* Windows are fine; they might heat the house up a little bit, but not too much, that is if you do it right. I think that if you put overhangs over the windows, and maybe screens, that your house will not be affected.

little bit, but not too much, that is if you do it right. I think that if you put overhangs over the windows, and maybe screens, that your house will not be affected." As was the case for Jordan, the content of these posts foreshadow the content of the final design. However, unlike the case of Jordan, the five comments can be traced back to the SenseMaker monologic activity.

Links between online monologue, dialogue, and final design

In examining the connections between Connor's on-line activity and the content and organization of the final design, we were struck by three important connections. The framing of the problem, the features of the design solution, and the direct connections that the students forged between the SpeakEasy dialogue and the SenseMaker monologue by cycling back and forth between the two on-line tools.

First, in framing the problem Connor and Tom integrate the two opposing design strategies—thermal mass to heat or cool the house at the appropriate time and insulation to limit the change in temperature from the outside conditions. Previously, they had these ideas in opposition to one another and physically separated in SenseMaker. In their problem statement below, we have italicized phrases or ideas that can be traced to the way they organized the seed comments in the SenseMaker activity:

> What we need to figure out is how to *naturallycool, and heat the house*, so that we can live comfortably in all conditions. Our design needs to be *a good insulator, so that very little heat energy can heat or leave the house*.

Second, we noticed that, like the case of Jordan, the features of Connor's design can be traced to the ideas he generated and the ideas he was exposed to in the second SpeakEasy dialogue. Most notably, the idea for the two tanks of water actually originated with a non-case study student who responds to one of Connor's posts. Connor's post questions a

thermal mass strategy of using glass bricks filled with water. Another student replies to Connor suggesting the use of tanks instead. Although we have no way to know for sure if Connor read the student's reply to his post, we do see the two-tank idea emerge as the centerpiece of their design. Additionally, insulation was mentioned in one of Connor's posts and is a feature of their design. Finally, and most directly, we see that the idea of using awnings and screens, which was introduced by Connor as a way to mitigate the problematic features of having windows, also becomes a major feature of their design. Thus, all three of their design features can be traced to the content of the SpeakEasy discussions.

The third important connection was the interconnections between the SenseMaker and the SpeakEasy activities. In the case of Connor and Tom, Connor posts two initial messages to the SpeakEasy discussion board: one about insulation and one about water and its thermal inertia. Then they engage in the SenseMaker activity in which they take the product of their dialogue so far as an object for further reflection and reorganization. It is from this reorganization of posts that they realize that they have unanswered questions. One of the tools that they use to answer these questions is further dialogue within SpeakEasy. One of their questions, the question about windows and vents, is the topic of all three of Connor's remaining posts. It was just these types of connections that were missing in the case of Jordan. Thus, SpeakEasy was used both to generate ideas and to remediate problems generated by reflecting on their progress toward their goals.

Interactions within the dyad

Even though Tom (Connor's partner) demonstrated a more complete understanding than Connor on the quiz and on the post-test, he also appeared to be more of a follower than a leader in the dialogic aspects of the activity. He contributed the minimum number of posts to the SpeakEasy dialogue, and these were all on one afternoon, after the SpeakEasy to SenseMaker activity. The content of all but one of his posts reflected ideas already posted by his partner. However, he did raise a new issue in his comments. It was Tom who first raised the issue of the house's color, which showed up in Connor and Tom's final design. This indicates that he was more of an active participant than Ann was in Jordan and Ann's design.

Summary: Connections between monologue and dialogue

As in the case of Jordan, in this case the seed comments started Connor thinking and initiated changes in his ideas about heat and temperature. However, unlike Jordan, in moving from dialogue to monologue, Connor consolidated his understanding of the problem and identified knowledge gaps. He then took these questions back to the dialogue, eventually incorporating their answers into the final product, which is yet another monologue. Connor was notably both more diligent about carrying themes between the dialogic and monologic activities and more successful in making progress on these ideas.

Discussion: Between information and communication

Earlier, we proposed some differences between information and communication interfaces. Theories of learning through social appropriation suggest that learners may benefit from

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moving through both communication-oriented and information-oriented activities along their learning trajectory. We have analyzed one environment that integrates two tools to support dialogue and monologue and the transitions between them. Our conclusions and findings are clearly limited by the case study nature of our design and by the lack of process data for the students. Still, our analysis was able to draw several explicit connections from what the students learned back to the traces of their activity with our mediating tools and our analysis suggests that these conjectures warrant further study. The key feature of these tools that seemed to facilitate successful transitions between monologue and dialogue is allowing external knowledge representations to move easily from interfaces that encourage dialogue to those that support monologue production and back again. In this manner, electronic media provide an important opportunity for learners to not only externalize their ideas through dialogue, but also to reflect on, reorganize—and some might say deconstruct—their own discursive production. This is an important advantage over typical school settings where dialogue is often oral and ephemeral, and monologues are seen as final products with little role or value after they are complete.

In our analysis, we have drawn several connections between information-based interfaces that mediate monologue and between communication tools that mediate dialogue. Dialogue and communication tools share a propensity toward context dependence, tightly coupled interaction and inclusion of a wide variety of communicative cues, such as socially relevant representations (Hoadley, 1999; Hoadley et al., 1995; Hoadley & Kirby, 2004). Monologue and information tools offer tightly structured ways of presenting information that constrain interpretation and encourage convergence.

Both processes are essential in education. We do not want students to have completely different understandings of a domain. Neither do we want students to merely memorize and parrot what a teacher has told them. If we take seriously the concept of a learning trajectory in which students learn first from dialogic activity and move toward the more structured communicative forms of extended monologues, then cycle back to dialogues, then we must better understand how tools mediate different types of interaction and how they can potentially mediate the shifts in activity that occur along a learning trajectory.

As it stands now, the divide between information interfaces and communication interfaces creates a chasm that learners must cross if they wish to internalize ideas and move towards more expert, independent practice and understanding in a domain. This study showed how the chasm was bridged by an activity structure and sequence that forged connections between an information tool and a communication tool. However, these two tools remained distinct as tools. This is a limit of this study and of the field in general. To the degree that information and communication tools are perceived by learners as distinct learning environments, they are less likely to transfer their habits of mind and ideas from one tool to the other. This argues for integrating computer-supported collaborative learning tools across the continuum to facilitate progressive discourse across both communication and information tools and for filling in the "middle spaces" within the continuum with new types of tools. The challenge presented to us is to design and build tools that transcend some of the either—or tradeoffs associated with the information—collaboration dimension and to support both dialogue *and* monologue.

Where are the crucial points of leverage that allow the design of such tools? We propose three strategies to help create middle spaces and support progressive discourse and learning: more open monologues, more structured dialogues, and semiotic pivots that permit transitions from one to the other. We take each of these suggestions in turn.

More open monologues

Digital tools open the possibility of more open, dialogic experiences while producing monologic texts. Digital tools permit activities like attaching discussions to monologues (for instance, linking Web boards to a PowerPoint slideshow), collaborative annotations (e.g., via Wikis), hyperlinking, referencing, and remixing (via cut-and-paste or Web linking), or weaving collaborative activity into monologic production (e.g., via a word processing program's "track changes" facility, which not only allows people to follow another author's actions, but also—through the "comments" feature—allows people to follow the reasoning behind the changes). Intertextuality becomes possible in digital media in a way that would be difficult to accomplish in oral or written monologues.

More structured dialogues

Similarly, new media may be able to support dialogue's move towards middle spaces. While flexibility is the watchword of technology's advantage for monologues, structure is the advantage new media can provide to dialogue. Most discussions of educational scaffolding (e.g., Pea, 2004; Wood, Bruner, & Ross, 1976) build on Vygotsky's (1978) zone of proximal development (ZOPD), and design technologies that take over the role of the more competent other by mimicking human tutoring and coaching via prompts, questions, and templates (e.g., Davis, 2003; Koedinger & Anderson, 1998; Suthers, Toth, & Weiner, 1997).

A second, more encompassing interpretation of the ZOPD is derived from Vygotsky's analysis of play. This notion of the ZOPD applies to situations where the model of competence is not represented by a person (or a computer facsimile), but is instead embedded into the tools and artifacts of the activity system that the students use to regulate their own behavior. Vygotsky (1978) introduced this version of the ZOPD with an example of two sisters *playing at being sisters*. In this case the sisters regulate their own behavior to only those actions that fit the rules of the play situation. As a result of playing sisters, the sisters come to understand that sisters have a different relationship to one another than to other people. Vygotsky (1978, p. 102) concludes, "this strict subordination to rules is quite impossible in life, but in play it does become possible: thus play creates a zone of proximal development of the child."

In the play example, it was the rules of the play situation that the sisters strictly adhere to, but do not fully understand, that takes the place of the more capable other. We think both interpretations—tutoring with a more capable other and self-regulated activity within a structured activity system—are important to the field of CSCL. However, the second interpretation is an important contribution to the design of computer-mediated learning systems that do not attempt to have the computer teach the students directly, but instead are designed to prompt and structure productive peer interaction.

Following this second interpretation of the ZOPD, scaffolding can be used indirectly to help constrain or support interaction. For instance, think types or semantic categories (Bereiter & Scardamalia, 2003; Hoadley & Bell, 1996) can help learners structure dialogue. The design of collaborative media allows inscriptions and social cues that help constitute the social context to be manipulated and designed (Hoadley et al., 1995; Kreijns, Kirschner, & Jochem, 2003; Suthers, 2006; Tomsic & Suthers, 2006). More recently, work on collaborative scripting (Fischer, Mandl, Haake, & Kollar, in press; Kollar, Fischer, & Slotta, 2005) has helped identify which types of supports can be used to make dialogic activities more productive for collaboration and learning. Indeed, it is still an open question what,

precisely, constitutes a script and which elements of dialogic activity should be mandated versus which should be left open (Dillenbourg, 2002).

Semiotic pivots

To facilitate the productive transitions between monologue and dialogue and back again, or more broadly what Suthers (2006) has referred to as CSCL's need to address "trajectories of participation," we introduce the concept of semiotic pivots. Interaction in CSCL environments leaves material traces of the interaction, such as chat transcripts, threaded discussions, or a web page. These traces can be leveraged for learning by porting them from one communicative context to the next, as was the case when points made in SpeakEasy were brought over into the SenseMaker environment. In the production of a monologue, viewing their own dialogue as an object can help students identify inconsistencies, incoherencies, or places where points were not discussed in the same depth (Suthers & Hundhausen, 2003). These observations are the first step in deconstructing, reorganizing, and reflecting on the ideas presented in the monologue. The traces can be seen as what Latour (1990) refers to as "immutable mobiles"—the text does not change as it moves from one context to the next. Because the communicative context around the text is changing, however, it creates an opportunity for the meaning assigned to the text to change. The textual trace of interaction becomes a semiotic pivot when it is engaged with in a new way and, as a result, the meaning of the text changes.

Our notion of semiotic pivots takes as its point of departure Vygotsky's notion of symbolic pivots. In his theorization of the development of the symbolic function through play, Vygotsky (1978) observed that in play a child assigns meaning to objects, but cannot yet assign arbitrary or purely conventional meanings as adults can. Instead, action provides a pivot for symbolization. Vygotsky (1978) uses the example of a child who places a broom between her legs to play horse. In this case, she assigns a symbolic meaning to the stick by using actions that can be used on both sticks and horses—both can be placed between one's legs. At the same time, she has chosen to ignore other aspects of the broom and by not assigning them significance, makes them semitotically invisible. Thus, in play, students are able to fluently use symbolism and abstraction in ways that remain difficult for them in other contexts. Likewise, with semiotic pivots the meaning of a text changes based on changes in the communicative context. We suggest that in the same way symbolic pivots contribute to cognitive development, semiotic pivots lay the developmental tracks for conceptual trajectories by facilitating changes along the trajectory of participation. For example, in the case of Connor, the partners engaged with the text of their previous dialogue with the goal of producing a monologue. They took the traces of that dialogue and engaged the entire exchange as a whole object, reorganizing the pieces of the whole to make it more topically coherent. This new engagement with the old text acted as a pivot for their understanding and led them to recognize the holes in their argument and the questions that they still needed to answer.

The importance of semiotic pivots in facilitating productive transitions between monologue and dialogue suggests three concrete design principles for CSCL environments. First, it suggests that our designs need to support the mobility of textual traces from one communicative context to the next. When a text produced in one communicative context is available in another context it has the opportunity to become a pivot. If the products of interaction cannot seamlessly move between tools, however, then the learning opportunities that come from engaging those ideas in a new way are lost. Unfortunately, this simple goal is often complicated by today's non-interoperable learning environments.

Second, the whole trajectory of participation may be productively viewed as a retraceable history. At times students will need to look back at their history of interaction as a resource to help resolve their current conceptual difficulty. The potential difficulty is that indexing and reference are based on different paradigms in the two modes of communication. In a face-to-face dialogue, indexing and reference are ephemeral are co-constructed in the moment through deictics, gesture, etc. In CSCL environments, these co-constructed forms of reference are reproduced via shared displays, visual highlighting, and the use of the pointer as a type of electronic, deictic gesture (Rummel, Spada, & Hauser, 2006; Stevens, Cherry, & Fournier, 2002). In monologues, indexing and reference are formal and often searchable (e.g., via a table of contents, hierarchical or tabbed browsing, hyperlinks, etc.). As a field, we would benefit from both conceptual and technical solutions that allow the whole history of interaction to be accessible to the participants at any point along their trajectory. One interesting solution would be to extend the work being done on collective annotation and video records (Pea, 2005; Stevens et al., 2002), generalizing these "guided noticings" to other types of texts and adding additional features that allow the user multiple access points and non-linear paths for the annotated interaction.

Third, when considering how to design semiotic pivots we also need to consider the direction of the transition we are intending to support. Transitions from monologue to dialogue, and vice versa, both ideally represent shifts in perspective, but each presents different conceptual hurdles. Transitions from monologues to dialogs seem much more common and easy to facilitate-formal presentations, movie screenings, and poetry readings are all colloquial examples of monologues that spark dialogues. Perhaps the most important consideration in facilitating this transition is to motivate the need and perceived value of engaging in a dialogue around a monologic text. In traditional classroom settings, the production of a monologue, such as a written report, is often seen as the end goal, and not one step along a longer process. Dialogs and critical discussions after the monologue is complete can be perceived to be tangential, inconsequential, or even as things that get in the way of the "real" work of producing an artifact for a grade. In these cases, students may be resistant or even unwilling to participate in dialogues. This suggests that for this direction of transition we need to *design to motivate* dialogue and critical engagement. In the opposite direction, from dialogue to monologue, the critical shift in perspective is from attending to the current turn or topic of discussion and attending to the whole dialogue as a single object from a global perspective. By seeing the structure and flow of the entire dialogue as a single object students are afforded the opportunity to engage with it in a new way and to see the ideas in a new light. Designing for this transition require us to *design for a shift to a global perspective*.

Conclusion

In this paper, we have attempted to illustrate how the ebb and flow of monologue and dialogue can lead to learning and to show the importance of supporting this cycle in the design of technological tools. Progressive discourse provides a venue for the growth of ideas through the interchange of these two processes—the dialogic process of interanimation in conversations and the monologic process of construction in text production. Our challenge is to learn how to create conducive middle spaces in our pedagogical designs, including both the structure given to learning activities and our tool design. This may be accomplished by designing activities that bridge communication and information technologies, as was the case in this study. This may also be accomplished by a new genre of technologies that do not honor the old dichotomies and support both

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communicative processes. While some formulations of learning and CSCL may presume that there are collaborative and non-collaborative forms of learning, we propose that this presumption may be counterproductive. All learning is communicative. Monologue and dialogue are important in isolation, but the middle spaces that connect them provide fertile ground for future research.

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AUTHOR QUERIES

AUTHOR PLEASE ANSWER ALL QUERIES.

Q1. Keywords were provided. Please check if appropriate.
Q2. Yakubinskii, 1923;1979 was changed to Yakubisnkii, 1923;1979. Please check if appropriate
Q3. Suther, Toth, & Weiner, 1997 was changed to Suthers, Toth & Weiner, 1997. Please check if appropriate.
Q4. Please update bibliographical information if this has already been published.
Q5. Hoadley & Enyedy, 1999 was not cited in the body. Please provide citation.