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Talking Science through Design: Children's Science Discourse within Software Design Activities

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Abstract. While educational research and practice have found many benefits of long-term and complex design activities, an issue of growing concern is that students might lose sight of science learning while diverting their attention to design aesthetics, collaborative management, and technology. A question is whether or not science is actually separate from these aspects; it may be that science permeates the design environment and is thus contexted within these other activities. To investigate this possibility, we followed three student simulation design teams and examined their science discussions during planning and what conversational contexts gave rise to science talk. These planning sessions provided a rich context for problematizing; however, the more students focused on the fine-grained details of the simulation itself, the more sophisticated their science talk was. Experienced designers played a crucial role in shaping their team contexts for science talk. We discuss the implications for how design tasks might be structured to facilitate fruitful science discourse.

In the past decade, project-based science classroom activities have gained increasing acceptance among educational researchers and practitioners [e.g. Blumenfeld et al. 1991; Brown & Campione 1994; Scardamilia & Bereiter 1994]. A particular kind of project-based activities are design projects, in which students are asked to design artifacts (computer-based or not) that direct, reflect, and incorporate their science inquiries [Baumgartner & Reiser 1998; Penner 1998; Puntambakar, et. al. 1998]. Our own focus is on projects in which students create computer software artifacts via programming and multimedia design. Unlike most traditional science classrooms where students engage in science activities together with the teacher, in software design projects students within a team decide on which research questions to ask, how to integrate them within their software simulations, and how to make connections between different science topics.

While research and practice has found many positive benefits of these integrative, long-term and complex design activities, an issue of growing concern is that students might lose sight of science learning while diverting their attention to all the other on-going tasks. Solutions to this issue have come in different forms: in some instances computer-based support and scaffolding has been provided to guide students in their science inquiries [Linn 1998; Guzdial 1994]. In other cases, researchers have constrained the design tasks in such a fashion that a science inquiry focus is predominant [e.g. Cuthbert & Hoadley 1998; Kolodner 1996]. In this paper, rather than constraining or providing explicit argumentative structures, we decided to follow students in their development of science inquiry over a period of ten weeks and examine how the given design tasks afforded opportunities for students to engage in science discourse. In previous research we had examined this issue by focusing on the final collaborative design products and analyzed to what extent particular multimedia designs afforded opportunities for individual learning about science and programming. [Kafai, Ching, & Marshall 1997]. Here we are more interested in the design practices that student teams developed for situating their science inquiries.

For that purpose, we have chosen to focus on how students choose to articulate science issues of any kind within the context of software design. The concept of "problematizing" has been developed by Hiebert and colleagues [1996] within the field of mathematics education. It integrates students' individual and collaborative efforts to connect their own learning to their previous understanding with the help of their teachers or peers. Within the software design context, we analyzed video data that captured students' collaborative planning sessions at the beginning (week 1), middle (week 5) and end (week 9) of the design project. Our results examine to what depth student teams verbally problematize science content during design planning, and in which design contexts students situated their science discourse. Furthermore, we paid attention to team-specific ways of situating science talk and development of science talk over time. In our discussion we address the issue of which contexts afford opportunities for richer discourse and the particular role that more experienced students play in shaping problematizing contexts.

Theoretical Background

Students' problems with science learning have been well documented in the research literature. From the informal knowledge gathered from everyday experiences that they bring into the classroom to problems with systematically conducting science research and analyzing evidence, coming to understand science concepts and practices is not an easy effort. Many interventions have been designed to help students with different aspects of science learning, such as explicitly addressing their informal knowledge [e.g. Hunt & Ministrell 1994], developing fruitful research questions [e.g. Scardamalia & Bereiter 1994] or making use of peer interactions to facilitate and enrich discussions [e.g. Brown and Campione 1994]. A number of computer-based inquiry and data analysis tools have been developed to assist students in visualizing and representing data [Gordin, Polman, & Pea 1994; Jackson, Hu, & Soloway 1994], communicating scientific findings to an audience [Songer 1996], and engaging in scientific discourse by examining and making arguments [Linn 1998].

The approach used in this software design project draws on this research but with a significant difference: rather than providing students with educational software designed by content specialists and programmers, here students themselves are placed in the role of instructional designers and collaboratively create and implement software to help younger students learn about neuroscience concepts. As part of this process they have to decide the focus of their science simulations to be designed, learn programming skills, deal with work and resource allocation issues, and they have to develop appropriate representations and explanations of science phenomena. Consequently, students' science inquiry is situated within all of these activities: while students are thinking about neurons and dendrites, they have to make decisions about their representation, whether to animate particular aspects, and who is going to work on different parts. This is different science practice than students traditionally experience in their science classrooms, and it requires some degree of adjustment for both the students and the science teacher involved [Marshall, Galas, & Kafai 1998].

The concept of problematizing has been introduced here as a gateway to examine students' science discourse within design activities. Problematizing as articulated by Hiebert et al. [1996] within mathematics education brings together student and teacher perspectives--in the same way as they run together in instructional design activities where students are teachers to younger students and learners at the same time. How do students then manage to keep these perspectives in sight while designing their science simulations about neuroscience? Another issue of interest is in which ways students bring science into the science discourse: on a surface level by starting to integrate science concepts and terms in their conversations or also by going deeper and providing descriptions and explanations? Of further importance is to what extent the team constellation plays a role of how science discourse is situated within the design conversations. In our particular study we had experienced student designers (i.e., oldtimers) work together with students new to the practices and demands of design projects (i.e., newcomers). Lastly we were interested in the developmental nature of science discourse. As the collaborative software to be designed takes shape over time, it is expected that science discourse would take on different dimensions.

Methods

Participants. Thirty-five fourth and fifth grade students participated in the design project. Students were divided into teams of 4-5 students each; they worked in these teams for the entire 10 weeks to collaboratively create their simulations. Each team contained at least one experienced designer, a mix of 4th and 5th graders, and a mix of both genders. The current analysis looks at three of those teams as case studies (13 students total).

Data Collection. Student groups were pulled out of science class one at a time to engage in these project planning sessions. During the sessions groups were given 15 minutes exclusively devoted to jointly creating and negotiating their plans for their developing simulation software. All group planning time for each of our 3 case studies was videotaped and transcribed completely. Transcripts were then coded for the extent to which students engaged in science talk during planning about their designs. The data corpus for this paper was nine total transcripts, three for each group, containing 135 minutes total of group talk about planning their software designs.

Data Coding. First we identified our unit of analysis, which was any segment of discourse in the transcripts containing science talk in some way. Segments were defined as however many conversational turns it took for a complete idea to be introduced, treated, and then dropped or closed. Thus segments could be of varying lengths. An example of a short segment is as follows:

> *Jamie: When you click on the neuron, it would show you the axon, the cell body, and the dendrites. And then it would go back here (pointing).*
> *Bob: Yeah, that's good.*

Many segments were longer than this, however, and they comprised more conversational turns, but they still dealt with a single complete idea and were thus selected for segments the same as the short one above. An example is as follows:

> *Andy: We can divide up the brain by lobes, and everyone works on one.*
> *Tracy: What?*
> *Alaine: So each lobe gets a different page?*
> *Andy: Yeah, like I get the temporal lobe, Tracy gets parietal, stuff like that.*
> *Tracy: No I don't want-*
> *Alaine: Okay whatever.*

After we identified all the segments of science talk in each of the nine transcripts, we double-coded each segment for the following: a) the level of science talk in which students were engaged, and b) the conversational context which triggered the introduction of science discourse.

In terms of the level of science discourse, we wanted to distinguish between *descriptive* talk, in which students incorporated the vocabulary of neuroscience into their discussions, and *systemic* science talk, in which students more deeply problematized their ideas and understandings about neuroscience within the context of planning their designs. (1) *Descriptive*. The segment above in which Jaime and Bob talk about Jaime's plan for what happens when the user clicks on the neuron is a good example of descriptive science talk. Jaime presents her idea, uses neuroscience terminology to describe it, but does not deal conceptually with the neuron in any more depth other than naming the parts that will appear on the screen. (2) *Systemic.* Compare Jaime and Bob's exchange above with another example from that same group, in which they talk about fetal brain development in a more conceptual manner.

> *Jaime: We were going to work on our page-*
> *Bob: The brain thing.*
> *Jaime: The one that shows the baby brain growing into a full brain.*
> *Val: Yeah, it's about the baby developing.*
> *Bob: The BRAIN developing.*
> *Calvin: I think the baby develops with the brain.*

In this segment, the group not does not use as many neuroscience terms as in the earlier examples from Jaime's and Andy's groups; however, the students are engaging with the idea of fetal brain development and are explaining to one another their views of what should appear on the screen. More importantly, in the last three turns among Val, Bob, and Calvin, they are attempting to decide what will appear on the screen based on their understandings of the phenomena of fetal brain development--whether they should show the brain developing independent of the fetus itself.

In our double-coding system, the second code each segment received was one that captured the conversational context in which science talk took place. Since the main goal of the planning sessions was to negotiate designs and work plans for each team's simulation, science talk in this context always arose out of talk about something else. We identified four topics that students dealt with which gave rise to talk about neuroscience. (1) *Simulation screens.* In this context students discuss the appearance, content, or functioning of an individual screen within their software. (2) *Software functioning*. Here students talk about the overall layout of their software, navigation between pages, or other topics concerning more than one screen at a time. (3) *User consideration*. In this context students consider how to make the software appealing or understandable to their younger users. (4) *Work distribution.* Finally, here students make plans for who in their groups will be responsible for various tasks in the implementation of their plans. We used the combination of context and the level of science talk to investigate how students used the design planning session as a forum for problematizing what they were learning about neuroscience.

All transcripts for our three case studies were coded by two independent coders. Inter-rater reliability was established for both science (alpha = .84) and context (alpha = .82); only exact agreement was considered acceptable for reliability purposes. Rater disputes on particular items were then resolved through discussion in order to obtain final codes for analysis.

Results

We found that science talk does happen within the context of design. Overall, there were 72 instances of science talk in our data corpus for the three groups. Out of these 72 instances, 45 segments of science discourse were descriptive talk involving neuroscience vocabulary but not conceptual treatment of science ideas (see table 1). The remaining 27 segments were systemic science talk involving further problematizing of some neuroscience idea in students' design plans. Science talk occurred most often in the context of discussing individual screens. Work distribution was the next most frequent context, followed by software functioning and user consideration. In terms of development over the three planning sessions, we found that although the second session was the most discursively productive for two of the groups, there did not seem to be a consistent pattern of development in science talk over time. Part of the reason for this finding may be that student groups devoted more or less time to science talk versus other issues at different time points. For example, Moira's group spent most of the first session arguing over whose names should appear on the credit screen, while in Jamie's group an argument about social loafing took over the last half of the third session.

Table 1: Combinations of Context and Science talk

	Descriptive	**Systemic**
Screens	15	19
Functioning	5	6
User Consideration	8	0
Work Distribution	17	2
Total	45	27

Context Affordance

An interesting result of this study deals with the affordances of the various design contexts for facilitating science discourse. As stated above, the most instances of science talk occurred in the contexts of discussing software screens or work distribution; however, the affordances of these two contexts for descriptive versus systemic science talk differ greatly. While talk incorporating neuroscience vocabulary was evenly distributed over screens and work distribution, more conceptual discussions happened almost exclusively within the context of science screens (see table 1). Thus it appears that while talk about software screens does not automatically lead to systemic science discussions, the affordances are there. Talk within the context of work distribution, however, apparently does not often lead to deeper level treatment of science concepts.

We found that while many discussions situated in the context of work distribution had potential to evolve into fruitful science explorations, students in these groups rarely picked up on the science part of the conversational thread; more often they focused on the labor distribution aspect. Take the following example from Moira's group:

> *Lynne: I'm going to work on my two hemispheres page. You know, where you click on the hemispheres button and it shows the brain split open and talks about what each part does.*
> *Moira: I'm going to work on my brain thingy where you click on a part of the brain and there's an animation of what the parts do.*
> *Lynne: Wait, which one is your part, Sean?*
> *Sean: (pointing at his paper) My part is that one right there with the eye.*

In this segment both Moira and Lynne make reference to brain functionality, but they don't pursue this topic any further. The girls could potentially use this brief reference to open up the discussion further and explore what they each mean by "what each part does," but they do not. Once it has been established what each person is working on currently, the conversation moves on.

When student teams focused more on the details of particular simulation screens, specifically, on science content and how it would be represented on particular screens in the software, we found that this context tended to lead to much more fruitful science discussions. In the following example from Jaime's group, the students start out discussing how they are going to draw a neuron on one screen, and they end up exploring ideas of neurotransmitters and electricity.

> *Jaime: So here is the dendrite and it sends a message up to the brain. With chemicals.*
> *Calvin: Yeah, I know what chemical they spit.*
> *Jaime: No, I mean I'm trying to think maybe like--*
> *Bob: I like Calvin's idea of showing them spitting out the stuff.*
> *Calvin: But the neurotransmitters have to be y ellow. It's because when they spit, it's electrical spit.*
> *Jaime: Well, electricity isn't always yellow. That's a good idea, though.*

Here we see how an initial description of the need for their neuron screen to include something about chemical messages evolved into a more in-depth treatment of what those chemicals are, how they are transmitted, and how they should be represented. While their conversation reveals some limited understandings, it certainly constitutes a more in-depth discussion of "science content" situated within the screen design context.

Team-Specific Findings

All three teams engaged in science discourse on a regular basis while planning their simulations. There were no significant differences among the teams in terms of the total number of instances of science discourse; however, Jaime's team had almost twice as many instances of systemic science talk as the other two. We hypothesize one possible reason for this outcome: the influence of oldtimers in each group. In each team, the student who had participated in a previous design project the year before was instrumental in directing the planning sessions at each of the three time points. Although Moira, Jamie, and Andy each had prior experience in software design, they approached the planning sessions, and thus shaped the conversational contexts for science talk in their teams, very differently. Jaime tended to focus on the issue of content coverage; most of her efforts at organizing the planning sessions were devoted to determining how to present clear and accurate neuroscience information for the users. Andy was a capable programmer and directed discussions about what to include in the software based on how much time various ideas would take to implement. Moira fixated on the issue of individual responsibility; she used her organizational influence to try and establish which member of the group would implement whatever ideas were suggested. In comparing all three groups, with Jaime's group having more instances of systemic discourse, it appears that a focus on content coverage was the most successful organizing principle for facilitating higher levels of science talk.

Discussion

In our analysis of how students contextualized science discourse within their design planning sessions, we found ample evidence that science is not left at the door; there were plenty of opportunities for bringing science into the room and making it part of the conversation. One of the issues that is often mentioned in conjunction with design projects (and also project-based activities in general) is whether too many learning activities are vying for students' attention. What we found was that the design activity provided different opportunities for student to bring science into the conversation. Students had to think about science in-context: how it related to their prospective users; how to connect the various topics they were planning to include in their software; how difficult it would be to program, etc.. Perspective-taking, representational issues, and explanations are all part of the scientific enterprise.

One might argue that the occurrences of science talk we documented during the planning sessions are not up to the level of the kinds of scientific discourse advocated by recent science standards [National Research Council 1995]; however, we should point out that these planning sessions took place within the context of a larger science inquiry environment. Students in our project engaged in various activities such as dissections, 3-dimensional modeling, field trips, and other investigations. We are not arguing that these sessions were the only time during the design project that students talked about science; on the contrary, they had many whole class and smaller group discussions that were devoted entirely to the treatment of some neuroscience concept. Our goal was to challenge the idea that design projects can be divided up into "science" and "not science" parts, which may or may not compliment one another. We selected the planning sessions for analysis to show that science talk in design units occurs not only in designated "science discussions," but also in tasks where students are focused primarily on the designs themselves.

The software design planning activities offered different problematizing contexts for science. One issue we need to address is whether the different organizing principles generated by oldtimers within each design team afforded equally beneficial opportunities to become engaged in science. It is obvious that when the focus is science that more sophisticated levels of science discourse result. But does this mean that the other contexts are less valuable? Students did bring up science when they evaluated it in terms of programming difficulty and who needed to do what. The role of oldtimers brings up an important issue of how students learn to contextualize science within design activities. Three students had expertise from participating in a previous design project (at that time they were the newcomers) on a different science topic--ocean environments. At several times in the current planning sessions, they made either direct or indirect reference to their previous design experience. What we observe here is not only how students choose to problematize science within their design projects but, equally importantly, what learning insights and practices they carried over into a new design experience. That these experiences and practices are not the same for each student becomes evident in the fact that each team had a different overall organizing context. These results need to be taken with caution, as it is difficult to determine what factors impact such problematizing decisions: was it that students felt other team members needed this context, or was it the experience and practice which students felt was lacking in their previous design project, or was it a problematizing framework that they felt most comfortable with? All of these interpretations are possible and plausible.

This study confirmed research we conducted previously in the field of mathematics regarding the effectiveness of a fine-grained focus in design for learning. Our results in this study showed that focusing on planning for individual screens within the software, rather than more abstract issues of product organization or implementation concerns like work distribution, was the most productive context for yielding systemic science discourse. Designers drew how each screen in their fractions software would look and described its functionality; their level of engagement with the subject matter went up significantly after the introduction of this focus [Kafai, Franke, Ching & Shih, in press]. It seems that encouraging students to focus on particular screens not only allows them to establish the most specific level of planning for their designs, but it also affords more problematizing of the academic content at higher levels.

Outlook

The preceding data analyses were conducted with a small number of teams. To gain more robust support for our results, it would be necessary to analyze the discourse data of the other four teams that participated in the design project. Furthermore, it would be important to situate the data collected in the rather controlled setting of the planning discussions with the science discourse conducted by student teams in their classrooms on an everyday basis. A study which will examine these issues in the context of apprenticeship patterns between oldtimer and newcomer students is in preparation [Ching 1998].

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