Sketching a Pathway Through Design Worlds: Multimodal Communication in a Fifth-Grade Collaborative Engineering Project

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Abstract: This qualitative case study sought to understand how disciplinary literacy practices associated with engineering design were used to facilitate communication among the four fifth-grade members of one collaborative learning group engaged in brainstorming initial design ideas for a remote-controlled, paddle-propelled robotic watercraft. Specifically, we focused on understanding how sketching was used by group members and for what purposes. Analysis of nine student-generated sketches and discourse during the team's first work session suggested that sketching was "mixed and mashed" with other literacy acts to create design worlds, facilitate deep learning, and navigate pathways towards engineering goals.

Introduction

The purpose of this study was to understand the role of disciplinary literacy practices to facilitate communication in engineering design work by investigating the ways fifth-grade students use sketches and sketching to construct knowledge, identify with the domain, and navigate pathways towards collaborative engineering goals (Lemke, 2000; Wilson, Smith, & Householder, 2014). Building on the first author's previous analyses of students' interweaving of virtual and print-based texts when designing physical artifacts (Jordan, 2014), we zoom in on sketches and sketching to investigate the roles that "mixing and mashing" (Jewitt, 2006) of texts play in elementary teams' design processes. Specifically, we focus on one fifth-grade team's creation of and uses for sketches while engaged in collaborative efforts to design, build, and program a remote-controlled paddleboat and achieve assignment objectives.

Current understanding of communication practices within engineering design contexts is limited, particularly for middle grade learners. Yet, communication is an integral part of the design process. Understanding how young adolescents learn to engage in collaborative engineering design practices entails understanding communication processes by which group members come to co-create design projects. In science and engineering contexts, successful communication usually entails the creation and use of multiple and multimodal literacy practices. Thus, understanding communication in learners' design practices requires understanding how they use literacy practices to engage in collaborative interaction during design project work.

Here, we examine the intertextual and multimodal relationships within collaborative interaction in an engineering learning context where learners had time and space to take up positions as drivers of creative products and robust learning. In doing so, we situate disciplinary learning of engineering design practices in the wider context of multiliteracies learning and design pedagogy.

Multiliteracies communication landscape: Design pedagogies

The communication contexts of the 21st century are rapidly evolving and increasingly diverse, shaping and being shaped by new literacy requirements (Cope & Kalantzis, 2009); engineering design contexts are no exception. As Siegel (2006) noted, "our social, cultural, and economic worlds now require facility with texts and practices involving the full range of representational modes" (p. 65). The current (and seemingly future) communication landscape and attendant literacy practices are increasingly multimodal as technological advances continually merge with new communicative affordances, generating a need for learners to develop communicative competencies in translating, transforming, and coordinating ideas across representational modes (Kress, 2010; Lemke, 2000). Additionally, professional, civic, and social participation norms have evolved toward more informal, self-directed structures. Thus, young learners need to engage in learning experiences that help them develop capacities for participating in cultures of "flexibility, creativity, innovation, and initiative" (Cope & Kalantzis, 2009, p. 133), i.e., *design pedagogy*. Collaborative design projects offer one such experience.

Design pedagogy requires attending to helping students learn to engage in design processes. To do so, they must acquire what Pendleton-Julian and Brown (2011) called design literacy as a "new instinct" to meet the educational needs of the 21st century. Design literacy entails the capacity to rapidly reiterate potential solutions in problem-solving settings, expand on brief specifications of problem, cope with the intensely public and personal experience of critique by understanding critique as a mechanism for linking thought and action, and orchestrate ambiguity that is inherent to design processes. Such processes are communication rich.

Design is communication-rich activity; communication plays critical roles in engineering design endeavors (NRC, 2011). Communication among team members is widely recognized as a fundamental aspect of design (Darling & Dannels, 2003; Sonnenwald, 1996). Learning to design requires learning to cope with communication challenges associated with collaboration (Jordan & Babrow, 2013, Jordan & McDaniel, 2014). Furthermore, design entails not only communication with people, but also "conversation with materials" (Schoen, 1992). Such communication is multimodal in that it entails translating among representations, particularly through sketching (Geisler & Lewis, 2000; Stevens, Johri, & O'Connor, 2014). Sketching fills a disciplinary need to communicate in more dimensions to decipher *design worlds* (Schoen, 1992).

Methods

The setting for this study was a regular fifth-grade class in a suburban school district in the southwest US. The 24 ethnically and academically diverse students in the class included 15 girls and 9 boys. Students engaged in three collaborative engineering challenges across the school year, working in three-to-four-member groups and changing membership for each project. The project that was the focus on this study was the third and final and the only design project of the school year. Students were first instructed to individually identify an environmental problem and to brainstorm ideas for addressing that problem through a robotic product. Each student brainstormed in an individual design journal before being assigned to one of six collaborative teams. The focal group whose communication was the object of analysis was comprised of four members, Ida, Bobby, Derrick, and Roy. The analysis described here focuses on data associated with Day 1 of the 14-day project, a conceptual-only session in which prototyping with physical materials took place only in students' imaginations. By the end of the day this team had decided to make a robotic boat to heat and cool a swimming pool and collect debris in a net, combining similar ideas Roy and Derrick had brainstormed separately.

Data sources included the video recording and transcript of the group's first hour-long work session (Day 1 of a 14-session project). Photographs of sketches and other artifacts also informed our interpretations. First, we sequentially analyzed the sketches themselves. Following Cardella, Atman, and Adams (2006), we noted the type of representation of each sketch (creating a new sketch, continuing a sketch, returning to add to a sketch after engaging in a different activity), perspective or vantage point (side, front, back, aerial, underneath, inside, outside), the modes present (e.g., text, numbers, icons, images), and the degree to which it was technical or narrative (using a scale from 1 to 4). We catalogued each image's basic components (number of structures present, connections among structures, details, relationship between structures, and the incorporation of technical components), and the extent to which context was envisioned. Following in the analytic path of Lewis (2000), we matched sketches to their in-context use to understand the interplay between the characteristics of sketches and the processes and functions of sketching practices. We identified which group members initiated and contributed to each sketch and when they were created in the sequence of design decisions that unfolded across the work session. We also tried to discern for what purposes they were created.

We then analyzed discourse from the collaborative work session in which the sketches and other multimodal texts were created and used in order to understand what ideas team members took up, how they took them up and to what effect. We drew from methods of mediated discourse analysis (Scollon, 2001) to understand the "cultural learning and social effects" to learners "actions with materials" as meditational means, tools with which individuals participate in social practices (e.g., designing, negotiating, sketching) using material resources (e.g., paper, pencil) to craft communicative messages. Through analysis of the discourse surrounding acts of sketching in conjunction with the transformation of sketches, we interpreted what was being designed, what ideas were created, kept, or discarded along the way, how sketching influenced members thinking about their design purpose and constraints, and how it supported and shaped communication.

Findings

The four members of this fifth-grade engineering design group engaged in rich communicative work in their pursuit of a design goal; various acts of literacies were integral to that process. Throughout the design process, students mixed and mashed fragmented and partial literacy acts to build pathways between independent and collaborative conceptions of their complex design worlds. No single literacy or text was powerful enough to sustain the evolution of a design project. The evolving engineering design world required students to work through the challenges of understanding their own perspectives as well as their peers' perspectives.

Before the group was even formed, three of its members had created a total of four sketches between them as they responded to their teacher's instructions to brainstorm possible design product ideas in their individual design journals. Bobby sketched a "trash picker-upper", his only idea. Ida sketched a "water consumer" and a "bag recycler", but did not sketch her other idea, a crane operated trash picker upper. Roy sketched a pool heater-cooler with a scoop and a net to clean the pool as a nod to the design specification's call for the product to

address an environmental problem. Of these initial sketches, Roy's was the most technical, the most complex in its depiction of the relationships among structural elements, and the only one to label parts. Bobby's sketch was the only one to include contextual features to help indicate the function of the product and the only one to include two frames to indicate the behavior of the product (i.e., one depicting the arms crushing trash, the other depicting the arms throwing trash into a receptacle). Derrick was the only group member who did not sketch during individual idea generation, choosing instead to create a list of possible design products. Among Derrick's many ideas was an octopus-shaped robot that heats a swimming pool. Once the group was formed, this was the first idea to be shared with the group: "Like, say this is the NXT; it'll be outside the pool and it'll be an octopus floating." This was followed quickly by Roy's exclamation:

> Mine is like the same idea almost! … but instead of just heating the pool, it has a like a heater and a cooler and when it was really hot outside it would cool it and whenever it's cold outside it would heat it for you. But not only will it do that, but it'll have an environmental cause too. It also has a net and a little scooper, so it can pick up trash.

Noteworthy is the different manners in which Derrick and Roy presented their ideas, with Derrick concentrating on structures and aesthetics, and Roy integrating explanation of structures with behaviors and functions of his robot. We hypothesize that Roy's integration and elaboration may have something to do with the elaborated thinking he engaged in through sketching his idea. Although Bobby and Ida shared four additional ideas in quick succession, Roy's suggestion in talk turn 81 to combine his and Derrick's ideas was tentatively taken up, perhaps driven by Roy's suggestion that they "draw a sketch of what it would look like if we combined them."

Over the next 50 minutes, the team created a total of nine more sketches, five were solo-authored by Roy, two were solo-authored by Derrick, and two were collective products of the three boys. Both of Derrick's sketches were more narrative than Roy's, both focused on aesthetic and contextualizing elements of a highly personified design in with the octopus shape of the structure and its facial features figured prominently. Roy's sketches took on more personification elements and more contextualizing elements across time. It is perhaps important that the two primary sketchers were Roy and Derrick, who were also the co-originators of the pool heater-cooler idea. Perhaps their authorship carried authority that made sketching those ideas their domain.

The evolution of the team's design ideas was captured in these sketches and these same ideas were reflected also in the group's talk. However, additional ideas were introduced in talk but were not captured the sketches. This is because the use of meditational means and materials varied among the four students. Although Bobby did not initiate any sketches and only contributed to two collective sketches, he nonetheless contributed substantive design ideas. The same can be said of Ida, though she did not sketch anything after being assigned to her group. Three shared aspects of Ida and Bobby's contributions are noteworthy. One is that both Ida and Bobby chose to contribute design ideas using a combination of verbal description, gesture, and manipulation of physical objects to represent structural elements of design ideas (e.g., pencils, books) rather than to depict ideas in sketches. The result of this choice was that their ideas were more ephemeral than the ideas depicted in sketches, and few of those ideas made it into the sketches initiated by Roy and Derrick. Another shared aspect of their contributions was that both modified elements of their own original designs for trash picker uppers, morphing them to apply to the pool cleaner robot the group decided to pursue. Ida proposed a crane to transport collected trash to shore and Bobby proposed a swinging arm to haul in the net. Bringing these ideas forward into the collaborative design was perhaps a way to integrate their thinking even though the group had not selected their designs. Finally, Ida and Bobby's contributions had the shared quality of persistence. Bobby was repeatedly adamant that the robot must include a net big enough to engulf the bottom of the robot. This idea was eventually incorporated in two sketches and carried forward. Ida was adamant about the need to identify materials and technical elements of the design. Although she did not sketch herself, she used other's sketches as vehicles to question what structures would be made of and how they would work. In this way she contributed substantively to the evolution of the team's design by focusing attention on important design decisions.

The final sketch created during this team's first work session was the only one not initiated by one of the group members. The teacher instead, initiated it following a quick check-in meeting in which team members explained their idea. This sketch, collectively drawn by the three boys, was the neatest among the collection and had the most labeled structures. However, there was little to suggest what materials elements are made of, and many of the elements depicted are aesthetic rather than functional (octopus legs, eyes, mouth, nose). Clear efforts were made to depict relationships among structural elements. Yet, no new design elements were added beyond those in former sketches. Essentially, the teacher initiation of a formal sketch curtailed design ideation.

Conclusions and implications

In the complex space of collaborative engineering design, projects, learners develop multimodal representations of their own design world to engage and co-construct the evolving design world of their collaborative team. Encountering communication challenges, the collaborators in the group observed here reached for self-generated sketches as well as self-generated uses of sketches in order to persist through the design problem. Sketches were integral meditational tools used to communicate with each other and with the design work. In the process of meeting communication challenges team members generated these multimodal resources, working to create their own texts in order to develop understandings, refine ideas, and move their design work forward. Students generated sketches to communicate their design ideas to themselves, advocate for their own ideas, collect design ideas together, and take their work to the next step on a pathway through the design world they were creating.

Learners were doing rich communicative work in the pursuit of a design goal and literacy acts are integral to making that happen. Learners used sketching to facilitate communication with their group members, and with the evolving design. As they negotiated communication challenges in their created design worlds, they interacted with objects available in the environment, using them to, among other things, generate sketches in service of shaping the social and material design worlds they were collectively creating. Sketching served as more than a just design tool; it served as a social glue within the students' co-constructed design world, supporting communication that gave way to collaborative pathways moving the design process forward.

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