Multimodal Engineering Design Notebooks and Meta-Representational Competence

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Abstract: Research in mathematics and science education shows that elementary students develop more sophisticated disciplinary ideas and practices when teachers provide explicit supports for discourse and representation. Extending this research to engineering education, we describe how a multimodal design notebooking app influenced fifth graders' work during a collaborative design challenge. Unexpected meta-representational competence emerged as students constructed and critiqued external representations of their engineering design solutions in notebook entries as well as in more formal texts.

Introduction

Research in mathematics and science education has generated powerful strategies that help young learners participate in the Discourses that mediate individual and collective knowledge building in a particular discipline (McKlain & Cobb, 2001; Michaels & O'Connor, 2012). Compared to mathematics and science, in engineering education less is known about how to support discursive and representational practices during learning experiences in elementary classrooms. Although a growing number of organizations offer K-5 engineering curriculum materials, the field is still discovering how instructional supports such as talk moves and student notebooks help create learning environments where all elementary students can fully participate in engineering.

The overall goal of our research is to explore the influence of multimodal documentation technology on elementary students' engineering design discourse and decision-making. Adapting earlier work on digital science notebooks and design diaries (e.g., Puntambekar & Kolodner, 2005) to both elementary-school engineering and to modern computing tools, we developed a design notebooking iOS app to support students in documenting and reflecting on their engineering design ideas, tests, and decisions in disciplinary ways. This poster reports on an early teaching experiment with the notebooking app in which we found that students' meta-representational competence mediated the influence of the technology on their engineering thinking.

Theoretical approach

In this research we draw on decades of learning sciences research on knowledge-building communities where thinking is made visible in order to apprentice learners to ways of representing ideas in a particular discipline (Brown, Collins, & Duguid, 1989) and to enable idea improvement by others (Scardamalia & Bereiter, 1994). Within the discipline of engineering, knowledge-building involves making evidence-based arguments about the soundness of design decisions. Documentation and visualization tools aid professional engineering designers in doing this work (Aurigemma, 2013). Young engineering students may need specific scaffolds to document and visualize their engineering design work in particular ways at particular moments. In turn, the acts of documentation and visualization may help them engage in the challenging discourses of small-group engineering design (McFadden & Roehrig, 2018). The design notebooking app that we developed and used in this teaching experiment offers seven multimedia notebook page templates: Problem, Ideas, Test, Final Design, Feature, Exploration, and Issues. Each template combines brief prompts with blank photo, video, sketch, or text fields to highlight a different epistemic practice of engineering design. These templates draw on the idea that disciplinary work involves using the discipline's *epistemic forms* – ways of organizing knowledge – and playing its *epistemic games* – sets of rules, strategies, and moves made to populate a form (Collins & Ferguson, 1993).

Methodological approach

The data for this study come from a teaching experiment that three authors conducted with two teachers at an elementary school in a city in the eastern United States. In a fifth-grade classroom where students had not previously participated in engineering design, the first author and lead teacher co-taught a unit on the engineering of "stomp rockets," paper devices launched by air pressure. Over the course of ten days (60 minutes each day), students planned, built, tested, documented, and discussed the success and failure of small rockets made out of lightweight paper and plastic. Working in teams of three or four, they used the design notebooking app for documentation, and at the end of the unit they created formal posters with both texts and figures to present design recommendations to another class of students. Before creating their own notebooks and posters, students analyzed several "mentor texts"– examples of completed digital design notebooks and design posters.

We utilized an interpretive case study approach and microethnographic analysis (Bloome et al., 2005) to explore the students' discursive and representational practices as they interacted with the notebooking app and created their design posters. Data sources included classroom field notes, digital and tangible student artifacts, video recordings, and transcripts of whole-class and team conversations. To characterize how fluently students created and critiqued different kinds of representations of their engineering designs, we turned to prior work investigating children's *meta-representational competence*, which is the ability to generate representations spontaneously, to judge the adequacy of such representations for a disciplinary task, and to notice differences between spontaneous representations and more canonical ones (diSessa, 2004).

Preliminary findings

As students captured their design work with the notebooking app and created posters to summarize their design recommendations, they displayed meta-representational competence frequently during whole-class discussions in two main ways. First, they intentionally generated new forms of representation to model aspects of rocket performance that photos or text alone could not show. For example, one student explained why she sketched wavy lines inside a wireframe drawing of her team's rocket: "See the squiggly in black? We drew that, since we couldn't get a clear picture of what it would look like on the inside of a rocket, so we decided to draw, estimate, what our picture would look like, so that squiggle in the hole is showing the air going into the hole, which would push the rocket up." Second, as the students judged the adequacy of their own and other teams' multimodal representations, they explicitly discussed the strengths and weaknesses of the notebooking technology for communicating about design ideas and results. In one whole-class discussion, several students talked about the value of being able to annotate and draw on top of photographs of design artifacts to draw attention to important features: "when we could take a picture and draw on top of the picture, it helped us with our ideas because we could get two ways to look at our ideas." In another design share-out, one student realized that his oral explanation of a rocket design failure was quite limited, and he asked for permission to project a video from his notebook on the classroom's projector screen because "it would help me explain my point."

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