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Using student positioning to identify collaboration during pair work at the computer in mathematics☆

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ABSTRACT

When students share a computer in a mathematics class, the types of interactions that constitute collaboration can vary from more typical group work settings. The way that students position themselves towards one another through utterances and exchanges has implications for how students collaborate. In this paper I illustrate a method that uses techniques from Systemic Functional Linguistics (SFL) to analyze how collaboration can be traced to strings of individual utterances and acts. Drawing on positioning theory and techniques from SFL, I pose the question, *how can episodes of collaboration be operationalized through individual utterances and actions?* These methods allow for comparison between different models of computer-based interaction and suggest how to foster collaboration in technology-rich settings. Additionally, this study suggests how a broad phenomenon such as collaboration could be described and measured by considering collaborative episodes on a small scale.

1. Introduction

Group work is held as one of the foremost activities through which students can develop problem–solving skills, conceptual understanding of mathematics, and positive identities as mathematics learners (Esmonde, 2009a). In mathematics education, as in many other disciplines (e.g., Quinn, Schweingruber, & Keller, 2012), learning standards and professional guidelines call for students to have opportunities to interact with peers for the purpose of learning to formulate arguments and to make sense of others' reasoning, and more generally to participate in the practice of doing mathematics (National Council of Teachers of Mathematics, 2000; National Governor's Association Center for Best Practices & Council of Chief State School Officers, 2010). Although group work is not synonymous with *collaboration*, through which students jointly construct ideas (Staples, 2007), many of the advantages of group work stem from the opportunity to promote collaboration among teachers and students. An important area of research, both in mathematics education as well as more generally, has been in understanding the skills and resources students need to establish collaborative practices through group work (Cohen, 1994a; Horn, 2012; Webb, 1989). This research has illustrated, for example, the importance of asking questions, the types of explanations that are most productive, and the importance of students challenging their peers, for students to equitably contribute to a jointly constructed solution.

With the increasing integration of technology in mathematics classrooms, there is an opportunity to consider how the use of technology tools can shape or change the nature of students' work together (e.g., Ares, Stroup, & Schademan, 2009; White, Wallace, & Lai, 2012). *Group work*, as a general term, can refer to many different types of student interactions. For example, problem-based mathematics textbooks typically call for students to work in groups of 3–4 (e.g., Dietiker et al., 2006). In some networked environments, as many as four students can share a single technology tool at one time, with each person maintaining control over some aspect of the tool (White et al., 2012). Computer–supported collaborative learning spaces may allow for several students to view and interact with a single environment through the use of large monitors and touchscreen technology (Mercier & Higgins, 2013). Finally, when working together at the computer, research from computer science education suggests that students may be most productive in pairs (Braught, Wahls, & Eby, 2011). Because of the increasing prevalence of technology tools in mathematics classrooms, and the diversity these tools bring to students' interactions, there is a need for more investigations of how students work together in these settings. This paper presents a methodological approach towards identifying units of collaboration through students' interactions while working in pairs at the computer. I pose the question, how can students' collaboration be operationalized through individual utterances and actions at the computer? I illustrate a method that uses techniques

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from Systemic Functional Linguistics (SFL; Halliday & Matthiessen, 2014) to analyze how collaboration becomes instantiated in cases where students use a computer environment for doing mathematics.

2. Research on group work with and without the use of technology

2.1. Group work in mathematics classrooms

Certain features of group work have been linked to positive learning gains across multiple settings (see Cohen, 1994b; Esmonde, 2009a; Webb & Palincsar, 1996 for reviews). For example, providing elaborated explanations to peers promotes student learning (Cohen, 1994b; Webb, 1989, 1991), and students benefit most from explanations when they immediately apply them to the task at hand (Webb, Farivar, & Mastergeorge, 2002). Students also benefit from shared decision making and shared monitoring of their progress (Chizhik, 2001; Schoenfeld, 1989). In general, group work creates opportunities for students to engage in behaviors such as explaining one's thinking, reflecting on solutions, and learning from peers, which support mathematics achievement.

Recent research in mathematics education has examined more closely the processes that contribute to making group work more or less successful. Students' mathematical understandings are typically shaped by their interactions, including whether students push one another to generalize mathematical ideas (Ellis, 2011) or to refine their claims (Francisco, 2013). When students tend not to listen to the suggestions of their peers, they are less likely to formulate a correct solution to a problem, even if correct ideas are presented within the group (Barron, 2000, 2003). A group may stall if one student is especially persistent with an idea that the group disagrees with (Watson & Chick, 2001), and groups of students who challenge one another's ideas may verbalize more reasoning and justification for their claims (Pimm, 2014). Students must constantly renegotiate mathematical authority within group work settings (Bishop, 2012; DeJarnette & González, 2015; Esmonde, 2009b; Zahner & Moschovich, 2010), which can create access for more students to participate in mathematical practices (Esmonde & Langer-Osuna, 2013). The interactional processes through which groups work together have important implications for the nature of students' mathematical learning.

2.2. Group work in technology-rich mathematics settings

Some mathematics learning environments provide either a collection of networked devices or a single monitor large enough for several students to use at single time, for the purpose of allowing groups of 3–4 students to work together on a single task with the use of a shared technology resource. A shared monitor for students to see each other's work can support students to learn from their peers' ideas (Mercier & Higgins, 2013). When each individual within a group controls a device that is connected to the others, it is important for students to achieve coordinated efforts and shared focus of attention in order to be successful with the given task (Lai & White, 2014; White et al., 2012). However, students sometimes find that they can work more efficiently by reducing the number of people engaged in the mathematical work to only one or two students (White & Pea, 2011). Shared technology resources among groups of several students can allow for students to use a variety of representations and coordinate their efforts towards solving a problem, although it can be challenging for all of the students within a group to sustain joint efforts.

There is relatively little research on the nature of students' interactions when students share a single computer, rather than working with a larger device or individual networked devices, in mathematics. When Healy, Pozzi, and Hoyles (1995) studied students' use of Logo programming environments on shared computers, they described several features of student interactions that they observed over the three years of the project. Some students, who were originally assigned into groups of 3 or 4, broke into smaller sub-groups to complete portions of the task and come to agreement on the overarching goal of the task. Other groups divided into subgroups and replicated portions of the task, with little to no discussion of their joint progress. Groups with a more integrated approach to the work showed greater gains in conceptual learning. Taking a step back from the computer, and talking about the outputs of their work on the computer, was critical for students' mathematical meaning making (Hoyles, Healy, & Pozzi, 1994). For group and pair work at the computer to promote mathematical learning, students needed to share responsibility over the task, and students needed to take time to reflect on the mathematical ideas.

2.3. Pair programming

Earlier research from Healy et al. (1995) and Hoyles et al. (1994) pointed to the potential to improve students' learning opportunities at the computer by reducing the number of students sharing a single device, so that students work in pairs rather than in larger groups. *Pair programming*, which originated in computer science settings, refers to an activity in which two individuals share a single computer and work together on programming tasks (Hanks et al., 2011). Typically, one individual on a pair programming team acts as the *driver*, who controls the mouse and keyboard, while the other individual acts as the *navigator*, keeping an eye towards the overarching goals and reflecting on the pair's work. Pair programming originated in industry settings (Jensen, 2003), and it has become a fairly typical practice in educational settings, particularly at the post-secondary level (Hanks et al., 2011). In a review of pair programming activities used primarily in undergraduate, introductory level computer programming courses, Hanks et al. found that students typically benefitted from pair programming as part of their coursework, as evidenced by higher passing rates at the end of the course and greater retention in future computer science courses. Students who participate in pair programming in an introductory programming class perform better on individual assessments of programming skills than those who do not pair program (Braught et al., 2011). These findings suggest that the activity of pair programming can support students' performance on collaborative as well as individual measures of programming skills.

There has been some research to better understand the nature of interactions during paired work at the computer that may best support students' learning. Students at the university level, for example, may benefit more from pair programming that incorporates principles of cooperative learning, such as positive interdependence, individual accountability, and face-to-face interaction (Mentz, van der Walt, & Goosen, 2008). Lewis (2011) found no statistically significant differences in learning gains among sixth-grade students, one group of whom engaged in pair programming and the other group of whom collaborated through discussion but worked at their own computers. Although there is clearly potential in having students work in pairs at the computer, there is still some question as to whether a strict pair programming model—in which one student acts as the driver and the other as the navigator—is the most productive when students are engaging with new content.

Research on pair programming, although not specific to mathematics classrooms, is relevant to the present study because it suggests one model of interaction for two students working together at a computer. The driver-navigator division of labor is, in some ways, analogous to the assignment of group work roles