Linguistics and Education 35 (2016) 37–49

Contents lists available at ScienceDirect

Linguistics and Education

journal homepage: www.elsevier.com/locate/linged

Thematic analysis of students' talk while solving a real-world problem in geometry[☆,☆☆]

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ARTICLE INFO

Article history:
Received 13 August 2015
Received in revised form 11 February 2016
Accepted 13 May 2016

Keywords:
Systemic Functional Linguistics
Mathematics learning
Thematic analysis
Semantic relations

ABSTRACT

From a social semiotic perspective, students' use of language is fundamental to mathematical meaning making. We applied thematic analysis to examine students' use of geometric and contextual ideas while solving a geometry problem that required them to determine the optimal location for a new grocery store on a map of their local community. Students established semantic patterns to connect the problem context to geometry. Groups differed in how they used geometry in their discussion of the solution, in particular with how students used distance to describe the location of a new grocery store. Overall, students' knowledge of the problem context served as a resource for them to establish geometric meanings. Thematic analysis, which describes the connections in students' talk between out-of-school and discipline-specific knowledge, highlights ways in which instruction can build upon students' prior experiences for the purpose of learning in school.

1. Introduction

There are many examples in research of the importance of discourse for learning and doing mathematics. Spoken language is one of a number of semiotic systems, which also includes symbolic notation, written language, and visual representations, through which mathematical knowledge is created and communicated (O'Halloran, 2014; Schleppegrell, 2007). Language, and in particular spoken language, may be considered the primary medium through which mathematics is taught in schools (Lemke, 1988). One particularly important aspect of classroom discourse is student talk, especially when students work in groups for doing mathematics. Because language is a fundamental means of doing mathematics, students' work in groups should create opportunities for them to engage in mathematical meaning making. At the same time, students bring a variety of experiences and knowledge to mathematical discussions (Moschkovich, 2008; Turner, Gutiérrez, & Sutton, 2011; Zahner, 2012), and students are not always familiar with the accepted ways of formulating arguments or explanations in mathematics (Forman, McCormick, & Donato, 1997). Groups of students are likely to construct different meanings, even while working on the same task. These differences may be compounded when students work on problems that have real-world connections and draw on students' prior experiences outside of school.

Real-world contexts can be useful for students to engage with mathematics concepts and procedures. We use the term *real-world problem* to refer to a mathematics problem grounded in a real-world context, for example a problem about sharing popcorn among friends (Lubienski, 2000) or evaluating a house plan (Boaler, 1998). Students can learn to appreciate mathematics as relevant through solving real-world problems (Boaler, 1998; Frankenstein, 1987; National Council of Teachers of Mathematics [NCTM], 2000). There is a strong international tradition of teaching and learning mathematics with real-world problems, as evidenced by a focus on teaching through problem solving (Lampert, 2001), project-based learning (Boaler, 1998, 2008), mathematical modeling (English, 2010), and the development of mathematics curricula through the framework of Realistic Mathematics Education (e.g., Gravemeijer & Doorman, 1999). Given the benefits of real-world problems to students' mathematical learning, there is opportunity

☆ An earlier version of this article was presented at the annual meeting of the American Educational Research Association, 2015. Thematic analysis of students' talk while solving a real-world problem in geometry.

☆☆ This study was partially funded by the National Science Foundation's grant to Gloriana González for the project entitled "CAREER: Noticing and Using Students' Prior Knowledge in Problem-Based Instruction," Grant No. DRL-1253081. Opinions, findings, conclusions, or recommendations are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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http://dx.doi.org/10.1016/j.linged.2016.05.002
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to better understand how students construct mathematical meaning through discussions of problems (Herbel-Eisenmann & Otten, 2011). Real-world problems often intend for students to focus primarily on mathematical relationships, but it can be difficult in practice to sustain this focus on mathematics (Otten & Soria, 2014). To support students' mathematical learning, it is helpful to examine how students engage in mathematical meaning making through their talk while solving a real-world problem.

We conducted a study in which students needed to use a map of their local community to determine the optimal location for a new grocery store, with the goal of understanding how students would use and discuss mathematical ideas to solve a real-world problem set in their local community. We asked two research questions: (1) What were the central ideas of students' discussions that shifted between contextual and geometric meaning? (2) How did students give geometric meaning to the task of locating a new grocery store on a map? With these questions we contribute to two interrelated objectives, understanding how students use real-world problems as opportunities to talk about mathematics and how students differ in the mathematical meanings that surface through their discussions.

2. Conceptual framework

We take a social semiotic perspective, which assumes that meaning is constructed through social practices and through choices of representation within specific settings (Kress & Van Leeuwen, 2006; O'Halloran, 2014). In order to communicate, individuals must select a representation that best expresses a particular concept or idea (Kress & Van Leeuwen, 2006). Spoken language is a primary means of expressing ideas (Lemke, 1988, 1990; Morgan, 2006), along with other semiotic systems. In mathematics education, visual representations serve a critical role for expressing mathematical relationships and supporting communication (Alshwaikh, 2011; Chapman, 1993; Dimmel & Herbst, 2015; O'Halloran, 2005). Communication in mathematics can also be achieved through the use of symbolic notation (O'Halloran, 2003) and through gesturing (Arzarello & Edwards, 2005; Radford, 2009). Teachers and students in mathematics classes typically use a variety of semiotic resources to convey ideas (O'Halloran, 2005, 2014; Schleppegrell, 2007). Because analysis of discourse can provide a way to understand which features of interaction are significant to creating mathematical meanings (Morgan, 2006), we focus specifically on students' conversations. We also recognize that there are instances in which students' use of semiotic resources such as visual representations support those conversations.

There are three important aspects of a social semiotic perspective—social practices, context, and language—that contribute to our examination of students' discourse while working on a real-world mathematics problem. First, to say that meaning is constructed through social practices suggests that mastering a discipline, for example mathematics or physics, requires correct use of the spoken or written language of that discipline (Lemke, 1988). To learn science requires speaking "according to the accepted ways of talking science" (Lemke, 1990, p. 12). Mathematics requires, in addition to knowledge of grammar and vocabulary, particular "styles of meaning and modes of argument" (Halliday, 1978, p. 195). A logical argument in geometry, or a description of a point on a 2-dimensional plane, requires a style that may not be present in other, everyday language. Although the discipline of mathematics requires a particular style of making meaning, students and teachers in different classrooms establish idiosyncratic practices (Chapman, 1993; Herbel-Eisenmann, Wagner, & Cortes, 2010). The meaning of a particular term, or the ways in which mathematical ideas become connected through a web of relationships, are likely to vary across different classroom communities.

Given the differences in how individuals may talk about mathematics within different settings, it is important to recognize how social practices are situated within contexts. We take a dynamic view of context, which is to say that the contexts in which individuals interact is constituted through those interactions. This view is aligned with a social semiotic perspective of interaction, as described by Halliday and Matthiessen (2014) as a two-way interaction between the ways that language is used and the context defined by those uses (p. 34). Language, in addition to other semiotic resources, is used to construe meaning, which contributes to the context in which that meaning is built. Morgan (2006) defined two different, and both necessary, ways of considering the context in which meaning is made. The *context of situation* includes "the goals of the current activity, the other participants, the tools available and other aspects of the immediate environment," and the *context of culture* encompasses "broader goals, values, history, and organizing concepts that the participants hold in common" (p. 221). We consider another aspect of context in students' discussions, the *problem context*, which refers to the elements included in a particular real-world problem. Although the problem context as it is presented to students is static, students contribute to that context in a dynamic way by drawing upon their knowledge of mathematics and of the world. In doing so, students create and draw upon the context of situation as well as the context of culture. Students in a mathematics class construct meaning according to the typical practices of the class, the goals of the activity, and the available resources. Additionally, students help define the context in which they interact by drawing on their prior experiences.

Language can be viewed as the primary means through which the fundamental ideas and concepts of an academic discipline are taught and learned (Lemke, 1988). There is evidence from prior research of the importance of studying the different ways that teachers and students in mathematics classrooms use language (e.g., Morgan, 2006; Schleppegrell, 2007). For example, teachers' use of the terms "base" and "height" can alternately reference a specific segment of a geometric figure (e.g., the base of a triangle) or the measurement of that segment (e.g., multiply base times height) when teaching about area formulas in geometry (Herbel-Eisenmann & Otten, 2011). Because either use of the term is appropriate in some settings, the example illustrates the importance of language for communicating the ideas of a discipline, as well as the potential ambiguities for students who are new to mathematical discourse. When students work together in groups, they incorporate mathematical language through their discussions with one another. One area of interest is how students construct meaning through their discussions of mathematics, and whether students across different groups establish the same, or different, meanings.

2.1. Thematic analysis to examine students' talk

We examined the ways that students constructed meaning through a *thematic analysis* of students' talk. Within the framework of Systemic Functional Linguistics (SFL), thematic analysis is a method to describe how ideas in a text are related to one another (Lemke, 1990; see also Chapman, 1993; O'Halloran, 2005). This use of the term "thematic analysis" is specific to the theory of SFL and distinct from other uses of thematic analysis in educational research (e.g., Braun and Clarke, 2006; Voigt, 1995). We use the method of thematic analysis described by Lemke (1990), which has also been applied in mathematics education research (Chapman, 1993; Herbel-Eisenmann & Otten, 2011; O'Halloran, 2005). By describing how students make connections between