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At the intersection of mathematics and language: Examining mathematical strategies and explanations by grade and English learner status

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ABSTRACT

Among the requirements of new College and Career Ready Standards are students' abilities to explain what mathematics problems are asking, how to solve them, and why solutions make sense. A fundamental question is, *how might the mathematical strategies that students adopt during tasks impact the language of their explanations?* Linguistic demands are expected to be challenging to English learner and proficient students alike. English learner (EL; $n = 62$) and English-only or proficient ($n = 58$) kindergarten, 3rd, and 5th grade students completed a mathematics task and explained their solutions. Overall, explanations of less complex strategies contained fewer words, shorter sentences, less frequent general academic vocabulary and temporal discourse connectors, and fewer characteristics of well-developed explanations. Explanations produced by English proficient students were linguistically more sophisticated but not more cogent than those of EL students. There were differences in connections between strategies and explanations by grade but few by EL status. We discuss implications for implementing new mathematics standards with all students.

1. Introduction

There is little doubt that students' mathematics knowledge will impact their performances on mathematics tasks in the classroom. But perhaps an equally important question arises related to the strategies students use to solve mathematical problems and how they might impact the students' competence in explaining mathematical reasoning cogently to their teachers and peers. New U.S. College and Career Ready Standards (CCRS) encourage students' use of explanations to both develop and communicate their mathematical understanding (e.g., National Governors Association Center for Best Practices, Council of Chief State School Officers [CCSSO], 2010). Therefore, it is necessary (if not sufficient) to ask *what factors might impact a student's ability to craft a well-organized and linguistically competent explanation?*

Imm and Stylianou (2012) have recently drawn attention to whether there is interplay between task and talk, and called for research to help determine how high-level discourse as a tool to support thinking may be more likely to occur with certain mathematics tasks and not others (i.e., with those tasks that lend themselves to more challenging, discursive problem solving). Similarly, we argue that the ways in which students solve mathematical problems cannot be assumed to

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have no effect on the nature of the oral explanations they give about their mathematical processes. However, studies with English learner (EL) students have almost exclusively focused on the reverse order of effects, namely the impact of language proficiency on students' performance in mathematics.[1]

Specifically, in this paper, we present the results of a study that examines how the mathematic complexity of the problem-solving strategies (i.e., counting, addition, multiplication) that students adopted in a mathematics task might be related to the linguistic and discourse characteristics of students' subsequent oral explanations.

2. Background context

The language demands inherent in new CCRS are likely to be challenging for many students and may specifically impact mathematical performances of students acquiring English as an additional language (Moschkovich, 2012). This perspective is underscored by the most recent data from National Assessment of Educational Progress (NAEP) mathematics assessments, which indicated that 41% of 4th grade EL students performed below "basic" (i.e., had not reached "partial mastery of prerequisite knowledge and skills that are fundamental") compared with 17% of 4th grade students overall. At 8th grade, 69% of EL students performed below basic on the NAEP compared with 26% of 8th grade students overall (National Center for Education Statistics, 2013).

Notwithstanding important questions about the size and meaningfulness of the achievement gap in mathematics between EL and non-EL students,[2] it seems reasonable to assume that the increased emphasis on collaboration and communication of content knowledge in the CCRS will indeed be a challenge for EL students. However, the heterogeneity in linguistic and discourse practices and abilities of the English-only and English-proficient (EO/P) student populations in the context of mathematics learning (e.g., Schleppegrell, 2007) suggests that these students should also be included in the broader discussion of the impact of the adoption of new mathematics standards.

The new requirements for all students mean that their teachers must be ready to recognize a cogent explanation of mathematical understanding, as well as model and assist the acquisition of such explanations in order to support the deeper mathematics learning that the CCRS hope to foster (Bailey & Carroll, 2015). Furthermore, the increased emphasis on communication and collaboration in new standards for mathematics compared with prior standards requires teachers to understand relationships between mathematical strategies and the nature of the language that students will need in order to display their mathematical understanding to their teachers and peers (Bailey & Heritage, 2014). The overarching purpose of this paper is to add to this prerequisite deeper understanding of the intersection of mathematics and language that both educators and researchers must develop.

In our study, students at kindergarten, 3rd and 5th grades were required to explain their procedure for completing a mathematics task aligned with CCRS for mathematics (i.e., state *how* to implement their adopted strategy) and justify their application of the strategy (i.e., reason *why* they adopted the strategy) to a hypothetical classmate not present when they completed the problem. We examined the mathematical problem-solving strategies the students used to complete the task and analyzed the linguistic and discourse features of their subsequent explanations.

The study was guided by the following main research questions:

1) In what ways are the strategies adopted to complete a mathematics task related to linguistic and discourse aspects of students' oral explanations? Do these relationships differ by grade?
2) To what extent do the relationships between mathematical problem-solving strategies and oral explanations differ by EL status?

2.1. Conceptual framework

This study was part of a larger project that has focused on providing elementary teachers with language learning progressions of explanatory talk that describe how the development of explanations occurs over an extended period. The progressions are an attempt to extend work with learning trajectories in the field of mathematics (e.g., Wilson, Mojica, & Confrey, 2013) to language learning. They include authentic examples of the characteristics of student language performance at different developmental points in a range of academic and non-academic contexts. It is intended for teachers to use the progressions as an interpretive framework for their formative assessment of EL students' language learning (Bailey & Heritage, 2014). With the specificity that progressions provide, teachers are better able to determine what evidence of language they need to obtain during the lesson, interpret the evidence in terms of where language learning lies on a

[1] We use the term English learner (EL) for students whose proficiency in English is considered to be developing and, as such, under Title III of the No Child left Behind Act (NCLB, 2001), are entitled to receive language support services to access content learning. These students are referred to in U.S. law as limited English proficient (LEP), and more widely as English language learners (ELL), and, increasingly, emergent bilinguals.

[2] The reported achievement gaps may ignore the achievements of EL students that are best expressed in their first or dominant language. Consequently, ability to accurately judge the achievement of EL students is limited (Bailey & Orellana, 2015). Published achievement data of EL students likely also contain distortions due to federal reporting policies requiring removal of redesignated fluent English proficient (RFEP) students from the EL subgroup (Saunders & Marcelletti, 2013).