Chapter 11
A Framework for Assessing Students' Written Explanations of Numerical Reasoning

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ABSTRACT

Disciplinary writing in mathematics supports the use of words, symbols, and visual representations, allowing one to communicate more fully in writing than through speech alone. This chapter explores the disciplinary writing of 394 fourth-grade students who shared their numerical reasoning in written explanations to seven whole-number and fraction comparison tasks. Data were collected via whole group administration procedures and students' explanations were scored using a validated framework for evaluating numerical reasoning. Results include descriptive statistics and qualitative analyses of student responses using the framework's five categories. A difference was found between the types of reasoning students shared for whole-number tasks versus those shared for fraction comparison tasks, favoring the incorporation of more conceptual reasoning for whole-number tasks. The framework is a practical and effective tool that teachers can use to examine the depth of student reasoning and disciplinary writing to document such reasoning.

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INTRODUCTION

Writing to learn mathematics significantly enhances the achievement of elementary school students (Graham et al., 2020). Writing to learn has been defined "as a vehicle for strengthening, extending, and deepening students' knowledge," (Graham et al., 2020, p. 180), and its benefits have been empirically supported in various meta-analyses (Bangert-Drowns et al., 2004; Graham et al., 2020; Graham & Perrin, 2007). Of similar value to writing to learn a discipline is learning to write in a discipline as emphasized through various standards documents (NGA & CCSSO, 2010a; National Council of Teachers of Mathematics [NCTM], 2000). Thus, disciplinary writing affords students the "dual benefit of communicating to learn mathematics and learning to communicate mathematically" (Pugalee, 2004, p. 27). As with any discipline, learning to write in mathematics requires an understanding of the purpose for writing (e.g., argument, justification, evaluation), the means available (e.g., words, symbols, visual representations), and the disciplinary norms for communicating (e.g., brevity, linearity).

Writing, as one form of disciplinary literacy, can provide benefits beyond those of disciplinary speaking, reading, or performing, particularly in the context of traditional classrooms. First, written work provides an immutable record of student reasoning at one time and thus can be used to measure growth in mathematical understanding over time. Second, writing allows for efficient large-group measurement of student reasoning sans the time and transcription demands of capturing verbal communication. Third, as Pugalee (2004) reported, disciplinary writing may encourage students to communicate their reasoning with more precision and accuracy.

In summary, empirical research on the benefits of writing to learn, professional standards emphasizing the importance of disciplinary writing, and the efficiency of measuring disciplinary literacy through writing provide three justifications for engaging students in mathematical writing. The intent of the present chapter is to share the exploration of the analysis of elementary-aged students' numerical reasoning expressed via writing, utilizing the *Framework for Evaluating Quantitative Reasoning Strategies*. Teachers, teacher educators, and researchers are provided with a range of examples that illustrate the complexity (or lack thereof) of student reasoning and their ability to communicate this reasoning through writing.

DISCIPLINARY LITERACY

Addressing disciplinary literacy in K-12 education has become a focus of discussions about learning and teaching in the various content areas (Fang, 2012a; Håland, 2016; Shanahan & Shanahan, 2008, 2012). Disciplinary literacy "is grounded in the beliefs that reading and writing are integral to disciplinary practices and that disciplines differ not only in content but also in the ways this content is produced, communicated, and critiqued" (Fang, 2012a, p. 20). In other words, discipline-specific literacy reflects the norms and values of experts in each field (Moschkovich, 2003). Research in disciplinary literacy has identified distinctions in how these experts read and write in the various disciplines (e.g., Johnson et al., 2011; Shanahan & Shanahan, 2008). Proponents of disciplinary literacy argue that literacy instruction should transcend general strategies that apply across content areas to include strategies that reflect disciplinary practices (Fang, 2012a; Shanahan & Shanahan, 2008, 2012) so that students develop "disciplinary habits of mind (e.g., reading-writing, viewing-representing, listening-speaking, thinking-reasoning, and problem-solving practices consistent with those of content experts)" (Fang, 2012a, p. 20).