Exploring Quantitative Measures of Symbolic Mathematics Language Literacy

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Introduction

The role of symbolic mathematics, as a language and writing system, in mathematics education is largely uninspected. The Common Core State Standards (CCSS) frame literacy skills as distinct from mathematical practices. However, the standards demand that students learn to read and write symbolic mathematics in the course of formal mathematics education. Yet, it is unclear how students acquire the ability to read symbolic mathematics such as $y = \sqrt{x}$.

For this study, symbolic mathematics language literacy (SMaLL) is defined as the ability to read and write the unique symbols and language of mathematics. According to this definition, SMaLL is distinct from numeracy, mathematical literacy, and mathematical proficiency as they are commonly understood. Collectively, those terms encompass a wide range of competencies necessary to employ mathematics for particular purposes (Diezmann & Lowrie, 2009). In contrast, SMaLL does not encompass number sense, facility with the calculations, efficient problem solving, or connections between mathematical concepts and graphical representations. Given this definition, mathematical development cannot be reduced to SMaLL development; however, SMaLL development is central to doing mathematics beyond arithmetic.

SMaLL is also distinct from English language literacy, which depends on associating phonemes, or units of sound, with letters of the alphabet. Despite this difference, it is possible that these literacies develop similarly along some dimensions. A rich body of literature suggests English language literacy is related to, among other things, orthographic awareness (i.e., the ability to recognize meaningful chunks of written text), print exposure, reading habits, and affect (e.g., Wolf, 2007). In contrast, SMaLL is scarcely acknowledged; and, it appears, no instruments exist for measuring variables related to SMaLL.

The purpose of this presentation is to describe the quantitative results from a mixed
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methods study. I explored SMaLL among middle school students in terms of orthographic awareness, print exposure, reading habits and mathematics anxiety using these adapted quantitative instruments: SMaLL convention decision task (SMaLL-CDT), Mathematics Print Exposure Survey (MPES), Mathematics Reading Habits Survey (MRHS), and Mathematics Anxiety Survey (MAS).

Methods

The research took place in a purposefully selected middle school. The school delivered core mathematics classes using a CCSS-aligned curriculum. In addition, the school offered a mathematics extension elective and a mathematics intervention elective. In order to maximize the range of mathematics ability among participants, students enrolled in both electives were invited to participate. The sampling process yielded a relatively large and diverse quantitative sample ($N = 158$) of students in seventh and eighth grades. The Institutional Review Board at the host university and an administrator from the middle school approved the research.

I used the SMaLL-CDT, a modified version of a lexical decision task (Lepore & Brown, 2002), to generate two measures of orthographic awareness: average response time (RT) and response accuracy rate (RA). Presented with samples of symbolic mathematics text, students responded as accurately as possible, as quickly as possible, to indicate whether the text was readable (conventionally written) or not readable (not written according to the conventions of the written language of mathematics). I used the MRHS to measure how often students intentionally engage in reading math text in different settings and for different purposes. I used the MPES to measure how often students have access to common symbolic mathematics text (Cunningham, Perry, & Stanovich, 2001). I used the MAS to assess students’ affect towards math (Bai, 2011).
To analyze the data, I conducted a psychometric analysis of each survey. Then, I conducted a correlational analysis across variables.

**Results and Discussion**

The psychometric properties of the surveys indicate the measures were reasonably reliable. The reliability of the MRHS total score was modest ($\alpha = .72$), and the exploratory factor analysis suggested a 4-factor solution. The reliability of the MPES total score was good ($\alpha = .81$), and the exploratory factor analysis suggested a 3-factor solution. The reliability of the MAS total score was excellent ($\alpha = .91$), and the confirmatory factor analysis showed that the expected 2-factor solution was a reasonable fit.

The correlational analysis showed statistically significant correlations between several variables (see Table 1). Although statistical significance is not an indicator of practical importance, the results indicate that several correlations can be characterized as moderate according to Cohen’s conventions (Lomax & Hahs-Vaughn, 2012).

Table 1

*Correlations between quantitative variables related to SMaLL*

<table>
<thead>
<tr>
<th></th>
<th>SMaLL-CDT Response time (RT)</th>
<th>SMaLL-CDT Response accuracy (RA)</th>
<th>Math Anxiety Survey (MAS)</th>
<th>Math Print Exposure Survey (MPES)</th>
<th>Math Reading Habits Survey (MRHS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA</td>
<td>-0.03</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAS</td>
<td>0.08</td>
<td>-0.41*</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPES</td>
<td>-0.12</td>
<td>0.43*</td>
<td>-0.35*</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>MRHS</td>
<td>-0.21*</td>
<td>0.16</td>
<td>-0.49*</td>
<td>0.39*</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*Note:  $^* p \leq .05$*
These results have implications for future research in disciplinary literacy. For example, the factor structures of the MRHS and MPES suggest directions for item development and refinement. The correlational analysis suggests that additional research is warranted to understand how math anxiety, math print exposure, and math reading habits make unique contributions to SMaLL. In sum, the psychometric and quantitative analyses suggest the measurement tools are a viable approach to exploring how SMaLL is analogous to English language literacy.

References

Cunningham, A. E., Perry, K. E., & Stanovich, K. E. (2001). Converging evidence for the concept of orthographic processing. Reading and Writing, 14(5-6), 549-568.


