Patterns of Student Engagement within an Online Supplemental Mathematics Curriculum

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Abstract

This paper describes how students, especially those with learning disabilities, interact with an online supplemental mathematics curriculum. It seeks to understand to what extent, and with what strategies, do students engage in reading, comprehending, and learning from such multimodal mathematical texts. Thirty students in grades 3, 4, and 6 worked in an online lesson on fractions. A keystroke monitor created a database of student/lesson interactions, which formed the data analyzed. The database records where organized and coded to allow types of student interactions with the curriculum to be tabulated and for the identification of cycles of student behavior. Of particular interest were quiz cycles, which were defined as the events leading up to and the taking a lesson quiz. Analysis of these quiz cycles showed students initially engaging with the lesson with strategies expected by the curriculum developers. However, those students who failed the quiz on their first attempt, adopted different interaction strategies, often at lower levels of engagement. This preliminary analysis supports four general observations: students will interact with lesson elements at different paces, they will choose where in a lesson to work, at what level of engagement, and they will set their own learning goals.

Keywords

Mathematics, Fractions Learning Disabilities, Keystroke Analysis
Introduction

This paper describes how students, especially those with learning disabilities, interact with an online supplemental mathematics curriculum. It seeks to understand to what extent, and with what strategies, do students engage in reading, comprehending, and learning from such multimodal mathematical texts. The results suggest that students exhibit a wide range of strategies in such learning environments, behaviors that differ between students, behaviors that evolve over time, and behaviors that are often at odds with the expectations of their teachers and of curriculum developers. This in turn suggests that students would benefit from training and practice in how to learn effectively online, that teachers monitor student progress and oversee that their work requires oversight, and that teachers capitalize on students' penchant for individuality and not seek to extinguish it.

This research was conducted by the Mathematics eText Research Center (MeTRC) at the University of Oregon in collaboration with Texas Christian University, with funding provided by The Office of Special Education Programs at the U.S. Department of Education. MeTRC investigates how students with learning disabilities can benefit from reading and writing mathematics in “supported text” learning environments (Horney & Anderson-Inman 1999, Anderson-Inman & Horney 1998, 2007). The central paradigm of supported text is that as students are studying an expository narrative, that is presented in a multi-semiotic exposition of text, notation, and multimedia (Schleppergrell, 2010) they should be able to draw upon a set of supporting resources that will assist in their process of reading, comprehending and learning. In doing so, it is expected that the selection and use of these resources will be driven by the characteristics of each student, the characteristics of the narrative, and the characteristics of the specific reading/learning task at hand. In the research presented here, these ideas are explored in
the context of a group of thirty 3rd, 4th and 6th graders augmenting their study of mathematics in an online supplemental curriculum: the Math Learning Companion.

**Math Learning Companion**

The Math Learning Companion (MLC) is a variant of the HELP Math program, which was researched and developed by Dr. Barbara Freeman, a Visiting Scholar at UC Berkeley, and Dr. Lindy Crawford of Texas Christian University (Freeman & Crawford, 2008; Crawford, 2013; Crawford, et. al, 2012). HELP Math was developed to provide supplemental mathematics instruction for Spanish speaking English language learners. It was later modified to strengthen its teacher interface, resulting in MLC. Freeman, Crawford and others then conducted a series of studies of its use with students with learning disabilities (Crawford, Higgins & Freeman, 2012; D’Angelo, Higgins & Crawford, 2014; D’Angelo, Higgins & Crawford, 2014b).

MLC consists of a series of lessons that encompass topics of the math curriculum for the 3rd through 6th grades, such as whole numbers, fractions, decimals percentages, money, graphs, basic geometry, and introductory algebra. Each lesson is divided into six sections: an introduction into how the lesson relates to the “Real World,” an overview of new Vocabulary, the Learn It section with the primary instruction, practice in the Try It and Games sections, and the Final Quiz. Each of the sections is divided into discrete pages. Students navigate among the pages by NEXT and PREVIOUS buttons and by maps and page markers allowing for non-linear jumps. The instructional animations can be controlled with PAUSE, PLAY and REWIND commands. From any page, students can access a Dictionary, a Calculator, two different Help Pages, a page of Formulas, and a Spanish Language Lesson Summary. Spoken audio, available in English and Spanish, is used in the instructional animations, to read words and definitions in the Dictionary and Formulas pages and to read questions and answers on the quiz. Students have
access to a NOTEPAD where they can type notes, draw images, and insert common mathematical symbols. Similar compositions can be posted to a WALL where they can be read and commented upon by classmates. Should a student not pass a quiz, they are returned to the Vocabulary section and are expected work through the lesson again.

MLC also contains multiple tools allowing teachers to control, manage, and monitor student progress and a click monitor that compiles an event database of student/MLC interactions. Each record in this event database represents a single student action within MLC such as moving from one page to the next, opening the dictionary, answering practice problems, writing notes, or taking the quiz. The results presented in this paper derive from an analysis of records from 30 students working in a single MLC lesson introducing basic concepts about fractions.

Participants

Participants included 30 students who attended special programs for students with learning disabilities or students who were challenged academically. All students performed below grade level in mathematics. Twenty-four students attended private schools in Texas and six students attended a special education supplemental math class in a middle school in Oregon. The students came from a variety of backgrounds and instructional circumstances, but all had been identified by their schools as either having a learning disability that was expected to degrade their ability to learn mathematics or they were otherwise at risk for low math achievement: grade 3, (N = 16), grade 4 (N = 8), and grade 6 (N = 6). Nineteen students were male (63%) and 11 were female (37%).

The Lesson: Math Foundations 1 Lesson 5: Fractions

This lesson introduces fractions, presenting ideas around the following terms: fraction,
number, whole, group, total number, equal, whole square, whole circle, problem, whole rectangle, whole triangle, halves, thirds, numerator, denominator, equivalent, value, equivalent fractions, represent, equivalent fraction, and equal parts. The lesson contains 54 pages:

<table>
<thead>
<tr>
<th>Real World:</th>
<th>5 pages presenting a total of 300 seconds of animation showing two characters encountering fractions at a football game.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary:</td>
<td>7 pages introducing fraction vocabulary using animated text, dynamic graphics, and a voice over reading the text and presentation, taking a total of 190 seconds; 2 pages presenting a task to reinforce the instruction: and 2 pages with additional practice problems. The problems are of different types such as manipulation of a figure, matching, or filling in a blank.</td>
</tr>
<tr>
<td>Learn It:</td>
<td>11 instructional pages operating as did the Vocabulary pages and including approximately 480 seconds of animation presentation, 11 reinforcement pages, and 5 practice pages.</td>
</tr>
<tr>
<td>Try It:</td>
<td>8 pages with practice problems.</td>
</tr>
<tr>
<td>Games:</td>
<td>1 page of practice problems presented as short games.</td>
</tr>
<tr>
<td>Final Quiz:</td>
<td>1 introductory page and 1 page presenting the quiz.</td>
</tr>
</tbody>
</table>

During the lesson, students were asked to make postings in either the NOTEPAD or WALL, such as asking a question about the lesson or answering another student’s question.

**Discussion**

*Engagement within MLC Sections*

The database contains 5,203 records showing the interactions of these 30 students with this lesson.
Fig. 1. Student Attention by MLC Sections.

Figure 1 shows a bar for each student, subdivided into their sequence of MLC sections, along with the score of each quiz attempt. The running time of the lesson is on the y-axis. The student-bars have been grouped by the number of times the quiz was attempted: Students 1-18 passed on their first attempt, with a score of at least 7 out of 10. Students 19-27 passed on their second attempt, Student 28 took the quiz 3 times, and Students 29-30 each took the quiz 5 times. The variance among students shown in Figure 1 suggests that:

- **Students worked at different paces**: Student 1 passed the quiz after only 30 minutes, the shortest time of all students, while Student 27 took the longest time, nearly three hours.

- **Students skipped sections**: The bar for Student 8 shows no interaction with the Vocabulary or Learn It sections, but a long period in Try It; Student 26 started work in the Learn It section, skipping the Real World and Vocabulary sections. Student 29 did
visit all the sections, he did so too quickly to have engaged with the instruction and took the quiz the first time after only 15 minutes.

- Students re-took the quiz with little review or additional instruction: Students 19, 20, 21, and 22 quickly scanned through the sections in order to retake the quiz; Student 29 took it three times without leaving the quiz section at all.

The differences shown in Figure 1 suggest student making independent choices about how to engage with this MLC lesson. The largest differences are evident for those students not passing the quiz on their first attempt, Students 19-20. The varying strategies students use in working up to a quiz attempt are examined in the next section.

*Engagement within Quiz Cycles*

A “quiz cycle” is defined as all the events leading up to taking the quiz and ends when the score is received. The bar for Student 2 in Figure 1 shows a straightforward quiz cycle pattern. The student begins with 5 minutes in the Real World section, then 7 minutes in Vocabulary, then 12 minutes in Learn It, 5 minutes in Try It, 3 minutes in Games, and 3 minutes taking the quiz, receiving a score of 7. Student 17 follows this same pattern, but takes considerably longer finish. With the exceptions of Students 8 and 29, and allowing for differences in pacing, all of the students had adopted a similar strategy during their 1st quiz cycle.

When students fail an MLC quiz, are expected to work back through the Vocabulary, Learn It, and Try It, before re-taking the quiz. Thus, 1st and 2nd quiz cycles are expected to display similar structures in Figure 1. However, only true for Students 25 and 27. The other students used other strategies during their 2nd quiz cycles, redoing some sections, but ignoring others, and often scanning quickly passed the instruction and practice pages to return to the quiz.
This can be seen for Students 19-21 as the small slivers of sectional activity between two quiz attempts.

These differences among quiz cycles suggest that students are more engaged during some cycles, and less engaged during others. To examine this, a set of rough measures of engagement within quiz cycles was developed. These measures are:

1. Total Attention – The total time where students attended to the lesson;
2. The average of the number of pages visited and the number of events performed;
3. The average of the events per page visit, and the number of switches from one type of lesson activity to another;
4. The average of the number of practice problems attempted; the time spent answering them, and the percentage of problems answered correctly;
5. The number of Vocabulary and Learn It animations watched completely; and
6. The number of NOTEPAD or WALL messages posted.

Together, these six measures describe an operational definition of engagement, based on the assumption that students who spend more time and perform more actions within a lesson are more engaged with the learning material. To provide a comparison, a model was then developed to estimate the values of the six engagement measures if students worked with this lesson as their teachers and the MLC curriculum developers might expect. The model is based on the features of the lesson, such as the total time of the instructional animations, and estimates of the number of practice problems presented, the time required to produce answers to those and the quiz questions, the time to post messages, and the time to move from page to page. This model estimates that to complete the lesson requires a total of 2738 seconds (≈ 45 minutes), 54 page
visits, 121 events, 27 switches, answering 43 of 62 practice problems correctly, and making 2 postings. In Figure 1, the model fits between Students 6 and 7.

Then, for each measure of each of the 56 quiz cycles shown in Figure 1, a ratio was calculated from the student values in relation to the value predicted by the model. When a ratio is greater than 1, then the student was more engaged than what was predicted by the model on that measure, and less engaged if the ratio is less than 1. These six ratios, taken together and treated as a vector, represent student engagement for the quiz cycle. For example, the vector for the 1st quiz cycle Student 27 is: [2.42, 1.74, 1.95, 2.63, 1.11, 1.33], showing him to be more engaged during that quiz cycle than predicted by the model, across all ratios.

These quiz cycle vectors were then analyzed to determine if the quiz cycles could be grouped into clusters of similar engagement. First, 10 quiz cycles were identified as outliers and placed in three clusters: (1) The “practice only” cycle of Student 8; (2) two “quiz only” cycles of Student 29; and (3) Seven “postscript” cycles containing a few events at the end of a lesson. The remaining 46 cycles were analyzed using the K-Means Cluster Analysis Algorithm (IBM, 2013) and four additional clusters were identified. Each of the seven engagement clusters is shown as a line in Figure 2.
Fig. 2. Quiz Cycle Engagement Clusters.

The lines are defined by the average value for each of the six ratios of the members of that cluster. The number of cycles within each cluster is indicated in the Legend and by line weights. The cluster labeled “Level 1” contains the two cycles showing the highest engagement: the 1st quiz cycles of Students 17 and 27. The clusters labeled “Level 2” and “Level 3” move in parallel, and are close to the model, differing most in the NOTEPAD ratio. The “Level 4” cluster shows students moving quickly, with much less engagement.

Figure 3 shows the how the engagement clusters are distributed among the 30 students.
Fig. 3. Student Lessons Coded by Quiz Cycle Engagement.

The bar for each student is divided into quiz cycles, each coded by its engagement cluster from Figure 2. The bars are divided into six groups:

**Group 1:** Students working more quickly, at Level 3, but passed the quiz in 1 attempt.

**Group 2:** Students also passing the quiz in one attempt, but working at the higher levels of engagement. A student working at the level of the model would be here, between students S5 and S9.

**Group 3:** Students who sustained the higher levels of engagement over 2 quiz cycles.

**Group 4:** The one student who increased her level of engagement.

**Group 5:** Students who dropped to the lowest level of engagement after their 1st cycle.

**Group 6:** Students working at different levels, but always with cycles at the lowest level.
Figure 3 shows that during their 1st quiz cycle, a majority of students (26/30) were engaged in this lesson at Levels 1-3, which are at or above the level predicted by the engagement model. Of the other four, Students 3, 26, and 29 began by scanning quickly to the quiz, and Student 8 focused the Try It section. However, this stronger beginning, changed for the 11 students in Groups 5 and 6, whose level engagement in later quiz cycles either dropped to the lowest levels, or began there. These 11 students— a third of the participants— adopted strategies of reduced engagement. They evidently did not believe that, having failed the quiz once, they should increase their engagement so as to not fail again. Instead they seem to have shifted their goal from learning mathematics, to just passing the quiz by repeated attempts.

Conclusions

The data and this preliminary analysis supports four general observations about how these 30 students interacted with this MLC lesson on fractions: students will interact with lesson elements at different paces, they will choose where in a lesson to work, at what level of engagement, and they will set their own learning goals. Next steps in this research include:

- This data are part of a larger data set, including 46 students, performing 60,000 events, in 660 quiz cycles, over 23 different MLC lessons. Analysis of this larger set will show how these results are supported, refuted, or extended;
- Case studies of individuals acting across lessons are needed to see how engagement in develops over a sequence of lessoning, and to better show how students differ;
- The measures of engagement must be improved and extended. They do not, for instance, adequately account for behaviors in the supporting resources such as the Dictionary.
• The current engagement model describes the minimal activities needed to complete the lesson as designed. It should be refined to better reflect the engagement needed for the successful learning of the mathematical concepts presented; and

• Student postings to the NOTEPAD and the WALL must be analyzed for their content and for any impact on engagement.

    Should the trends seen here be maintained in this more extensive analysis, it will suggest that schools be careful in their use of such autonomous learning environments and make provisions to provide direction, leadership, and oversight to help students make the best use of such materials. As part of this, teachers should seek ways to make productive use of students’ inevitable choices, rather than fighting against them.

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Works Cited


