ASSESSMENT ANALYSIS OF GRAPHING LINEAR EQUATIONS ON MYLABMATH

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Abstract

Developmental mathematics courses have significantly adopted computer-assisted learning platforms that offer opportunities for students to access mathematics contents, instructors' presentations, practice activities, assessments, and instant grading and feedback. Research shows that web-based platforms emphasize procedural fluency over the development of students' conceptual understanding. In this paper we present our analysis of assessment tasks in graphing linear equations in a developmental mathematics course that uses MyLabMath. We aimed to examine how graphing linear equations tasks help students develop conceptual understanding and quantitative reasoning. Our findings show that a large percentage of tasks stress drill and computational skill that contribute to rote learning that targets a lower level of depth of knowledge, while compromising the practice of mathematical reasoning. Despite the availability of dynamic tools within the adaptive learning platform, the curriculum design does not fully utilize interactive tools for students to explore and construct relationships between quantities involved in graphing linear equations.

Keywords: Quantitative reasoning, MyLab Math, Assessment analysis

Introduction

Over three decades, computers have been introduced to aid mathematics learning. This evolution has progressively shaped teaching and learning mathematics, incorporating the use of computers and interactive digital technologies. When students come into contact with computers, they are provided with contextual information and exercises at an appropriate level of difficulty and offered feedback to prompt thinking about their thinking (Papert, 1980). When the pandemic restricted in-person gatherings, it prompted classes adaption of virtual, synchronous, and heavy reliance on digital textbooks to facilitate student learning. One of the most used technological tools in undergraduate mathematics education is the MyLabMath curriculum. MyLabMath is a web-based learning management system that offers learning content, instructors' presentations, practice activities, assessments, and instant grading and feedback. The primary objective of employing these programs is to elevate students' comprehension and mastery of various mathematical concepts. Furthermore, these resources enable a student-centric atmosphere, while empowering instructors to tailor assignments to individual student needs. Web-based learning materials are also expected to support diverse multimedia resources such as animation, video, and audio, fostering enriched student learning experiences and promoting effective communication between students and instructors. These systems present adaptable instructional tools, delivering prompt feedback to students, timely monitoring students' test scores, and summary of their academic performance.

In line with the advancement of the use of technology in education is the study of change. The premise in which mathematical thinking is developed through an individual's contact with computers has been explored in research on quantitative reasoning (i.e., Panorkou et al., 2023; Panorkou & Germia, 2021), specifically on graphical thinking (i.e., Paoletti et al., 2021). Quantitative reasoning about the simultaneous changes between two quantities has been referred to by researchers as covariation (Carlson et al., 2002; Thompson & Carlson, 2017). Engaging students in analyzing change and variation has been critically important to promote quantitative reasoning which will be significantly encouraged in future generations. Despite its importance in understanding interdisciplinary phenomena such as in economics, physics, and meteorology, covariation is being undermined and packed away in mathematics courses. Even when covariation is offered in undergraduate courses, activities mostly pertain to symbolic manipulation with little understanding of change between quantities (Tucker, 1990). Conventional curriculum materials found in printed textbooks lack focus on how quantities change; thus, neglecting or delaying students' access to quantitative reasoning (Roschelle et al., 2000). One way to promote quantitative reasoning is through engaging students with dynamic interaction with tables, graphs, and other user-interactive artifacts (Panorkou et al., 2023). In this paper, we explore the ways in which web-based learning systems, such as MyLabMath, contribute to developing students' quantitative literacy.

Review of Related Literature

MyLab Math has been incorporated into developmental mathematics and college credit-bearing courses. This literature review examines the research on students' and instructors' perspectives of MyLab Math, and remedial pedagogy in developmental mathematics education.

Students' Perspective on MyLab Math

Research on using web-based learning management systems focused on student perspectives. For instance, in Serhan and Almeqdadi's (2020) study, students were asked about the advantages and disadvantages of using MyLab Math and their habits of using the system. They found most students spend three to six hours each week on their homework (78%) and appreciate the immediate feedback (22.4%). However, technical difficulties and lack of access to internet in completing the work was a main issue (34.7%) (Serhan & Almeqdadi, 2020). Olsen's (2020) study found that students appreciated the use of "help me solve this," "view an example," and the ability to advance through the material at their own pace. Overall, the video feature, text, and animation features were not commonly utilized among students. In Adewumi's (2020) study, 52% of students stated they never used MyLab Math's multimedia library (Adewumi, 2020). The video and animation features are not available for all problems on MyLab Math and students mentioned not noticing these features while working on MyLab Math (Wells, 2014). Students reported that they did not use the videos provided by MyLab Math because there were discrepancies between the videos' instruction and their in-class lectures (Wells, 2014; Bamba Adewumi, 2020). Students also expressed frustration when MyLab Math did not accept answers due to formatting issues (Gromilovitz 2018). Studies show there were positive correlations between homework scores and exam grades, homework scores and test scores, and the amount of time students spent using MyLab and their final exams (Ajaz, 2020). Despite these findings on students' perceptions on using web-based systems in learning, there is much-needed research on the mathematical contents and students' development of quantitative literacy through MyLab Math.

Instructors' Perspective on MyLab Math

Instructors in various studies shared the advantages and disadvantages they encountered using MyLab Math in their courses. Instructors who participated in Olsen's (2020) study provided feedback about their thoughts on students' experience with MyLab Math. Instructors in Olsen (2020) and Gromilovitz's (2018) study believed MyLab Math enhanced students' performance and provided student learning support outside of class. In Adewumi's (2020) study, instructors were concerned that students were not doing the homework themselves or were using Photomath. Although students can successfully complete assignments that did not translate during assessments (Adewumi, 2020; Gromilovitz, 2018). Also, in Grubb and Gabriner's (2013) work an instructor who observed students doing homework assignments on computer-based programs reported that students were using a "hacker approach" by not thinking about how to solve the problems they were presented with but they were inputting responses until they got it right. Faculty discussed the amount of time that was saved from grading and having the ability to pull up the eText during lectures to review problems. This was beneficial when students did not have the textbook (Gromilovitz 2018). Also, similar to students, faculty pointed out students' frustrations on issues with answer formatting. As a result, instructors began to address how MyLab Math wanted answers entered (Gromilovitz 2018).

Despite these findings on students' and instructors' perceptions of using web-based systems in learning, there is much-needed research on the mathematical content and students' development of quantitative literacy through MyLab Math. These studies do not investigate the complexity of mathematical tasks presented by MyLab Math.

Remedial Pedagogy in Developmental Education

Students who are placed into developmental mathematics courses are revisiting concepts they failed to grasp during their K-12 education. Therefore, this provides an opportunity for students to relearn the same material through a new lens. However, evaluations of pedagogy in developmental mathematics show that teaching approaches focus on building procedural fluency. Grubb (2012) argued that remedial pedagogy is present in developmental education, primarily in developmental mathematics classes. There is an emphasis on getting one correct answer by presenting students with drill and skill questions that do not allow them to build understanding or to connect the mathematical procedures and how they apply to the real world. Instructors from other disciplines shared that students struggled to apply the knowledge from their mathematics course to science because they lacked the skills. Consequently, students feel confused when they encounter problems that differ from those covered in class (Grubb, 2012). Students faced challenges in answering contextualized questions because the expected clues they were instructed to find were missing. (Grubb, 2012).

Textbooks and computer-based instruction also emphasize remedial pedagogy. However, computer programs have not been reviewed for their pedagogy or effectiveness (Grubb, 2012). Textbooks and computer-based instruction programs contain numerous routine problems that lack the effort to develop mathematical understanding. Computer programs can be beneficial for students to review but they do not encourage reasoning and mirror remedial pedagogy (Grubb, 2012). This supports the findings by Chekour (2014), which found that computer-assisted instruction produces higher achievement for students; however, there were also findings that computer-assisted instruction was more beneficial for teaching lower cognitive material than higher cognitive material. Remedial pedagogy in developmental mathematics is present across instruction, textbooks, and computer-based instruction, preventing students from building mathematical proficiency through the instructional practices identified by Kilpatrick et al. (2001) conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. Although, there is innovation in developmental mathematics classes, remedial pedagogy seems to dominate the instruction.

Theoretical Background

In higher education, quantitative literacy and quantitative reasoning are used interchangeably. In this paper, we refer to quantitative reasoning as the process by which quantitative literacy can be achieved. Quantitative reasoning serves as an intended learning outcome measuring students' ability to interpret and represent information presented in mathematical equations, graphs, tables, and words accurately and effectively, and to address real-world problems. In mathematics education research, quantitative reasoning refers to the process of conceiving a mathematical situation, identifying quantities that change, and constructing relationships between the changes in quantities (Thompson, 2011).

Framework 1: Depth of Knowledge (DOK)

We follow Webb's (2002) Depth of Knowledge which elaborates on how tasks foster different levels of knowledge as shown in Table 1. According to Webb (2002), the interpretation and assignment of these levels to learning objectives and assessment items are essential in alignment analysis. Webb recommends that large-scale, on-demand assessments in mathematics should only assess Depth of Knowledge Levels 1, 2, and 3. Depth of Knowledge at Level 4 in mathematics should be reserved for local assessment.

Table 1. *Depth of Knowledge (Webb, 2002)*

Level of Depth of Knowledge	**Action and keywords**
Level 1: Recall & Reproduction	Recall of information such as facts, definition, term Performing simple procedure/algorithm/applying a formula key words: identify, recall, recognize, use, measure.
Level 2: Skill & Concept	Make decisions on how to approach the problem Imply more than 1 step action key words: classify, organize, estimate, collect and display data, compare data, carrying out experimental procedures, displaying data in tables, graphs, and charts
Level 3: Strategic Thinking & Reasoning	Reasoning, planning, use of evidence, explain thinking, justify answers, make conjectures, developing logical arguments
Level 4: Extended Thinking	High cognitive demands, designing and conducting experiments, making connections between a finding and related concepts, combining synthesizing ideas into a new concept, critiquing experimental designs.

In this framework, we argue that the act of observation expected in an assessment should be at Level 1 instead of Level 2. Observation fits into the first level action of identifying or recognizing potentially applicable mathematical facts as a single-step action.

Framework 2: Dimensions of Task Analysis

Additionally, we explored Gracin's (2018) instrument for textbook analysis to examine other dimensions of textbook analysis and Snelson's (2002) framework to investigate the use of technology in representing mathematical concepts in computer-assisted instructions. Then, we examined the intersection of the two frameworks with Webb's (2002) depths of knowledge. In this paper, we combined the representation categories for quantitative content (Snelson, 2002) and the instrument for textbook analysis (Gracin, 2018). Although both frameworks are used to analyze textbook contents, we argue that these frameworks may be useful in examining assessment tasks that may be reflective of what students are expected to learn from the course.

From Gracin's framework, we included the mathematical activity (e.g., representations and modeling, calculation and operation, interpretation, argumentation and reasoning), complexity level (e.g., direct application of basic knowledge and skills, constructing and dealing with connections, reflection or applying reflective knowledge), answer form (e.g., closed answer, open answer, multiple choice), and context (e.g., intra-mathematical situation, realistic content, authentic context). We omitted the analysis of mathematical content that evaluates the concept students must know to perform the task. Since we focused on the graphing linear equations contents of the course, we deliberately excluded the mathematical content component from the combined framework because this may only result in redundant information.

Table 2. *Five-Dimensional Textbook Analysis (Gracin, 2018)*

Dimension	**Descriptions**
Mathematical Activity	Representations and modeling Calculation and operation Interpretation Argumentation and reasoning
Complexity Level	Direct application of basic knowledge and skills Constructing and dealing with connections Reflection or applying reflective knowledge
Answer Form	Closed answer Open answer Multiple choice
Context	Intra-mathematical situation Realistic context Authentic context

Table 3. *Representation Categories for Quantitative Contents (Snelson, 2002)*

Categories	**Descriptions**
Mathematical Text	Mathematical symbols used to convey mathematical concepts.
Verbal Text	Non-mathematical symbols used in words, sentences, and lists
Graphics	Graphs, diagram, or images related to the concept.
Tables	Tabular organization of content.
Animations	Instances of graphics or text with motion.
Audio	Stand-alone audio clips.
Video	Video clips of instruction content such as teacher preparations.
Interactive components	Interactive practice problems or graphs with user input.

Additionally, Snelson's (2002) representation categories for quantitative content analysis seem to primarily involve the multimedia components of the tasks in addition to the textual statement forms. We have not included in this paper our analysis of the textual statement (Snelson, 2002) of the assessment tasks due to the focus on evaluating items regarding fostering quantitative reasoning. The excluded criterion may be irrelevant to this report. This criterion only examines whether an item involves mathematical symbols or non-mathematical symbols to convey concepts, which either notation may show inconclusive remarks about assessment for students' quantitative reasoning. Since our analysis aimed to examine the opportunities for quantitative reasoning, we hypothesized that multimedia components such as graphics, tables, animations, audio, video, and interactive components may contribute to achieving this goal. These multimedia examples may help students visualize and examine how quantities change and how the changes are related to each other. Thus, we only included the multimedia components in our combined framework.

We merged the two frameworks into the Dimensions of Task Analysis for Quantitative Reasoning framework (see Table 4) to evaluate the complexity levels, mathematical activity, answer form, contextual features, and multimedia components of each assessment task. Consequently, we sought answers to the following research questions:

1. What characteristics of assessment tasks do graphing linear equations in a MyLabMath developmental mathematics course have?
2. To what extent do assessment tasks in graphing linear equations in a MyLabMath developmental mathematics course evaluate students' quantitative reasoning?
3. What technological features do the graphing tasks have that may support students' quantitative reasoning?

Methodology

We examined seventy assessment items (n = 70) from a developmental course material on MyLab Math. The items included were only limited to the tasks on graphing linear equations to measure how these items help develop students' quantitative reasoning. We analyzed our data using the merged framework of Depth of Knowledge, Categories of Quantitative Contents, and Five-Dimensional Textbook Analysis as shown in Table 4.

Table 4. *Framework for Analyzing Graphing Linear Equations Tasks*

<table>
<tr><th>Depth of Knowledge (Webb 2002)</th><th>Complexity Level (Gracin, 2018)</th><th>Mathematical Activity (Gracin, 2018)</th><th>Answer Form (Gracin, 2018)</th><th>Contextual Features (Gracin, 2018)</th><th>Multimedia Component (Snelson, 2002)</th></tr>
<tr><td>Level 1: Recall and Reproduction</td><td>Direct application of basic knowledge</td><td>Representations and modeling</td><td rowspan="4">Closed answer

Open answer

Multiple Choice</td><td rowspan="4">Intra-mathematical situation

Realistic context

Authentic context</td><td rowspan="4">Graphics

Tables

Animations

Audio

Video

Interactive components</td></tr>
<tr><td>Level 2: Skills and Concepts</td><td></td><td>Calculation and operation Interpretation</td></tr>
<tr><td>Level 3: Strategic Thinking and Reasoning</td><td>Constructing and making connections</td><td>Argumentation and Reasoning</td></tr>
<tr><td>Level 4: Extended Thinking</td><td>Reflection</td><td></td></tr>
</table>

There were two stages of data analysis. The first stage of analysis, the researchers served as the two raters who independently coded each assessment item using the combined framework with moderate to nearly perfect (0.54 to 0.99) agreement across categories. We refer to Landis and Koch's (1977) recommendation of interpreting inter-rater values 0.41 and 0.60 as moderate, 0.61 and 0.80 as substantial, and 0.81 and 1 as nearly perfect agreement. In the second stage of analysis, we negotiated the coding of each item to resolve disagreements made in the first stage.

For example, items that require the generation of graphs were initially coded as either Level 1 which recalls the basic knowledge about graphing from completing the table of x and y values, or Level 2 which engages students to use substitutions of arbitrary values and operations on equations. To resolve this disagreement, we agreed to consider such item as Level 2 in terms of the Depth of Knowledge category. Similarly, when items involved completing a table of values and selecting the corresponding graph of the ordered pairs, those were initially coded as either Direct Application of Basic Knowledge to refer to the application of knowledge about ordered pairs or Constructing and Making Connections to refer to the connections that students may have made between the table and graph artifacts. In this case, we agreed to code such items as Constructing and Making Connections in terms of their Complexity Level. There are also instances where we found emerging subcategories which resulted in initial disagreements. Later, we agreed to develop additional subcategories or combinations of them to appropriately illustrate the assessment items.

Findings and Discussions

I. Distribution of Criteria

We present and discuss the findings of our analysis of the formative and evaluative assessment items on graphing linear equations. Table 5 illustrates the summary of the distribution of these assessment items through our theoretical lenses as we discuss each in this section. To answer our first research question regarding the characteristics of assessment tasks and the second question on how the assessment tasks in graphing linear equations evaluate students' quantitative reasoning. In this section, we also describe the multimedia features of the graphing tasks that may support students' quantitative reasoning to answer our third research question.

Table 5. *Distribution of Criteria in the Assessment Content of Graphing Linear Equations*

Depth of Knowledge	
Level 1: Recall and Reproduction	58.57%
Level 2: Skills and Concepts	40.00%
Level 3: Strategic Thinking and Reasoning	1.43%
Complexity Levels	
Direct Application of Basic Knowledge	61.43%
Constructing and Making Connections	38.57%

Math Activity	
Representations and Modeling, Calculation and Operation	30.00%
Calculation and Operation	30.00%
Representations and Modeling	20.00%
Identification	14.29%
Calculation and Operation/Identification	1.43%
Argumentation and Reasoning	1.43%
Representations and Modeling/Identification	1.43%
Observation	1.43%
Answer Form	
Closed Answer	70.00%
Closed Answer/Multiple Choice	20.00%
Multiple Choice	10.00%
Contexts	
Intra-mathematical situation	97.14%
Realistic Content	2.86%
Multimedia Components	
Interactive Component only	31.43%
No multimedia component	31.43%
Video only	11.43%
Animations, Video, and Interactive Component	5.71%
Table, Animations, and Interactive Component	4.29%
Video and Interactive Component	2.86%
Graphics and Animations	2.86%
Graphics and Video	2.86%
Graphics only	2.86%
Table, Video, and Interactive Component	1.43%
Animations only	1.43%
Animations and Video	1.43%

Depths of Knowledge

Our findings show a skewed distribution of items that engage students in different levels of depth of knowledge. We identified most assessment items as inducing Recall and Reproduction (Level 1) (58.57%) and Skills and Concepts (Level 2) (40%), while only 1.43% involved Strategic Thinking and Reasoning (Level 3). This shows that the assessment items are primarily focused on evaluating students' recall of basic knowledge (see Figure 1 as an example), and use of rote mathematical operations (see Figure 2 as an example), rather than intensively engaging students in quantitative reasoning. The literature shows that rote learning and imitative use of mathematical operations were more common in mathematics textbooks than mathematically founded reasoning (e.g., Sidenvall, et al., 2015).

Figure 1. *Assessment item Q.4 as Level 1.*

Find the slope of the line that passes through the given points.

(8,2) and (− 2,2)

Select the correct choice below and, if necessary, fill in the answer box to complete your choice.

- ○ **A.** The slope is ☐. (Type an integer or a simplified fraction.)
- ○ **B.** The slope is undefined.

Answer: A. The slope is **0**. (Type an integer or a simplified fraction.)

Figure 2. *Assessment item F.6 as Level 2.*

Find an equation of the line passing through the pair of points. Write the equation in the form Ax + By = C.

(4,3) and (3,1)

The equation of the line in the form Ax + By = C is ☐.
(Simplify your answer. Use integers or fractions for any numbers in the equation.)

Answer: 2x − y = 5

One assessment item seemed to prompt students' reasoning (see Figure 3). However, this item only pertains to the nature of finding three ordered pair solutions of a linear equation to graph a line, rather than prompting students in reasoning and argumentation. This finding also shows a lack of opportunity for students to reason quantitatively in a quantity-focused context.

Figure 3. *Assessment item 6.2.10 as Level 3.*

Which of the following statements best describes why you should find three ordered pair solutions of a linear equation in two variables in order to graph the line?

Choose the correct answer below.

- ○ **A.** You should find three ordered pairs because there are three variables in a linear equation, and you need one point for each variable.
- ○ **B.** It takes two points to determine a line; the third point is a check on your arithmetic.
- ○ **C.** You actually need four points to determine a line, but only finding three points is a shortcut.
- ○ **D.** It takes one point to determine a line.

Answer: B. It takes two points to determine a line; the third point is a check on your arithmetic.

Although assessment item 6.2.10 is indeed encouraging students to make sense of the condition of graphing a line, it does not reflect the idea of quantitative reasoning that is foundational and essential in many career-oriented tasks. Quantitative reasoning should at least involve understanding how two quantities change, as variables per se, and how their changes relate to one another when the variation happens simultaneously. Despite the rigorous campaign to help undergraduate students develop this form of reasoning, it might still be difficult for both teachers and students to practice this in mathematics classrooms. Additionally, students rely heavily on studying what is required in the assessment or illustrated in the instructor's lecture, rather than accommodate other mathematical practices that are more important to experience and encourage meaningful learning.

Complexity Level

In terms of examining the Complexity Level, the direct application of basic knowledge is primarily assessed among students (61.43%), while 38.57% of the items evaluate the construction of connections, but none of the items require reflective thinking. The assessment tasks illustrate the lack of cognitive complexity required for students to develop a higher order of thinking. For example, majority of the tasks evaluate students' use of direct application of basic knowledge by recalling the definition of coordinates, identifying where points can be located in a coordinate grid, or computing the value of one variable given the value of the other using substitution of values in a linear equation involving two variables. This application of basic knowledge only engages students in applying concepts, rules, procedures, and representations (Gracin, 2018), which we found necessary during the introductory chapter of the course. However, this category has been recurring through the conclusion of the material. The remaining assessment items cover the construction and making connections, where students are frequently asked to use what they know about finding relative values of an equation and create a linear graph. What students learn from the basic knowledge is not only used as a direct application, but a necessary tool for translating information from one artifact into another while maintaining the meaning of the context. For example, students are asked to graph a linear equation. This task requires students to construct a set of data using an equation to form a table, and then the data from the table are translated into a graph. However, the two complexity levels may not be enough for students to develop a more rigorous understanding of how this mathematical concept of graphing relates to real-life situations, nor is it sufficient to claim that the assessment helps foster quantitative reasoning.

Mathematical Activity

We examined the mathematical activity criterion and found that the assessment items primarily illustrate a combination of representations-modeling and calculation-operation (30%) and solely calculation-operation (30%). This was expected to come up in our analysis of this component since most of the assessment items in the depths of knowledge measure students' use of mathematical operations such as finding a value of one variable by substituting a given value of another using a linear equation. This also shows that the priority of the assessment items is on the representation and modeling of data from different artifacts (table, equation, and graph), which are necessary initial tools for reasoning about quantities. However, representation and modeling are not complete without reflecting on what the data mean or how the data are related to one another. Meanwhile, the least mathematical activities being used for assessment are argumentation and reasoning (1.43%) and observation (1.43%). The argumentation-reasoning component is logically low because the course only has one item that engages students in strategic thinking and reasoning (Level 3) of the depths of knowledge.

In our analysis, we found emerging categories for mathematical activities such as identification (14.29%), observation (1.43%), a combination of calculation-operation and identification (1.43%), and representations-modeling and identification (1.43%). These categories are important to include to illustrate how mathematical activities are distributed.

This also shows the lack of intention to activate students' use of higher-order mathematical thinking.

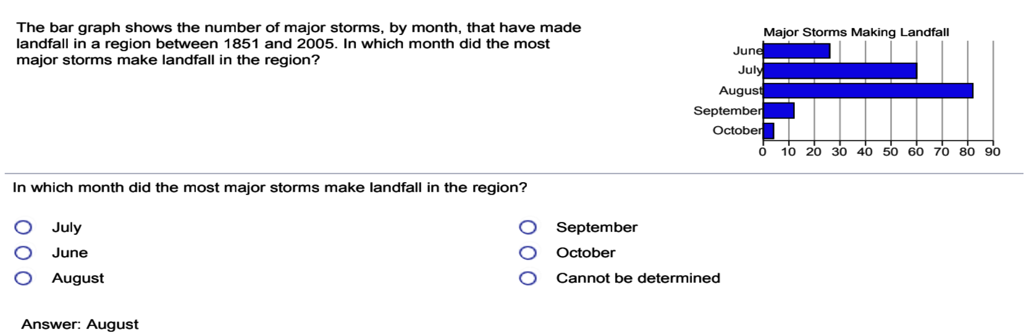
Answer Form

The answer form category showed that the majority of the assessment items are closed answer forms (70%) that require students to type in specific answers such as the equation of the line passing through a pair of points, the slope of the line that goes through given points, and determining whether a pair of lines are parallel, perpendicular or neither. In most cases, we classified questions that ask students to create a graph for an equation using interactive grids as a closed answer form in the sense that the students are only expected to generate a graph that looks exactly the same as the ones in the answer key. There are also questions that only ask students to select the graph from the provided choices that best match the given set of ordered pairs. When assessment tasks are a combination of closed answers and multiple choice (20%), students are often asked whether there is a defined value for slope and answer the value, and an option that the slope is undefined. Since none of the assessments offer an Open Answer form, we infer that there is a lack of opportunity for students to reflect on the relationships between artifacts such as the equation, the generated ordered pairs summarized in tabular form, and the graph that reflects the locations of the ordered pairs. By making sense of the quantities, how the quantities are changing in table and graph with a platform for writing these mental constructions, students may be able to begin to reason about the quantitative relationships between them.

Contextual Features

In terms of the contextual features, we found that most of the assessment items (97.14%) involve making use of contextual knowledge about definitions, representations, operations, and procedures. This seems common across assessments where students are evaluated according to how much they know about mathematical definitions and procedures. Only two items were coded as involving realistic contents (2.86%) where students were asked to analyze a graph using data from a real-life situation such as the number of major storms per month as shown in Figure 4. Although this example uses a real-life example, the assessment item does not seem relevant to the graphing linear equations nor sufficiently prompts students to reason quantitatively about two quantities. Instead, it only refers to the representation of a change in a single quantity over a set of qualitative data.

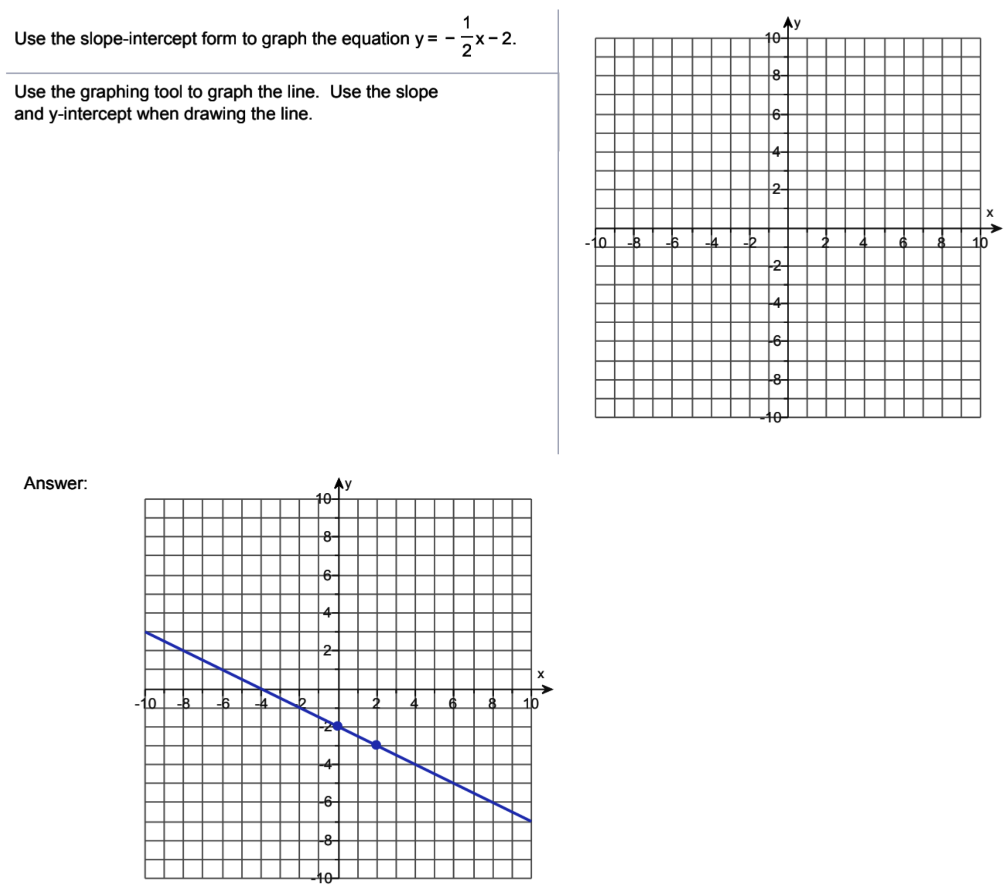
Figure 4. *Assessment item 6.1.11 as involving Realistic contents.*



Multimedia Component

When analyzing the assessment items according to their multimedia components, we found that about one-third of the number of items are using interactive components only (31.43%) such as an interactive graphing grid where students can plot points for the desired ordered pairs and connect them to create a line (see Figure 5). Interestingly, about one-third of the items (31.43%) do not have any multimedia components, while some offer video components (11.43%) on side tabs that students could use to review the underlying concepts of the item being answered. The rest of the assessment tasks (25.71%) include a combination of some video animations, lecture videos, interactive components, table of values, and graphics. Although these items utilize multiple media, they do not sufficiently support students' independent construction of quantitative reasoning. More importantly, using an interactive graphing grid component does not imply that students are making connections between order pairs as a set of quantities and the differences or changes between them.

Figure 5. *Assessment item Q.9 as composed of an interactive component only.*



II. Cross-examination of Depth of Knowledge, Mathematical Activity, and Multimedia Components

In this section, we cross-examined how the categories on mathematical activity and multimedia components may interplay with the depth of knowledge. We chose to analyze the mathematical activity in terms of the depth of knowledge that students may engage with (see Table 6). This summary shows that the majority of the items use calculation and operations and only draw students to Level 1, recall and reproduction of basic knowledge. This case is often related to prioritizing procedural understanding of how equations can be manipulated to find the ordered pairs rather than conceptually relating the changes of values such as doubling, tripling, or reducing by halves leading to quantitative reasoning. In contrast, the only item that prompted students in reasoning may have been classified as Level 3, strategic thinking and reasoning. However, this case fell short on our anticipated construction of meaningful reasoning about quantities in ordered pairs. In other words, it does not sufficiently approach the relationship between quantities as depicted in graphs. Instead, it only focuses on the act of graphing.

Table 6. *Distribution of Depth of Knowledge for Math Activity*

Math Activity	**Level 1: Recall and Reproduction**	**Level 2: Skills and Concepts**	**Level 3: Strategic Thinking and Reasoning**	**Total**
Representations and Modeling, Calculation and Operation	3	18		21
Calculation and Operation	20	1		21
Representations and Modeling	5	9		14
Identification	10			10
Calculation and Operation/Identification	1			1
Argumentation and Reasoning			1	1
Representations and Modeling/Identification	1			1
Observation	1			1
Total	**41**	**28**	**1**	**70**

Table 7. *Distribution of Multimedia Components for Depth of Knowledge*

Multimedia Components	Level 1: Recall and Reproduction	Level 2: Skills and Concepts	Level 3: Strategic Thinking and Reasoning	Total
No multimedia component	21		1	22
Interactive Component only		22		22
Video only	8			8
Animations, Video, and Interactive Component	1	3		4
Table, Animations, and Interactive Component	2	1		3
Graphics and Video	2			2
Graphics and Animations	2			2
Video and Interactive Component		2		2
Graphics only	2			2
Table, Video, and Interactive Component	1			1
Animations and Video	1			1
Animations only	1			1
Grand Total	**41**	**28**	**1**	**70**

We also looked into the ways in which the multimedia components in each assessment item may have been used to engage students in different levels of knowledge (see Table 7). In this cross-examination, we found that regardless if assessment items have an interactive graphing grid component or they do not use any multimedia at all, they primarily engage students at Levels 1 and 2. The only item for Level 3, reasoning, does not include any multimedia component. Instead, it offers students multiple choices to select the best possible reasoning for considering a number of ordered pairs on a graph. This shows that the assessment items may have underutilized the power of multimedia components. In particular, the interactive tables and graphing grids could have been used for engaging students in transitioning between these artifacts and prompting them with questions about the changes in quantities and relationships between those changes.

Conclusions

Although developmental mathematics courses are primarily offered to students who may not take advanced mathematics courses in the future, it is essential to help students articulate the kind of mathematical reasoning at this stage that is necessary for their career success later on. We argue that students, at any level of education, must be given the opportunity to make sense of the mathematical relationships between quantities that they often encounter in real-life situations. Our findings from this study show that the tasks being offered to students in a college developmental mathematics course using MyLab Math lacks this kind of intellectual opportunity. Not only that most mathematical activities are focusing on calculations and operations targeting the first level of depth of knowledge, it also underscores the power of technological tools such as interactive tables and graphing grid for students to make sense of the relationships between quantities. When reasoning was included in the assessment, students were given multiple choices to choose their answer from, instead of providing them with a platform to express their authentic thinking. We offer some suggestions where these components of the assessment items could be improved and incorporate the idea of engaging students in quantitative reasoning. To further this study, we aim to look into the pedagogical perspectives of instructors and their implementation of development mathematics courses using MyLab Math into their classes in light of the quantitative reasoning approach.

References

Adewumi, A. E. B. (2020). *The Impact of Using Adaptive Learning in a Remedial Mathematics Course at an Urban University* (Order No. 28490104). Available from ProQuest Central; ProQuest Dissertations & Theses Global. (2593183351).

Ajaz, A. (2020). *Analyzing the Effects of MyMathLab on Undergraduate College Students Achievement in Pre-calculus Mathematics I* (Order No. 27962289). Available from ProQuest Dissertations & Theses Global. (2403113071).

Carlson, M., Jacobs, S., Coe, E., Larsen, S., & Hsu, E. (2002). Applying covariational reasoning while modeling dynamic events: A framework and a study. *Journal for Research in Mathematics Education*, *5*(33), 352–378.

Chekour, A. (2014). *The Effectiveness of MyMathLab (MML) Learning System on Developmental Math Instruction* (Order No. 3644344). Available from ProQuest Dissertations & Theses Global. (1636532848).

DeRouen, Sheila Duplechain, "MyMathLab Educational Intervention to Enhance Student Performance in Calculus I at Historically Black Colleges and Universities" (2018). LSU Doctoral Dissertations. 4679. https://digitalcommons.lsu.edu/gradschool_dissertations/4679

Gracin, D. G. (2018). Requirements in mathematics textbooks: a five-dimensional analysis of textbook exercises and examples. *International journal of mathematical education in science and technology*, *49*(7), 1003-1024.

Gromilovitz, K. (2018). *Perceptions of Faculty Using MyMathLab in Traditional, In-Seat Math Classes* (Order No. 10981061). Available from ProQuest Dissertations & Theses Global. (2154870219).

Grubb, W. N. (2012). *Basic skills education in community colleges : Inside and outside of classrooms*. Taylor & Francis Group.

Kilpatrick, J. (2001). Understanding mathematical literacy: The contribution of research. *Educational studies in mathematics*, *47*(1), 101-116.

Landis, J. R., & Koch, G. G. (1977). An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers. *Biometrics*, 363-374.

Olsen, L. S. (2020). *MyMathLab and Nontraditional Students' Attitudes Toward Technology in Mathematics* (Doctoral dissertation, Walden University).

Panorkou, N., & Germia, E. F. (2021). Integrating math and science content through covariational reasoning: The case of gravity. *Mathematical thinking and learning*, *23*(4), 318-343.

Panorkou, N., York, T., & Germia, E. (2023). Examining the "Messiness" of Transitions Between Related Artifacts. *Digital Experiences in Mathematics Education*, *9*(1), 131-162.

Paoletti, T., Corven, J., & Gantt, A. (2021). Supporting Middle-School Students' Development of Emergent Graphical Shape Thinking. *North American Chapter of the International Group for the Psychology of Mathematics Education*.

Papert, S. (1980). Computers for children. *Mindstorms: Children, computers, and powerful ideas*, 3-18.

Roschelle, J., Kaput, J., & Stroup, W. (2012). SimCalc: Accelerating student engagement with the mathematics of change. *In M.J. Jacobsen & R.B. Kozma, Learning the sciences of the 21st century: Research, design, and implementing advanced technology learning environments.* Hillsdale, NJ: Earlbaum

Serhan, D., & Almeqdadi, F. (2020). Students' Perceptions of Using MyMathLab and WebAssign in Mathematics Classroom. *International Journal of Technology in Education and Science*, *4*(1), 12-17.

Sidenvall, J., Lithner, J., & Jäder, J. (2015). Students' reasoning in mathematics textbook task-solving. *International journal of mathematical education in science and technology*, *46*(4), 533-552.

Snelson, C. (2002). Online Mathematics Instruction: An Analysis of Content. Paper presented at the Annual Meeting of the Northern Rocky Mountain Educational Research Association (Estes Park, CO, October 9-12, 2002).

Thompson, P. (2011). Quantitative reasoning and mathematical modeling. *New perspectives and directions for collaborative research in mathematics education: Papers from a planning conference for WISDOM^e.* Laramie: WY.

Thompson, P. W., & Carlson, M. P. (2017). Variation, covariation, and functions: Foundational ways of thinking mathematically. *Compendium for research in mathematics education*, 421–456.

Tucker, T. (1990). *Priming the calculus pump: Innovations and resources.* Washington, DC: MAA.

Webb, N. L. (2002). Depth-of-knowledge levels for four content areas. *Language Arts*, *28*(March), 1-9.

Wells, T. J. (2014). *A mixed methods investigation of developmental math students' perspectives on successes and challenges in math and with MyMathLab* (Order No. 3647877). Available from ProQuest Central; ProQuest Dissertations & Theses Global. (1645427754). https://kean.idm.oclc.org/login?url=https://www.proquest.com/dissertations-theses/mixed-methods-investigation-developmental-math/docview/1645427754/se-2