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THE IMPLEMENTATION AND EFFECTS OF THE MATHEMATICS DESIGN COLLABORATIVE (MDC): EARLY FINDINGS FROM KENTUCKY NINTH-GRADE ALGEBRA 1 COURSES

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Abstract

With support from the Bill and Melinda Gates Foundation, researchers and experts in mathematics education developed the Mathematics Design Collaborative (MDC) as a strategy to support the transition to Common Core State Standards in math. MDC provides short formative assessment lessons known as Classroom Challenges for use in middle and high school math classrooms. UCLA CRESST's study of ninth-grade Algebra 1 classrooms in Kentucky implementing MDC showed strong support from teachers for the intervention and a statistically significant positive impact on student scores on the PLAN Algebra assessment, as compared to similar students statewide in Kentucky.

Chapter 1:
Introduction

Kentucky was the first state to adopt new, more rigorous college and career ready standards—the Kentucky Core Academic Standards (KCAS)—and commit to statewide implementation to ensure that students acquire the knowledge and skills they need for future success. There is no doubt that the KCAS substantially raises the bar for expected student learning. In mathematics, the KCAS demands that students not only understand mathematics concepts and procedures, but also are able to apply and use their knowledge to model and solve real-world problems. The result is a set of intellectually demanding standards that call on the integration of mathematical content—the basic concepts and procedures of mathematics—with mathematical practices—the habits of mind, thinking, reasoning, and modeling which characterize mathematics competency.

KCAS implementation brings with it important challenges for teachers as well as students. To prepare students for these new demands, teachers must not only adjust and deepen the content of their curriculum and teaching, but also make substantial changes in their pedagogical practice. Building students' capacity to think critically, analyze, communicate, and model and solve novel problems in mathematics requires that classroom teachers engage and support students in such practices, which is at odds with the teacher-directed instruction and basic mathematical knowledge and procedures foci which have typically dominated mathematics classrooms (National Mathematics Advisory Panel, 2008; National Research Council, 2011).

The Bill and Melinda Gates Foundation invested in the Mathematics Design Collaborative (MDC) as one strategy to support teachers' and students' transition to more rigorous mathematics standards. Although MDC is at a relatively early stage of implementation, the Foundation was interested in obtaining early evidence on program effectiveness and contracted with the National Center for Research on Evaluation, Standards, and Student Testing (CRESST) to conduct a quasi-experimental study of its implementation and learning impact. The study examined MDC as it was implemented in ninth-grade Algebra 1 classes from selected Kentucky districts during the 2012–2013 school year and is the subject of the current report.

In the remainder of this chapter, we present background on the study, including a brief description of the MDC intervention and the evaluation questions that guided the ninth-grade study. In the following chapters, we summarize the study methodology, present the implementation and outcome results, and examine the implications of our findings.

Mathematics Design Collaborative Overview

MDC supports the transition to the Common Core State Standards (CCSS) by providing Classroom Challenges that can be used in conjunction with ongoing curriculum and instruction. Each Challenge is designed as a two- to three-day formative assessment lesson (FAL), anchored in the Common Core State Standards for Mathematics (CCSS-M), to help secondary mathematics teachers monitor and assess their students' development of key mathematical skills and understandings. The Challenges are also intended to model and help teachers incorporate deeper mathematical reasoning and thinking into their practice. Towards this end, there are two primary types of Challenges, one focusing on conceptual understanding and the other on problem solving. At the time of the study, participating teachers could choose from among 40 Challenges at the high school level, as well as 61 Challenges geared towards middle school mathematics.

Developed by the Shell Center at the University of Nottingham in collaboration with the University of California, Berkeley, each Challenge follows the same general structure: (a) Students engage in a pre-assessment, including challenging problems or questions involving previously learned concepts or principles. (b) Teachers review student responses to assess student approaches, solution strategies, and understandings and misconceptions. (c) Students then engage in whole-class and small-group collaborative activities to discuss alternative approaches, bring misconceptions to the surface, deepen their understanding, and connect and apply their knowledge and skills in new contexts. (d) At the end of the Challenge, students return to the initial problems or questions, revise their initial responses, and reflect on what understandings have been gained.

The Challenges incorporate key changes in pedagogy and classroom culture to support CCSS-M learning goals. According to the developers (Math Assessment Project, 2013, p. 2), these include the following:

- Students take more responsibility for their own work.
- Students engage in “productive struggle” with rich challenging tasks. Resolution comes only gradually through interactions and discussion in the lesson as students gain new facets of connected understanding.
- Students study fewer tasks, but in greater depth. They are asked to draft solutions, compare their approaches to others, and redraft their ideas as a result of their discussions.
- The teachers’ role is to prompt students to reflect and reason through their ideas. Teacher questioning is central to support students’ thinking and depth of knowledge, and student growth. The teacher’s role is not to provide answers and solutions.

Evaluation Questions

At the time of the study, teachers had had only one or two years of prior experience in implementing MDC. These teachers were part of the initial trials of MDC with early district implementers. At this early phase of MDC development, the study addressed a comprehensive set of evaluation questions:

1. How do teachers implement MDC?
2. What is the impact of MDC on student learning?
3. What conditions and contexts, including implementation quality, influence MDC effectiveness?

In addressing these questions, the study used a quasi-experimental design (QED) and developed and validated new measures of implementation and learning impact, as described in the next chapter.

Chapter 2:
Study Methodology

The study focused on ninth-grade Algebra 1 teachers and their students to examine study program effects over the 2012–2013 school year. Study methodology featured a strong quasi-experimental design to examine MDC's effects on students' state assessment performance, and also used implementation and student outcome measures that were specially developed to align with MDC goals. The implementation measures included logs, teacher surveys, and analysis of student work. Next, we provide details about the study methodology.

Implementation Measures

Our implementation measures draw on research on instruction and instructional change, given that the ultimate goal of the MDC intervention was to support teachers' and students' transition to new College and Career Ready Standards (CCRS) that emphasize mathematical reasoning and the solving of authentic problems. However, while classroom practice is notoriously impervious to reform (Cuban, 1984; Lortie, 1975), an emerging body of research has documented the relationship between student achievement and specific instructional practices that create opportunities to learn (see Bryk, Sebring, Allenworth, Luppescu, & Easton, 2010; Rowan & Correnti, 2009; Winters & Herman, 2011). Our implementation measures thus focus on classroom instruction, even as we recognize the many influences on the implementation of new practices. Study implementation measures included web-based teacher logs, the collection and analysis of MDC artifacts, and teacher surveys. When teachers had more than one Algebra 1 class, they were asked to focus on one class randomly selected by CRESST.

Web-based teacher log. Study teachers were asked to submit four to six logs over the course of the school year. Each log was supposed to be completed during the days directly following administration of a Classroom Challenge. The logs focused on (a) the degree to which instruction generally aligned with the structure of the MDC intervention and (b) the quality and extent of formative assessment practices incorporated into the instruction. The logs were structured with conditional branching so that teachers were first given a general set of questions about the components of the Challenge they implemented and then were directed to additional sets of questions about the pre-assessment, small-group collaborative work, whole-class plenary, and post-assessment depending upon their initial responses. Log administration was conducted from September 2012 through May 2013. (See Exhibit A1 in Appendix A for a copy of the teacher log.)

During analysis, log data were aggregated by teacher and then were summarized across teachers in the sample. That is, item-by-item mean scores were computed for each teacher across all logs submitted. The computations did not include any sections that were skipped because of the conditional branching.

Analysis of MDC artifacts. As part of the log process, teachers were asked to submit electronic or hard copies of students' pre- and post-assessment responses for each Challenge completed. Students' pre- to post-assessment improvement was treated as a measure of teachers' quality of MDC implementation. Our assumption was that teachers who implemented the Classroom Challenges well would produce greater student learning improvement than teachers whose implementation was less expert.

Toward this end, three rubrics were developed to examine how students' mathematical learning progressed from pre- to post-assessment for each Challenge. These included rubrics to address two positive dimensions of learning, content accuracy and quality of mathematical explanations, while a third rubric examined evidence of misconceptions. Accuracy items and misconceptions were generally scored on a scale of 0–1. In contrast, explanations were scored on a scale of 0–3, with 0 meaning no response, 1 meaning no conceptual understanding, 2 meaning partial understanding, and 3 meaning there was evidence of full understanding. (See Exhibit A2 in Appendix A which includes exemplars and the rubrics used to evaluate student learning on each assessment.)

A subset of Challenges that were commonly used and well aligned to the special CRESST mathematics measure were selected for scoring, and individually linked pre- and post-assessment scores were used to create a measure of implementation quality. A minimum of 10% of the responses for each assessment item were double-coded by specially trained members of our research staff, reaching reliability of ≥ .80 per item and ≥ .90 per Challenge. Our assumption was that greater pre-to-post learning progress could serve as an indicator of higher quality MDC implementation.

Teacher survey. CRESST collaborated with Research for Action (RFA) on the design of the spring 2013 implementation and scale-up survey for MDC teachers. The survey included a section on module implementation with items designed to mirror the intent of the log items, and to augment information on factors likely to influence MDC implementation. As such, the survey emphasized implementation of the Challenges during the 2012–2013 school year; use of the Challenges during previous school years; support received for implementation (e.g., professional development, collaboration, etc.); and teacher perceptions about the Challenges, their impact on students, and mathematics skills in general. We drew on RFA survey variables as indicators of implementation quality as well as context and possible moderators of MDC implementation and impact (e.g., experience using MDC, attitudes regarding mathematics instruction, extent of professional development, leadership support, and collaboration). Descriptive statistics were computed at the teacher level. (See Exhibit A3 in Appendix A for a copy of the teacher survey.)

Post-intervention opportunity-to-learn survey. Participating teachers were asked to complete a short one-page survey at the time that they administered the CRESST-designed mathematics assessment. This survey included questions on the administration of the assessments (i.e., the administration date and amount of time students spent completing them) as well as several questions about the Challenges implemented during the 2012–2013 school year (i.e., number taught and topics covered). The survey also asked teachers to report on the degree of emphasis they placed in their 2012–2013 instruction on the content areas covered by the CRESST mathematics assessment. The answers to these questions were intended to provide valuable data on students' opportunity to learn (OTL) the content tested and to help tease out the effects of OTL and MDC instruction. Although results were summarized at the teacher level, because of low return rates the data were of limited utility. (See Exhibit A4 in Appendix A for a copy of the OTL survey.)

Student Outcome Measures

Study outcome data included individual student-level achievement data from Kentucky's state assessment program and the special CRESST measure. The following describes each of these in turn.

Longitudinal state assessment data. All Kentucky students take ACT's PLAN test in the fall of 10th grade. The mathematics component of ACT PLAN is a 40-minute multiple choice exam, including 22 items addressing algebra and pre-algebra content and 18 items addressing geometry. The exam yields subscores for each of these areas. Score reliabilities for the subscores and total scores ranged from .65 to .86, with a reliability of above .80 for algebra, the primary area of interest in the current study (ACT, 2013).

Tenth-grade ACT PLAN scores from the fall of 2013 for students participating in Algebra 1 during the 2012–2013 academic year served as the outcome measure for the study's QED analyses. In addition, the study gathered prior years of Kentucky state assessment scores going back to 2008–2009 for study students, teachers, and schools. These data were used in Coarsened Exact Matching (CEM) to create a comparison group that was carefully matched to the MDC group in student and school characteristics, prior achievement, and prior teacher and school effectiveness. Further details about the matching are presented in Chapter 4.

CRESST mathematics assessment. CRESST developed and administered a mathematics learning measure to students in participating MDC teachers' classrooms (see Exhibit A5 in Appendix A). This measure was aligned with the conceptual content of the five Challenges most commonly implemented by study participants during the 2012–2013 school year. The measure is composed of a variety of item types that, as described in Table 1, address different kinds of knowledge.

Table 1

Item Types and Knowledge Targets for CRESST Mathematics Assessment

Item type	Description of knowledge targets
Basic computation (BC)	Respond to a simple, well-defined problem, e.g., a computation problem that requires finding an answer or missing variable. Knowledge required is recall of concepts or procedural rules or principles. Problem represents an application of the relevant big idea or key concept.
Word problem (WP)	Generate a written solution or product in response to a problem-solving prompt. Problem solution requires application of one or more big ideas and integration of declarative (factual), conceptual, and procedural knowledge. Problem situation is described in text or represented graphically, followed by a short (1–2 sentence) question or prompt. It should be possible to read the directions and complete the task in 5 minutes.
Word problem with justification (WJ)	Generate a written solution or product in response to a problem-solving prompt, and explain the what and why of the solution. Problem solution requires application of one or more big ideas and integration of declarative (factual), conceptual, and procedural knowledge. Problem situation is described in text or represented graphically, followed by a short (1–2 sentence) question or prompt. It should be possible to read the directions and complete the task in 5–7 minutes.
Explanation (EX)	Generate a clear, coherent explanation of a big idea and indicate how it can be used to solve problems. Students must support their explanations with examples and illustrations. Directions may provide an authentic context to frame the writing, consisting of the intended audience and a situation or scenario to which the student should respond.

The assessment included five sections, or mini-tests, aligned to the content of the following Challenges most commonly administered by participating ninth-grade Algebra 1 teachers: (FAL03) Solving Linear Equations in Two Variables, (FAL13) Sorting Equations and Identities, (FAL16) Interpreting Algebraic Expressions, (FAL20) Forming Quadratics, and (FAL22) Finding Equations of Parallel and Perpendicular Lines. Each mini-test was composed of five or six items.

Rubrics and scoring keys were developed by CRESST in order to score each assessment item. All multiple choice and short answer (fill in the blank) items, including basic computation and word problems, were scored using a 0–1 scale (0 = *incorrect*, 1 = *correct*). In contrast, a scale of 0–2 was used to score extended response items involving justification and/or explanations (0 = *incorrect*, 1 = *partially correct*, 2 = *correct*). Exhibit A6 in Appendix A contains the rubrics used to score the explanation items on the CRESST math assessment.

Data on score reliability are shown in Table 2. As would be expected, reliability was highest for the overall assessment (α = .82). In contrast, reliability of the mini-tests addressing each commonly used Challenge ranged from .35 to .64, with all but one above .52. While these results are not surprising given the small number of items constituting each mini-test, they do argue against the use of mini-test scores in subsequent analyses. Interestingly, the reliability of the extended response items (α = .67) was also somewhat lower than the reliability for the multiple choice and short answer items when collapsed together (α = .73). Because of the reliability results for the mini-tests, descriptive analysis was limited to overall total scores and scores by item type.

Table 2

Reliability Statistics for CRESST Mathematics Assessment

Section	Number of items	Cronbach's alpha (reliability)
Results by mini-test		
Solving Linear Equations in Two Variables (FAL03)	5	.59
Sorting Equations and Identities (FAL13)	6	.55
Interpreting Algebraic Expressions (FAL16)	5	.35
Forming Quadratics (FAL20)	6	.52
Finding Equations of Parallel and Perpendicular Lines (FAL22)	6	.64
Results by item type		
Extended response items	7	.67
Multiple choice and short answer items together	21	.73
Overall	28	.82

Study Sample

Population. The population of interest was all Algebra 1 teachers (and their students) in the six districts and 17 schools across the state of Kentucky that were the earliest adopters of MDC. This included the teachers who participated in the Phase 1 MDC implementation in 2010–

2011 or its Phase 2 expansion in 2011–2012, and who continued to teach Algebra 1 in the 2012–2013 school year. We focused on ninth-grade Algebra 1 teachers because of (a) their relative concentration in the larger population of teachers participating in MDC, (b) the availability of a statewide Algebra 1 measure that could serve as an outcome measure for the study, and (c) the importance of Algebra 1 performance in students' subsequent academic success.

All MDC teachers were required by their districts to implement at least four to six Challenges over the course of the study year (2012–2013), and in some cases implemented many more. While some districts integrated specified Challenges within their pacing plans and teachers were required to follow these plans, in other districts the choice and timing were at the discretion of the individual teachers.

Study completion rates for MDC-only measures. Schools with teachers who were implementing MDC in ninth-grade Algebra 1 were invited to participate in the study. Once district and principal permissions were obtained, district leadership and project coordinators provided CRESST with support in determining eligibility, and provided contact information for those considered eligible. All participation was voluntary and varied across districts and schools. Based on information received from the districts, and subsequent communication with teachers, we estimated that there were 46 teachers eligible for the study. As shown in Table 3, nearly two thirds of all eligible MDC teachers consented to participate in the CRESST implementation study, and over three quarters completed the RFA survey. Almost all of the teachers who consented for the study also turned in artifacts, completed logs, and administered the CRESST mathematics measure to their students. In contrast, less than half of consented teachers completed the OTL survey.

Table 3

MDC Study Completion Rates

MDC teachers (ninth grade, Algebra 1)	*n*	% relative to all eligible MDC teachers	% relative to consented teachers
Eligible teachers	46	--	--
Teachers consenting to CRESST implementation study	30	65	--
Logs	27	59	90
Teacher artifacts	28	61	93
CRESST mathematics measure	26	56	87
OTL survey	12	26	40
Teachers completing RFA survey	36	78	--

Sample for quasi-experimental design. All MDC teachers in the study population and their students during the 2012–2013 school year were included in the QED study of MDC effects on student learning. Collection of linked teacher and student data from school district points of contact yielded a larger group of eligible teachers than originally identified for participation in the MDC-only implementation measures: 97 teachers in total. However, after removing teachers who did not teach Algebra 1 classes according to received state databases, only 59 teachers and their students remained for the analysis. Given the importance of sample size to our analyses, we erred on the side of inclusiveness, and relied on this larger sample for the QED study rather than the smaller sample from the implementation measures. Using longitudinal student and teacher data from Kentucky's state database, and drawing on ninth-grade Algebra 1 students in similar courses across the state, we used CEM to create a comparison sample of students who were nearly identical to the MDC group in demographics, prior academic performance, and selected school and district characteristics. Comparison students needed to have an ACT PLAN outcome score to be eligible for matching. Because treatment students and teachers were not randomly selected to participate in the MDC initiative, it was necessary to use a matching technique, such as CEM, to control for the effects of student, teacher, and school characteristics that might influence student outcomes. The CEM process led to the loss of 374 students and three of the 59 teachers.

Table 4 shows the demographic and prior achievement characteristics of the MDC and comparison student samples for the QED design, based on available state data. These data indicate that the study's student population was predominantly White, with a nearly equal representation of males and females. Nearly half of the students qualified for free or reduced price lunch. Although just over 10% of the students were identified as students with disabilities, very few were classified as limited English proficient (LEP).

Table 4

Demographic Characteristics of Kentucky Students in Eligible and Matched Samples for QED Study

Student characteristics	Eligible sample MDC (*n* = 2,690)	Eligible sample Comparison (*n* = 28,892)	Matched sample MDC (*n* = 2,316)	Matched sample Comparison (*n* = 15,325)
Prior achievement	0.056	-0.005	0.090	0.065
Female (%)	49.6	50.2	48.5	48.6
Ethnicity				
White (%)	86.1	82.4	92.4	90.3
Hispanic (%)	4.0	3.2	1.7	2.1
Black (%)	6.1	11.7	3.9	5.0
Asian (%)	1.0	0.6	0.4	0.7
LEP (%)	2.3	1.4	0.5	0.8
Special education (%)	11.8	11.6	13.6	12.0
Free or reduced price lunch eligible (%)	48.5	61.7	56.3	53.4

Note. Prior achievement scores are standardized.

As can be seen in Table 4, matched MDC and comparison student samples were very similar in demographic makeup and mean prior achievement.

Chapter 3:
MDC Implementation

In this chapter, we present descriptive findings from our implementation measures, including teacher logs, surveys, and artifacts from the Classroom Challenges. In reviewing these findings, it is important to keep in mind the small sample sizes on which results are based, and that while logs, surveys, and artifacts overlap, they are not fully the same. For example, some teachers completed the survey but did not complete the log and vice versa (see Table 3 in Chapter 2). Tabulated results for the teacher log and teacher survey can be found in Appendices B and C respectively.

Teacher Background

Teachers' background, prior experience, and attitudes about mathematics instruction, gleaned from teacher survey responses, provide important context for the implementation findings. Survey responses indicate a wide range of experience among participating Algebra 1 teachers (see Table C2 in Appendix C). On average, teachers reported having taught for nearly 9 years, with some having only 2 years of experience and others up to 21 years. A majority of the average teacher's experience was within her current district (M = 6.96 years) and within her current school (M = 5.86 years). At the time of the survey, all but one of the participants was currently teaching Algebra 1, with many also teaching other mathematics subjects, for example, geometry or Algebra 2 (Table C1). Almost all teachers reported that they had at least some students who were classified as special education or who were struggling in mathematics (Table C3). About two thirds of the teachers also indicated that they had students who were English language learners (ELL) and/or in advanced mathematics.

Teachers also varied in whether or not their participation in the initiative was mandatory, with about two thirds stating that they volunteered to participate (Table C4). On average, the teachers who completed the survey reported a small increase in the number of Challenges they implemented from approximately five during the 2011–2012 school year to six in the 2012–2013 school year (Table C5). This increase is not surprising in that most teachers agreed at least somewhat that the Challenges were aligned with their school curriculum and the Common Core, and prepared their students for the state assessments. These teachers also tended to report that they saw the value of MDC for addressing the CCSS (Table C6).

Teacher Logs

As previously indicated, participating teachers were asked to complete logs after four to six Challenges. Of the teachers who completed logs, two thirds (n = 18) completed at least four and approximately one fifth (n = 6) submitted six or more. Among the teachers who did not meet these thresholds, about half (*n* = 4) consented for the study approximately one third of the way into data collection and thus likely completed Challenges prior to their study participation.

Teachers tended to follow guidelines concerning the length of time allocated for each Challenge, spending an average of approximately two class periods or 100 minutes on each. Furthermore, teachers reported spending about a week of classroom time on the mathematics concept(s) central to each challenge prior to their implementation (see Table B1 in Appendix B). There was, however, wide variability in the amount of prior instruction, ranging from one half to 15 class sessions on Challenge concepts (*M* = 4.64, *SD* = 4.01). Furthermore, teachers reported that they mostly followed the detailed lesson plans for the Challenges they implemented (Table B2).

Considering the variability in time allotted to different major and minor components in the teacher guides, it was not surprising to find variability in the times teachers reported in their logs (Table B3). In general, teachers spent an average of about one third of their Challenge time engaging students in small-group collaborative work and about one fifth with whole-class discussion. Pre- and post-assessments as well as teacher-led review of content and concepts each averaged about 10% of the time per Challenge. Consistent with guidelines, little time was spent on individual student work or student presentations.

Turning to the pre-assessment component, teachers generally asked students to complete the assessment prior to the first day of implementing the Challenge (Table B4). As with other implementation questions, teachers showed wide variation in the time they spent reviewing students' responses to the pre-assessment (Table B5). Over half (57%) spent 16 or more minutes on their review, with the modal response of 16–30 minutes spent in review (34%). Teachers most typically reported reviewing their students' pre-assessment responses alone (49%) or with a colleague (38%). Very few teachers reviewed the answers with their class (Table B6). Whichever the context, teachers reported reasonable confidence in their understanding of their students' misconceptions based on their review of the pre-assessment responses (Table B7).

In contrast to other log responses that showed close fidelity of implementation, teachers' responses showed some deviation relative to the feedback they provided students about their pre-assessment responses. Over half of the teachers (58%) reported reviewing students' common errors at the start of class, with the next most popular form of feedback being commenting on papers (14%). At the same time, many teachers (46%) reported providing no feedback since they felt the Challenge lessons addressed the misconceptions, and very few teachers wrote questions on individual students' papers (Table B8). These findings stand somewhat in contrast to

Challenge guidelines, which suggested following up on misconceptions via whole-class probing or writing questions on individual students' pre-assessments.

Teacher reports showed more fidelity to Challenge guidelines in providing feedback during small-group collaborative work (Table B9). When teachers observed students struggling in their small groups, most reported that they raised questions (93%) or asked another student to explain a concept (78%). Although there was a great deal of variation among teachers, on average 45% noted that they would offer hints and suggestions, 41% stated that they would listen but not intervene, and 30% noted that they would stop the group work to review a concept with the whole class. In addition, almost no teachers reported providing struggling students with the answer.

Similarly, teachers' log responses showed substantial compliance with Challenge guidelines in implementing questioning during whole-class plenary sessions (Table B10). Teachers uniformly reported asking students to self-reflect (e.g., Why do you think that?) or to reflect on the work of their other classmates (Do you agree?). Furthermore, over three fourths of the teachers reported asking students about their mathematical reasoning (84%) and/or to find patterns or make conjectures (77%). At the same time, a majority of teachers (65%) employed the Initiate-Respond-Evaluate (IRE) technique. This finding seems inconsistent with Challenge pedagogy since in IRE, teachers provide feedback on the correctness of the response, pose yes-no questions, or encourage students to recall facts or definitions. Teachers also reported that they asked relatively few of their students (5–25%) to present their solutions or to articulate their reasoning to the whole class (Table B11).

Finally, most of the teachers (82%) reported having their students complete the post-assessment in class, at the end of the Challenges (Table B12). In evaluating student success, teachers typically reported that between 25% and 50% of their students struggled with central concepts during small-group collaboration and that only about 50% of their students had a strong grasp of the target concepts by the end of the Challenge (Tables B13 and B14). These results suggest that teachers and students may have needed additional support to increase the effectiveness of the Challenges.

Teacher Survey

In this section, we present descriptive results from the RFA/CRESST teacher survey, concentrating on the subset of items most relevant to the implementation study. This includes items developed to parallel questions in the teacher log as well as a series of questions about teachers' sense of efficacy for teaching MDC, school and district support for the initiative, extent of informal teacher collaboration and formal professional development, and teacher perceptions of the impact of the intervention on students.

When asked about their implementation of the MDC lessons, most teachers (94%) reported that they mostly or completely adhered to the teacher guides (Table C7). On average, results showed that teachers generally followed or exceeded recommended lengths of time for the Challenges,[1] with a majority indicating that they spent three class periods on each (Table C8). Even so, while the vast majority of teachers (89%) reported that their students completed the post-assessment for their most recent Challenge, two teachers did indicate that they could not because they ran out of time (Table C10). In implementing the Challenges (Table C9), over half of the teachers assigned students to homogeneous collaborative groups (57%), while the others assigned heterogeneous groupings (20%) or let students group themselves (23%).

Teachers were also asked to share their perceptions about the effectiveness of various pedagogical strategies during Challenges (Table C11). They agreed most strongly about the effectiveness of having students ask guiding questions and about teachers acting more as facilitators or coaches. Teachers also tended to agree that peer-to-peer problem solving and giving students time to persevere through difficult problems benefited student understanding of mathematics.

Teachers felt that the MDC lessons benefited their teaching in a number of ways (Tables C12 and C13). Most prominent among these were teachers' beliefs that the lessons provided effective strategies for teaching mathematics (89%), taught them new formative assessment strategies (89%), helped them promote mathematics discourse (86%), and helped them determine their students' strengths and weaknesses (81%). Although still noted by two thirds of the teachers (69%), the least cited benefit involved being able to provide students with more detailed feedback about their work. Teachers typically agreed that MDC was a useful resource for addressing the CCSS and helped them to use formative assessment to identify student strengths and weaknesses and inform their instruction. Teachers also generally felt that their MDC participation encouraged them to focus on building conceptual knowledge rather than on process.

It is also interesting to note that teachers tended to agree somewhat that they had sufficient time to prepare for the Challenges and for the pre-assessment specifically, and that they were adequately prepared to effectively use the lessons. During the Challenges, teachers also tended to feel they were able to interact with all of the collaborative groups in their classes (Table C14).

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[1] Recommended times for the Classroom Challenges teachers reported implementing ranged from 75 to 120 minutes.

When reporting on administrator support and collaboration with colleagues, over two thirds noted that other teachers (94%), their department head (77%), and/or their district or network MDC lead (71%) visited their classroom during the MDC lessons. In contrast, less than half (40%) reported that their principal observed their MDC teaching (Table C15). Similarly, teachers tended to disagree that their school administrator provided them with feedback about their MDC instruction or attended MDC professional development. Despite this, teachers overall agreed somewhat that their school administrator encouraged them to participate in MDC and emphasized formative assessment at the school. Interestingly, teachers felt somewhat more strongly about district support for MDC (Table C16).

In addition to having their colleagues visit their classroom, 60% of the teachers noted that they had regularly scheduled planning time with other MDC teachers and two thirds reported that they met at least once per month (Tables C17 and C18). On average, teachers perceived many benefits from peer collaboration (Table C19), indicating most prominently that it helped them determine where to use MDC within their existing mathematics units, effectively use the formative assessment strategies emphasized in MDC, develop feedback questions, and identify common mathematics misconceptions. Collaboration with their colleagues was least helpful, as rated by teachers, in determining how to group students for instruction.

Three fourths of the teachers reported participating in MDC professional development during the 2012–2013 school year (Table C20). On average, teachers participated in three sessions, with some attending as few as one session and others participating in as many as eight sessions (Tables C21 and C22). Teachers most frequently participated in sessions focused on developing feedback questions (100%), identifying misconceptions through analysis of the pre-assessment results (96%), and facilitating small-group work (93%). The least common topics focused on how to implement MDC with special education students (33%) or with ELL students (15%).

Teachers also reported on the format of their professional development and their perceptions about the effectiveness of the format (Table C23). Over four fifths of the teachers noted that their professional development involved small-group meetings (93%), schoolwide meetings (85%), districtwide meetings (85%), and/or coaching (82%). Of these most popular formats, teachers found the small-group meetings and coaching sessions most effective (100%).

Finally, teachers were asked their opinion about the impact and effectiveness of the MDC Challenges (see Tables C13 and C24 through C26). Interestingly, while on average, teachers at least agreed somewhat that MDC helped them make instruction more engaging, only about one third (39%) reported that their students were more engaged during MDC than during other instruction and half (50%) indicated that engagement was the same. Nevertheless, teachers tended to agree at least somewhat that MDC improved students' mathematical reasoning and supported students' college readiness. Finally, most teachers (83%) felt that participation in MDC helped most of their students improve their content knowledge and/or conceptual knowledge.

Analysis of MDC Student Work Artifacts: Pre-to-Post Evidence of Learning

As noted earlier, student work was collected as part of the log process and used to create indicators of implementation quality. Individually linked pre- and post-assessments were scored using rubrics to examine the quality of responses and evidence of misconceptions. The logic of using student responses to judge teacher implementation derived from our assumption that well-implemented Classroom Challenges would lead to higher gains in the quality of responses from pre- to post-assessment, as well as a reduction in common misconceptions. While teachers submitted class sets for 18 of the Challenges, our analyses focused solely on four of the most commonly administered by participating ninth-grade Algebra 1 teachers. Furthermore, of the 28 teachers who submitted any student work for these four, only 29% to 57% submitted matched pre- and post-assessment class sets for each of these Challenges (Table 5). Because of this lack of representativeness within and across Challenges, results should be interpreted with caution.

Table 5

Number of Classroom Sets of Student Work Analyzed by Classroom Challenge

	Pre- and/or post-assessment		Matched pre-post	
Challenge	Class sets (*n*)	Teachers (%)	Class sets (*n*)	Teachers (%)
Solving Linear Equations in Two Variables (FAL03)	17	60.7	16	57.1
Sorting Equations and Identities (FAL13)	16	57.1	16	57.1
Interpreting Algebraic Expressions (FAL16)	13	46.4	13	46.4
Finding Equations of Parallel and Perpendicular Lines (FAL22)	11	39.3	8	28.6
Total (one or more common Challenge)	25	89.3	25	89.3

Note. n of teachers = 28.

Table 6 presents descriptive statistics for the pre- and post-assessments that were linked for individual students. Although results were generally low, considerable variation was found. On the pre-assessments, the average student only earned between 23% and 35% of possible points on the explanation items and between 21% and 63% of the possible points on the accuracy items. Furthermore, students received an average misconceptions score of between 43% and 81% on their pre-assessments. Note that the misconceptions scores are reverse coded; that is, a higher misconceptions score in Table 6 indicates a lower presence of misconceptions. Post-assessment performance also showed variation across Challenges. More specifically, average scores on the post-assessments ranged from 29% to 43% on the explanation items, from 27% to 72% on the accuracy items, and from 38% to 89% on the misconceptions scores.

Part of the explanation for this variability in performance at both time points may involve differences in the focus for each of these Challenges (see Appendix D). For example, FAL16, on which the average student tended to score higher, focused on algebraic expressions, a content area initially introduced in middle school, while FAL22, with which students tended to most struggle, focused on high school standards involving geometric theorems and formal representations of functions such as $y = mx + b$ and graphs. In contrast, both FAL03 and FAL13 focused on linear equations, content that has been traditionally taught in Algebra 1, but with which many students still struggle.

Table 6

Mean Score Percentages for Individual Classroom Challenges by Rubric Type and Assessment

	n	Accuracy *M* (*SD*)	Explanation *M* (*SD*)	Misconceptions *M* (*SD*)
Solving Linear Equations in Two Variables (FAL03)				
Pre-assessment	307	.45 (.28)	.23 (.18)	.69 (.19)
Post-assessment	307	.53 (.29)	.29 (.21)	.72 (.18)
Sorting Equations and Identities (FAL13)				
Pre-assessment	96	.37 (.18)	.30 (.18)	.81 (.15)
Post-assessment	96	.58 (.19)	.43 (.20)	.89 (.11)
Interpreting Algebraic Expressions (FAL16)				
Pre-assessment	96	.63 (.18)	.35 (.27)	.50 (.25)
Post-assessment	96	.72 (.16)	.41 (.27)	.61 (.26)
Finding Equations of Parallel and Perpendicular Lines (FAL22)				
Pre-assessment	56	.21 (.13)	.23 (.21)	.43 (.28)
Post-assessment	56	.27 (.17)	.33 (.23)	.38 (.28)

Note. For this analysis, misconceptions were reverse coded so that higher means indicate a lower presence of misconceptions.

Less variability was found when examining pre- to post-assessment changes in performance (Table 7). More specifically, average student accuracy and explanation scores increased by only 6–9% for three of these Challenges (i.e., FAL03, FAL16, and FAL22). In contrast, FAL13, which was the only Challenge to include multiple choice items, showed an average improvement of 21% on the accuracy items and 14% on the explanation items. At the same time, FAL13 showed little improvement (8%) in regards to evidence of common misconceptions, which may indicate improvement in computation rather than in conceptual understanding of algebra. It also should be noted that FAL22 was the only Challenge to show a slight average increase in misconceptions pre- to post-assessment.

Collectively the findings indicate limitations in the quality of MDC implementation in that students did not evidence strong improvements in learning from pre- to post-assessments, nor did they demonstrate solid mastery of Challenge goals.

Table 7

Mean Percentage Change in Performance for Individual Classroom Challenges by Rubric Type

	n	Accuracy *M* (*SD*)	Explanation *M* (*SD*)	Misconceptions *M* (*SD*)
Solving Linear Equations in Two Variables (FAL03)	307	.08 (.35)	.06 (.22)	.02 (.24)
Sorting Equations and Identities (FAL13)	96	.21 (.21)	.14 (.24)	.08 (.17)
Interpreting Algebraic Expressions (FAL16)	96	.09 (.22)	.06 (.31)	.11 (.34)
Finding Equations of Parallel and Perpendicular Lines (FAL22)	56	.06 (.17)	.09 (.23)	-.05 (.29)

Summary of Implementation Data

Results from teacher logs, surveys, and the analysis of student work from commonly taught Challenges provide at least one consistent finding: Across all sources, the data show substantial variation across teachers in all aspects of MDC implementation. This included how much prior instruction students received on Challenge concepts, how teachers allocated instructional time across the various Challenge components, the pedagogical strategies teachers most used, the specific strategies they used to formatively assess and provide students with feedback on their learning, and their opinions about MDC effectiveness. The analysis of student work during the Challenges also showed substantial variation across teachers in the quality of implementation.

With this variation as a caveat, the findings provide a portrait of how and with what support MDC was implemented by the study sample, and participating teachers' impressions of effectiveness.

Who. Study teachers showed a range of teaching experience, with an average of about nine years. Most had spent the bulk of their careers in their current districts and schools. Nearly two thirds indicated that they had volunteered, rather than had been required, to work with the MDC tool during the 2012–2013 school year. Most teachers had only one year of experience implementing MDC beyond their initial training year. On average, study teachers implemented six Challenges during the study year and five during the prior year.

How. Nearly all teachers reported that they mostly or completely adhered to the MDC guidelines in implementing the Challenges, which typically took two to three class sessions for them to complete. Teachers, however, varied considerably in the time they spent analyzing students' pre-assessments and in the time and specific strategies they used in implementing each component (i.e., the pre-assessment, small-group collaborative activity, whole-class discussion, and post-assessment). Although teachers tended to deviate from guidelines in the feedback they provided to students about their pre-assessment performance, their reported interactions during small-group and whole-class activities were in accord with MDC's productive struggle philosophy. Teachers raised questions, asked students to explain their reasoning and solicit feedback from peers, and asked students to self-reflect rather than provided them directly with answers.

Analyses of student performance on the Challenges, as judged by evidence of student learning from pre- to post-assessment, however showed a somewhat different picture of implementation fidelity. In general, these analyses showed that teachers had difficulty helping students to achieve the Challenge goals. Results indicate that improvements in student understanding were generally scant and evidence of misconceptions remained. Students appeared to particularly struggle with providing explanations of their reasoning.

With what support. Survey responses indicated that teachers felt strong support for MDC from district leadership, but school-level principal support was less consistent across the sample. Three fourths reported participating in professional development to prepare for MDC implementation and those who did found it beneficial. Although formal time for collaborative planning and feedback varied across the sample, the great majority of teachers reported meeting informally at least every other week to discuss their MDC work. Teachers also reported that they found their peers to be highly collaborative and the collaboration helpful to their MDC implementation.

Attitudes toward MDC. Teachers were very positive about key MDC pedagogical strategies such as teacher as facilitator, asking guiding questions, and peer-to-peer problem solving, and they found the small-group and plenary approaches helpful to student learning. Although they felt that the Challenges benefited students' conceptual understanding and mathematical thinking, they reported that sizable proportions of their students struggled during the Challenges and failed to achieve a firm grasp of the intended target—on average they felt that only about half of their students reached this level. As with the MDC findings, these results suggest that participating teachers may have needed additional help with the implementation of the modules and with their MDC instruction.

Chapter 4:
Student Outcomes

The study used multiple measures of student learning to examine both the effects of MDC and the relationships between the MDC implementation variables and student outcomes. In this chapter, we first provide descriptive results for the CRESST mathematics measure and the ACT PLAN state assessment for the MDC sample only, followed by the results of the QED analysis of MDC effects on learning in Kentucky.

Descriptive Results

CRESST mathematics assessment. As noted earlier, CRESST specially developed a mathematics assessment to align with the five most commonly implemented Classroom Challenges. The assessment included five or six items on each topic, and was composed of multiple choice, short answer, and extended response explanation items. Following preliminary analyses, results for the multiple choice and short answer items were collapsed together (Table 8).

The mathematics assessment was administered in 27 study classrooms, with 471 students completing the instrument. Although results revealed considerable variation in performance across students, the generally low level of performance was clear. On average, students earned 26% of the possible points on the extended response questions, and 30% of the possible points on the multiple choice and short answer questions combined. Overall, students generally earned only 29% of the total possible points on the exam.

Table 8

Descriptive Statistics for CRESST Mathematics Assessment

Type	*n*	Total possible score	Mean	*SD*	Minimum	Maximum
Extended response	471	11	2.83	2.26	0	10
Multiple choice and short answer	471	22	6.71	3.62	0	18
Overall	471	33	9.55	5.39	0	28

Part of the explanation for this low performance may reside in students' opportunity to engage in the Challenge topics addressed by the measure. As was previously mentioned, since the specific Challenges that were implemented as part of MDC were at the discretion of individual districts, schools, and/or teachers, there was no common set in which all students were engaged. CRESST used log responses to ascertain the five most commonly used Challenges, which were then used to ground the tested constructs. It should also be noted that while we sought to confirm student exposure to these Challenges through the post-intervention OTL survey, only 12 of the 26 teachers completed the instrument. Because of this, the results should be interpreted with caution.

Of the teachers who completed the survey, at least 50% reported that their students had been engaged with three of these Challenges. In contrast, the remaining two Challenges were addressed in less than one third of these study classes (Table 9).

Table 9

Teacher-Reported Coverage of Classroom Challenges Used to Ground CRESST Mathematics Assessment

Classroom Challenges	*n*	MDC teachers %
Finding Equations of Parallel and Perpendicular Lines (FAL22)	4	33.3
Forming Quadratics (FAL20)	3	25.0
Interpreting Algebraic Expressions (FAL16)	6	50.0
Solving Linear Equations in Two Variables (FAL03)	10	83.3
Sorting Equations and Identities (FAL13)	8	66.7

Note. $n = 12$.

In addition, teachers who completed the survey were asked to report on the level of emphasis they placed on the math standards addressed by the assessment. As seen in Table 10, the great majority of the teachers who responded to the survey reported giving each assessed standard at least moderate attention during the school year, except for "use coordinates to prove simple geometric theorems algebraically." Based on these results, it seems likely that most students in the study had at least moderate engagement with most of the test content.

Table 10

Teacher-Reported Degree of Emphasis Placed on Standards During 2012–2013 School Year

Standards	*n*	No emphasis	Slight emphasis	Moderate emphasis	Sustained emphasis
a. Interpret the structure of expressions	11	0.0 (0)	0.0 (0)	72.7 (8)	27.3 (3)
b. Rewrite rational expressions	11	9.1 (1)	18.2 (2)	72.7 (8)	0.0 (0)
c. Write expressions in equivalent forms to solve problems	12	0.0 (0)	8.3 (1)	50.0 (6)	41.7 (5)
d. Create equations that describe numbers or relationships	12	0.0 (0)	0.0 (0)	33.3 (4)	66.7 (8)
e. Solve systems of equations	12	0.0 (0)	0.0 (0)	25.0 (3)	75.0 (9)
f. Use coordinates to prove simple geometric theorems algebraically	11	27.3 (3)	63.6 (7)	9.1 (1)	0.0 (0)
g. Analyze functions using different representations	11	0.0 (0)	27.3 (3)	54.5 (6)	18.2 (2)

ACT PLAN results. As described earlier, the study drew on students' performance on the ACT PLAN assessment administered to study students as they entered 10th grade in fall 2013, following their ninth-grade Algebra 1 course. Students' prior year performance was based on the 2011–2012 K-PREP data, collected in the spring of eighth grade, as well as prior years. Table 11 presents descriptive results for these data, which essentially reflect MDC students' performance prior to and subsequent to their MDC exposure. As presented earlier in Table 4, the prior achievement of MDC students was very similar to students statewide both before and after matching.

Table 11

MDC Students' Performance Before and After Intervention: ACT PLAN and K-PREP Mathematics Results

Variable	*n*	Mean	*SD*	Minimum	Maximum
ACT PLAN, Fall 2013					
Algebra	2,690	7.42	2.85	1	16
Total	2,690	16.40	3.07	2	30
K-PREP Mathematics, Spring 2012	2,690	203.54	13.48	109	242

Quasi-Experimental Analysis of MDC Effects

This section presents the results of our quasi-experimental design examining the impact of MDC on ninth-grade Algebra 1 students' learning. We begin by describing the treated (or study) teacher and student samples for the analysis. We then summarize the matching process we used to select similar comparison students and to control for the prior effectiveness of teachers and schools. Next, we outline the structure and design of the two hierarchical linear models (HLM) we employed to estimate the impact of MDC. Finally, we present the results of MDC's impact on student learning, as judged by ACT PLAN scores, using the two modeling approaches.

Teacher and student sample. As described earlier, our MDC teacher sample includes all ninth-grade Algebra 1 teachers in the six target Kentucky school districts who began teaching MDC in either 2010–2011 (Phase 1) or 2011–2012 (Phase 2), and who continued implementing MDC in 2012–2013. As we will discuss further, where possible our analyses controlled for the prior effectiveness of teachers by calculating the value added to their students using assessment scores from prior to the start of the MDC initiative (2008–2009 and 2009–2010). Unfortunately, these scores were only available for 24 of the 56 teachers in the post-match treatment sample.

The eligible student sample for the analysis included all students who were (a) enrolled in a ninth-grade Algebra 1 class taught by one of the 56 teachers, and (b) for whom prior achievement scores were available. As noted in Chapter 2, the 2,690 students eligible for the treatment sample were quite similar to the eligible comparison students statewide on both demographic and student achievement variables. The eligible treatment sample did have a slightly higher proportion of White students, a slightly lower proportion of Black students, and a lower proportion of students who were eligible for free or reduced price lunch than did the eligible comparison sample of students drawn statewide.

Selection of comparison students. As was previously noted, treatment students and teachers were not randomly selected to participate in the MDC initiative. Because of this, we employed the CEM technique to identify comparison students. CEM is a flexible matching approach with many favorable properties, and allows the researcher to specify the precise conditions under which a comparison student can be matched with an intervention student. For categorical variables, such as race/ethnicity or free/reduced price lunch status, this often entails exact matching, while for continuous measures, such as prior outcomes and prior teacher effectiveness scores, cut-points for matching can be specified. With this approach, precise cut-points can be set on the most important prior indicators, such as prior academic achievement, to ensure that, where possible, every treatment student is matched with a suitable comparison.

Table 12 summarizes the variables used for the matching. Please note that although we included indicators for students, teachers, and schools, all matching was completed at the student level. Student characteristics in the model included a number of demographic variables (e.g., race/ethnicity categories, gender, and free or reduced price lunch eligibility) as well as prior mathematics achievement on state assessments. In addition to controlling for these student characteristics, our matching methodology selected comparison students whose teachers had similar prior effectiveness. The prior effectiveness variable was produced by calculating each teacher's value added to students' mathematics learning in 2009–2010. Students under teachers without prior effectiveness data were matched to comparison students under teachers with missing data as well. Finally, a school prior effectiveness variable was calculated using 10th-grade mathematics assessment data. These data were used to ensure that the school effectiveness variable was independent of the teacher effectiveness variable in the matching model.

Table 12

Summary of Matching Variables

Indicator type	Variable
Student	Gender
Student	White
Student	Hispanic
Student	Black
Student	Asian
Student	Special education
Student	Free/reduced price lunch eligible
Student	Title I
Student	Limited English proficient
Student	Prior achievement in mathematics
Teacher	Availability of teacher prior effectiveness data
Teacher	Teacher prior effectiveness
School	School prior effectiveness

The CEM process was successful in finding similar matches for a large majority of the eligible MDC students. As can be seen in Table 13, 86% of the treatment students were retained in the sample for the QED study. Furthermore, as previously shown in Table 4, the matching process was effective in achieving a close balance with regard to prior student scores and demographics, as well as the teacher and school effectiveness indicators.

Table 13

Summary of Treatment and Comparison Samples

Sample	Treatment	Comparison
Eligible sample	2,690	28,892
Matched sample	2,316	15,325

Modeling approach. Two separate two-level HLM models were used to conduct the matching. Both of these attempt to model students' dosage under treated and non-treated teachers in ninth-grade Algebra 1 courses. In each model, where possible, measures of teacher effectiveness on the outcome measure of interest prior to the MDC intervention were estimated and used as value-added controls. Student demographic and prior achievement variables, as well as teacher and school prior effectiveness were included in the models. Our estimates therefore controlled for observables in two ways, at the matching and modeling stages. The models also examined potential interactions between MDC treatment and prior school and teacher effectiveness as well as student characteristics. These interaction variables were intended to test whether MDC had differential effects on student learning depending on the school, teacher, and/or individual student's standing on the given variable. These interaction analyses should be considered highly exploratory and results treated as tentative.

Table 14 summarizes how observations were defined at each level in the two models. In Model 1, the Level 1 observations were student course combinations for the year. Depending upon the district and/or school, each student could have more than one Algebra 1 course during the school year (i.e., teacher changes from one quarter, semester, or trimester to the next), so each student could be represented multiple times at this level. To account for this, a weight was applied to Level 1 observations so that each student's total summed to one. Furthermore, one teacher was associated with each student/course observation and thus each individual teacher was treated as an independent observation at Level 2.

Table 14

Observations by Level for Two Hierarchical Linear Models

Level	Model 1	Model 2
Level 1	Student/course combinations	Student
Level 2	Teacher	Teacher

In Model 2, each observation at Level 1 represented one student. Level 2 observations represented the Algebra 1 teacher to whom that student was assigned. Students who had more than one Algebra 1 teacher were randomly assigned to only one of their teachers. Therefore, each Level 1 observation was associated with one Level 2 observation. This issue did not present a significant problem, as a substantial majority of students during the 2012–2013 school year were associated with only one Algebra 1 teacher. Prior teacher and school effectiveness indicators were aggregated as cumulative sums to the teacher/combination level at Level 2.

Each of these models had different advantages. In Model 1, it was not necessary to remove any teacher observations. However, the repetition of students at Level 1 was somewhat nonstandard and therefore the standard errors may have been underestimated. On the other hand, the structure of Model 2 required the elimination of a small amount of information on teacher impact. Despite this, the structure of the model was more standard, and therefore provided a higher level of confidence regarding the standard errors. Overall, we favored Model 2 over Model 1 because we had greater confidence in the standard errors. Because of this, the following section will focus on the Model 2 results. Detailed results from both models, which generally show a high level of consistency across model specifications, can be found in Appendix E.

As was previously noted, although prior teacher effectiveness was a variable of interest, it was missing for some teachers. We assume that this was because they were relatively new to the system or were not teaching ninth grade at the prior time point. To deal with this issue, treatment teachers whose prior effectiveness data were missing were matched with comparison students whose teachers also had missing scores. In these cases, the teacher effectiveness scores were set at zero. Since we had greater confidence in the match for those teachers who were not missing data from the period prior to the intervention, we created a "missing" variable to test the effect of these missing data: the interaction between the treatment and teachers who were missing their prior effectiveness data. Because some power was lost by doing this, we also tested the joint significance of the main MDC effect and its interaction with the missing variable. As these analyses showed no significant interaction effects for these missing data, the interaction term between treatment teachers and teachers who were missing their prior effectiveness data was excluded from subsequent analyses.

HLM results. Results from the Model 2 HLM model on students' ACT PLAN scores for algebra are displayed in Table 15. While the model did control for all of the student, teacher, and school indicators previously discussed, we limit our presentation to the intervention effects of interest. These effects included potential interactions between the MDC treatment, prior teacher and school effectiveness, and student characteristics. A statistically significant interaction effect indicates that MDC had differential effects on students' learning, depending upon their school's prior effectiveness, teacher's prior effectiveness, individual demographics, and/or prior achievement. These interaction analyses should be considered exploratory and any results should be treated as tentative.

Table 15

MDC Effects on ACT PLAN Algebra Scores, Including Interaction Effects (Model 2)

ACT PLAN mathematics (algebra)	Model 2 Coefficient (*SE*)
MDC treatment	0.130 (0.030)**
School effectiveness	0.309 (0.103)**
Teacher effectiveness	0.060 (0.087)
MDC treatment by teacher effectiveness interaction	0.420 (0.178)**
Treatment by demographic characteristic interactions	
Gender	0.005 (0.026)
Special education	0.070 (0.044)
Free/reduced price lunch eligible	0.027 (0.039)
Prior achievement	0.030 (0.016)

Note. Fixed effects for demographic predictors not shown.
$^{**}p \leq .01$.

A statistically significant positive effect was found for MDC treatment. To provide a benchmark for interpreting this effect, we used a relatively new methodology to convert the effect size into a gross indicator of the number of months of learning it represents (see Hill, Bloom, Black, & Lipsey, 2007). Using this approach, we used available data to estimate the growth in mathematics scores from eighth to ninth grade. We then determined the proportion of typical growth represented by the observed MDC effect size, that is, the MDC effect size divided by the effect size expected between eighth and ninth grade. Finally we used this proportion to calculate the number of months of additional growth associated with MDC, relative to a nine-month academic year. Relative to typical growth in mathematics, this calculation found that the effect size for MDC represented 4.6 months of schooling. The effect is quite dramatic given that a typical teacher spent less than a month of class time teaching Challenges.

The results also show a positive interaction effect for prior teacher effectiveness. This positive interaction indicates that students whose teachers were more effective prior to using MDC, as measured by their students' prior state assessment scores in mathematics, benefited more from MDC compared to students with lower value-added teachers. We speculate that the more effective teachers also had higher pedagogical knowledge in mathematics (see, for example, Hill et al., 2007) that enabled them to implement MDC better.

Full results for both Model 1 and Model 2, including the effects at both the student and teacher level are presented in Appendix E. The results from these two modeling approaches were very similar, although there was one notable difference. In Model 1, the interaction between treatment and prior student achievement was significant. In contrast, the interaction between treatment and prior teacher effectiveness approached but did not reach the significance threshold. These findings were reversed in Model 2, such that the interaction between treatment and prior teacher effectiveness was significant, while the interaction between treatment and prior student achievement approached but did not reach the significance threshold. The student prior achievement interaction would suggest that students entering MDC instruction with relatively higher prior performance benefited the most. This matches our observation that the Challenges seek to develop and draw on students' conceptual understanding of mathematics, though this is likely more accessible to higher achieving students.

Chapter 5:
Relationship Between MDC Implementation and Student Learning

This chapter shares exploratory analyses that were conducted to investigate relationships between MDC implementation and student learning, based on log, survey, and MDC artifact measures. Drawing on the QED analyses described in the prior chapter, our approach used HLM to identify implementation variables associated with teacher effectiveness during the MDC study year, after taking account of prior teacher effectiveness. Implementation data were available for MDC teachers only, so all of the analyses presented in this chapter are within treatment.

Methodology for Exploratory Analyses

A first step was constructing our measure of teacher effectiveness. Bayes estimates for each teacher's effectiveness for the study year were saved from HLM Model 1 described in Chapter 4. Since the teacher-level variables in this model included effectiveness prior to MDC, our teacher effectiveness measure should essentially be considered a measure of the value MDC added to effectiveness.

A second step was to identify implementation variables that appeared related to teacher effectiveness. During this stage of the analysis, we explored correlations between log/survey responses and teacher effectiveness as well as a cross-tabulation of log and survey responses with teachers of high, medium, and low prior effectiveness, with cases equally represented in each group. Whether teachers' participation in MDC was mandatory or voluntary as well as their attitudes about the extent and helpfulness of teacher collaboration emerged as potentially important. Other variables potentially related to teacher effectiveness included items on the assessments and feedback strategies, such as time spent analyzing the pre-assessments and providing students with feedback on the pre-assessments and subsequent MDC activities. Since both the pre-assessment and feedback strategies are unique to the Challenges, the patterns of results seemed to suggest that teachers who more faithfully implemented MDC and its tenets of productive struggle were more successful.

Separate HLM analyses were used to examine the relationship between each potentially promising variable and teacher effectiveness. The analysis of log variables included complete data for 25 teachers. All Level 1 covariates, as used in the QED model, were group-mean centered within this sample and weights normalized. Teacher survey analyses included complete data for 30 teachers.

Finally, variables yielding consistent, statistically significant results for both the correlation and preliminary HLM analyses were retained for a combined analysis (i.e., an HLM model including all of the identified implementation variables as moderators of teacher outcome year effectiveness). At Level 2, these included the variables listed in Table 16, as well as our prior teacher effectiveness variable.

Table 16

Statistically Significant Variables From the Exploratory Analyses

Source	Variable	Prompt/response option
Teacher log	Reviewed pre-assessment with class	How did you review students' answers to the pre-assessment? Option selected: With the class
Teacher survey	Special education teacher	What is/are your current position(s)? Option selected: Special Education
Teacher survey	Voluntary MDC participation	How would you describe your participation in the MDC initiative? Option selected: Voluntary MDC participation
Teacher survey	Majority of students improved their conceptual understanding	When I taught my most recent MDC Lesson, the majority of my students improved their conceptual understanding. Coding: 0 = *no*, 1 = *yes*.
Teacher survey	Informal teacher collaboration	About how often do you have informal discussions (as opposed to scheduled meetings) with your MDC colleagues to discuss student work, instructional strategies, or teaching approaches? Coding: 1 = *at least once a week*, 2 = *every other week*, 3 = *once a month*, 4 = *once per quarter/trimester/semester*, 5 = *never*.

Combined Model: Teacher Log and Survey Variables

The final estimation of fixed effects, with robust standard errors, is displayed in Table 17. The results indicate that higher prior student achievement is associated with higher teacher effectiveness in the outcome year, and Title I status is associated with lower effectiveness. Of direct interest to our study, statistically significant relationships showed that teachers' voluntary participation in the study was associated with higher levels of effectiveness, as were teachers' perceptions of how much MDC improved their students' conceptual understanding. Lower effectiveness was associated with teachers who reviewed the pre-assessment results with their class as well as with teachers who taught special education. Although the helpfulness of teacher collaboration was positively related to teacher effectiveness, results did not reach statistical significance.

Table 17

Final Estimation of Fixed Effects With Robust Standard Errors (2012–2013)

Fixed effect	Model coefficient (*SE*)
Level 1 variables	
Female	0.013 (0.036)
White	-0.070 (0.078)
Hispanic	-0.144 (0.104)
Black	-0.048 (0.103)
Asian	-0.058 (0.343)
Limited English proficient	-0.167 (0.179)
Special education	0.048 (0.038)
Free/reduced price lunch eligible	0.036 (0.034)
Title I	-0.089 (0.033)**
Prior achievement	0.486 (0.017)**
Level 2 variables	
Teacher effectiveness	0.822 (0.108)**
Reviewed pre-assessment with class	-0.873 (0.217)**
Special education teacher	-0.742 (0.083)**
Voluntary MDC participation	0.316 (0.057)**
Improved conceptual understanding[a]	-0.496 (0.073)**
Teacher collaboration[a]	-0.071 (0.042)

[a] These items were reverse coded. Because of this, negative coefficients indicate an association with increased effectiveness.
**$p \leq .01$.

Relationship Between Artifact Implementation Measure and Teacher Effectiveness

As noted earlier, CRESST created indicators of implementation quality based on an analysis of the pre- to post-assessment performance for four of the most commonly implemented Challenges by study teachers. The indicators were based on students' pre- to post-assessment improvement in content accuracy (i.e., short answer and multiple choice items), quality of students' explanations, and the presence of misconceptions that are common for the targeted standards. Although recognizing serious limitations in available data, we then examined the relationship between these measures of implementation quality and teacher effectiveness.

A first step in our analysis was to run an HLM model with the purpose of identifying individual MDC teacher's effectiveness on improving student performance on Classroom Challenge assessments. As was previously noted, because different teachers submitted student artifacts for different Challenges, it was important to control for potential differences in the Challenges when creating our estimates. Our ratings and analyses were limited to four of the Challenges most commonly implemented (i.e., FAL03, FAL13, FAL16, and FAL22). A two-level HLM model was used to estimate performance on the post-assessments by controlling for the effect of each Challenge as well as pre-assessment scores at both the student and teacher levels. Separate models were initially run for each rating (i.e., accuracy, explanation, and misconceptions) and then, based on the results, another model was run that combined the mean scores for both the accuracy and explanation ratings. Bayes estimates for each teacher's effectiveness at improving student performance on the Challenge assessments for each rating were saved. Due to the small sample and the lack of a fully crossed design with respect to teachers and student artifacts for the Challenges, these analyses should be considered exploratory.

A second step was to examine the relationship between teacher effectiveness on each of the Challenge assessment ratings and teacher effectiveness on state PLAN scores. During this stage of the analysis, we explored correlations for the effectiveness scores for the individual Challenge ratings as well as for the combined accuracy-explanation score. Table 18 presents the correlations between these various effectiveness scores. As can be seen, both the accuracy and explanation scores showed strong positive relationships with teacher effectiveness on PLAN, and the combined accuracy-explanation score showed a very strong, significant relationship. That is, teachers who better implemented the Challenges, as evidenced by their students' improvement on Challenge assessments, also were more effective in having an impact on student scores on the PLAN state assessment. These results are suggestive of a relationship between quality of MDC implementation and student learning, although given the data limitations already discussed, the results should be treated as highly tentative.

Table 18

Pearson Correlations for Teacher Effectiveness on Classroom Challenge Ratings and PLAN Scores

	1	2	3	4	5
1. Accuracy and explanation (combined)	—				
2. Accuracy	.839**	—			
3. Explanation	.775**	.487	—		
4. Misconceptions	.248	.493	-.198	—	
5. PLAN Algebra	.746**	.581*	.527*	.251	—

Note. Aggregate scores for item types control for student pre-assessment scores.
**p* ≤ .05. ***p* ≤ .01.

Chapter 6:
Summary and Conclusions

This report has described CRESST's study of the implementation and effects of MDC in early-implementing ninth-grade Algebra 1 classrooms in Kentucky. Examining how MDC supports secondary teachers and students' transition to the Common Core, the study addresses the following evaluation questions:

1. How do teachers implement MDC?
2. What is the impact of MDC on student learning?
3. What conditions and contexts, including implementation quality, influence MDC effectiveness?

In the following sections, we consider contextual factors that are important in interpreting study results before summarizing our findings with regard to each question. We conclude with implications and next steps for research and practice.

Contextual Considerations

The nature and generalizability of the sample present important limitations for the study. First, the study addressed only a subsample of those schools, teachers, and students across the country, including in Kentucky, who currently are implementing MDC. The study included only teachers and students in those districts and schools that were early MDC implementers, and of these, only those in ninth-grade Algebra 1 courses. Because of the Foundation's interest in a rigorous quantitative study, our design required common outcome measures and could not accommodate scores from different grade levels or courses. Further, the study focused on teachers who had at least one year of prior experience in implementing MDC so that it would not be attempting to judge intervention effects as teachers were initially learning how to implement the Challenges. Thus, the study was limited to districts that were funded in both Phase 1 and Phase 2 of MDC's initial pilot and rollout.

As a result, study power and generalizability were limited. The rigorous quasi-experimental design included students taught by 46 ninth-grade Algebra 1 teachers and a carefully matched comparison group, which provided limited power to detect moderate program effects. Our ability to identify relationships between MDC implementation and outcomes was even more constrained, as only about two thirds of the teachers agreed to participate in the implementation components of the study.

The representativeness of the study sample further limited the generalizability of any study findings. Demographically and in prior achievement, our MDC sample generally looked similar to the state as a whole. However, the study could not control for unobserved variables that may have influenced student success and indeed, by virtue of their willingness to participate in early MDC piloting, the districts and schools in the study may well be at least somewhat atypical.

That study teachers had minimum prior experience implementing the intervention was still another important contextual consideration. Before the study year, the majority of these teachers had only one year of prior experience implementing MDC and, in fact, that prior year included both initial learning and implementation. One year was hardly adequate time for teachers to meaningfully integrate and become effective with new practices—and the MDC student-centered, formative assessment lessons certainly involved transformation of usual teacher-centered mathematical practices.

Intervention dosage was still another factor worth consideration. For the study year, most teachers implemented approximately six Classroom Challenges, which translates into only about 12 to 18 days of instruction over the course of the year. It is ambitious, in short, to expect MDC to have a measurable impact on student learning at this early point in implementation.

How Did Teachers Implement MDC?

End-of-year survey responses indicated that the majority of teachers participated in professional development to support their MDC implementation and felt well supported by district leadership and their teacher colleagues. School leadership support for implementation appeared more variable across teachers and schools.

Both log and survey results suggested that the great majority of teachers mostly or fully adhered to MDC guidelines in implementing individual Challenges, but varied substantially in the specific timing of and strategies used during the various components. Teachers reported frequent use of formative assessment, using a variety of strategies to monitor their students' ongoing learning and taking action consistent with MDC's productive struggle philosophy when misunderstandings and/or problems were observed, again with substantial variation in the strategies used. However, analysis of students' pre- to post-assessment responses on the most commonly implemented Challenges indicated that teachers had difficulty in helping students achieve fully the Challenge goals.

Such difficulties were to be expected at this early stage of implementation, particularly as the Challenges demanded sophisticated pedagogical and assessment strategies. The variation in reported strategy, in fact, may be an indicator that teachers had not yet solidified their MDC practice, but instead were trialing a variety of potential actions. The inconsistency in strategy may provide one reason why we were unable to find strong relationships between any single MDC implementation measure and student learning outcomes. Further, the quality and effectiveness of implementation depended on how well teachers were able to implement Challenge activities and respond to students' needs in classroom interaction, among other unobservables. Challenges not implemented with effective teaching, assessment, and learning strategies would not be expected to have a strong effect on student learning.

How Did MDC Affect Student Learning?

Teacher perspectives. Survey responses showed that teachers were very positive about key MDC pedagogical strategies and felt that the Challenges benefited their students' conceptual understanding and mathematical thinking. At the same time, they reported that sizable proportions of their students struggled during the Challenges and only about half achieved intended goals. As with the analysis of students' pre- and post-assessments, these results suggest that participating teachers may have needed additional help with the implementation of these Challenges and with their MDC instruction.

CRESST mathematics assessment. Performance on the CRESST mathematics assessment underscores teachers' reports that many students struggled with the Challenges. Because the specific Challenges that were implemented varied across schools and/or teachers, the mathematics assessment focused on the standards and content addressed by the five that were most frequently used. This design constraint meant that not all students in the study had an equal opportunity to learn all of the assessment content and, in fact, based on the OTL survey completed by teachers at the end of the study year, it seems likely that relatively few classes engaged in two or more of the five Challenges assessed. Even with this caveat, student performance was very low, suggesting the limits of the conceptual understanding students achieved. Student motivation may have been another mitigating factor as the test was administered at the end of the school year. Nonetheless, the results suggest the challenge of moving student performance to the expectations of the Common Core.

MDC impact on student learning. Our QED methodology used CEM to identify a group of comparison students who were demographically and academically similar to the study's MDC students. The matching was done at the student level, but accounted not only for student demographics, prior achievement, and course enrollment, but also for the prior effectiveness of teachers and schools. The resulting treatment and comparison student samples were used to test the effects of MDC on students' performance on the ACT PLAN, which is administered in the fall to 10th-grade students as part of Kentucky's state assessment program. The analysis used two separate, two-level HLM models to test MDC effects, each modeling students' dosage under treated and non-treated teachers in ninth-grade Algebra 1 courses, and each incorporating measures of teacher effectiveness as additional value-added controls. Student demographic and prior achievement variables, as well as school prior effectiveness, were also included in the models, as were the interactions of these variables with the MDC treatment. Our estimates therefore controlled for observables in two ways, at the matching and modeling stages.

Results were consistent for both models, suggesting the robustness of these findings. MDC showed a positive, statistically significant effect on students' ACT PLAN performance in algebra, indicating that students who experienced MDC learned more than students who did not have the benefit of MDC. The observed effect size for MDC represented 4.6 months of schooling (see Hill et al., 2007), decidedly positive news for the intervention.

What Conditions and Contexts Influenced MDC Effectiveness?

Interesting interaction effects emerged from our QED analysis that point to conditions and contexts that influenced MDC implementation and impact. In particular, results were suggestive of a positive interaction between students' prior achievement and/or teachers' effectiveness prior to MDC implementation. The two statistical models utilized in study analyses revealed similar directions in interaction findings but differences in statistical significance. That is, in one model, students' prior achievement showed a statistically significant interaction with the treatment, and prior teacher effectiveness showed a positive interaction that approached statistical significance; the statistically significant findings for these interactions were reversed in the second model. Given the likely relationship between teacher quality and student achievement, these inconsistencies are understandable. The combined findings suggest MDC students who were relatively higher achieving prior to their MDC experience and/or those whose teachers were more effective prior to using MDC benefited more from the intervention compared to their peers.

Conclusions

In summary, MDC showed promising, positive results in supporting teachers' transition to the Common Core expectations for college and career readiness and in improving student learning. At the same time, however, study findings suggest challenges that MDC will need to overcome to move to higher levels of success. Next, we summarize our perspective on major study implications.

Positive effects on student learning. Study findings of MDC's statistically significant, positive effects on Kentucky students' ACT PLAN performance are worth underscoring, particularly in light of both study teachers' limited prior experience implementing the tools and the limited dosage students experienced. As previously noted, study teachers had only one or two years of experience with MDC prior to the study year, and the great majority had only one year of prior experience. Research on teachers' implementation of new practices suggests that this is insufficient time for teachers to become fully comfortable and competent with the kinds of new pedagogical practices that MDC represents (Coburn, 2003; Hargreaves & Fullan, 2012).

Student intervention dosage is another important consideration. In general, the longer and more intensive the treatment, the more likely an intervention is to show measurable effects. Most teachers implemented MDC for only 12–18 days of instruction, a small fraction of the full academic year in which the study took place. Nonetheless, the study found a statistically significant learning effect equivalent to approximately 4.6 months of schooling.

Positive effects on teachers. The effect found for student learning was matched by teacher enthusiasm for MDC. Study teachers were positive about the professional development they received and reported that they found the tools helpful and effective in meeting a variety of goals, including implementing the new standards, using formative assessment, incorporating more complex thinking and problem solving into curriculum and instruction, and improving student learning. Teachers' reports about their fidelity of tool implementation provided additional evidence of their positive attitudes.

Struggles in moving to higher standards. While our study found positive effects on teachers and students, findings also demonstrated the challenge of moving to standards that are more rigorous. We see evidence of this challenge in students' low performance on measures specifically designed to reflect the deeper learning demands of the new CCRS, and in teachers' reports that sizable proportions of their students struggled with the Classroom Challenges and did not achieve success with Challenge goals. Our analysis of MDC classroom artifacts also suggested that teachers and students struggled in their implementation efforts, as would be expected given this early stage of implementation.

That some teachers and students struggled is not meant to imply that the new standards are unattainable or that CCRS expectations for students should be reduced. After all, we know that returning to prior standards will not get our children to 21st century success. However, the evidence does suggest that change will not come overnight and that both teachers and students will need support to meet the challenge. The issue is twofold: (a) how to address the needs and better prepare students and teachers who may not yet be ready to be successful with the challenges of MDC; and (b) how to modify and/or adapt MDC tools to scaffold teacher and student learning more effectively.

Achievement gap implications. Although we regard findings of interactions between MDC and both student ability and teacher prior effectiveness as tentative and subject to further validation, they raise important questions for policy and practice. The overall results indicated that MDC was effective for all study students, but the interaction findings indicated that initially higher achieving students and/or those taught by initially more effective teachers benefited more than did their comparable peers. Such a finding makes intuitive sense in that lower achieving students have most likely been exposed to the “drill and kill” test preparation curriculum of the past, are least likely to have acquired the prior grade knowledge and skills, and are also the least likely to have engaged in the mathematical practices expected by the new standards. Similarly, the possible interaction between prior teacher effectiveness and MDC tells a similar story. Students of teachers who initially were relatively more effective appeared to benefit more from MDC than did students of initially relatively less effective teachers.

Strengthening implementation. Although teachers reported implementing all components of MDC, the findings suggest substantial variation in how teachers implemented each component and in the relative time and specific strategies they used in doing so. The study did not achieve strong findings with regard to what aspects of implementation mattered most or what specific strategies were most effective. The findings are suggestive, however, of some factors that might be important to success: District support for MDC was clear across the sample, yet principal or local school support was more variable, suggesting a potential problem point. Teachers found their peers highly collaborative and helpful in supporting MDC implementation. The extent of such collaboration tended to be associated with MDC success. Moreover, having a teacher who volunteered to participate in MDC, rather than having participation required, was associated with positive effects on student learning.

Concluding thoughts. In summary, our study reveals that study teachers were enthusiastic about MDC, and that MDC showed important effects on student learning. Even so, study results suggested areas for improvement. Mathematics teachers who have deep content-pedagogical knowledge in their course content are likely to be more successful in implementing MDC, and many teachers may need help to reach these deeper levels of knowledge. Additional supports for struggling students, and training on how to implement MDC successfully with diverse and low-achieving students could potentially help close achievement gaps.

We leave it to future research to examine the generalizability of these findings in the larger samples of teachers and schools that are now implementing MDC. Cost-effectiveness studies should be of interest. Future research and development also should continue the quest to identify the most critical aspects of implementation in improving student learning and the key infrastructure and supports that students and teachers who currently are struggling need to propel their success.

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Appendix A: MDC Instruments and Rubrics

Exhibit A1: MDC Teacher Log

Thank you for taking the time to complete your teacher log for MDC instruction. This log should take no longer than five (5) minutes to complete. As you answer the questions below be sure to limit your responses to (a) the classroom challenge (FAL) you just completed; (b) the class period listed in your reminder email (in the event that you teach MDC to several classes).

If you have already completed the log and would like to upload student work, click "upload student work" below. Otherwise, please click on "Continue with log."

○ Skip log to upload student work
○ Continue with log

Classroom Challenge (FAL) title or number (e.g., “Boomerangs”)”

How many days did you spend teaching a Classroom Challenge (FAL) this week?

1	2	3	4	5
○	○	○	○	○

What was your purpose for teaching this particular Classroom Challenge? (check all that apply)

☐ District mandate
☐ Review for test
☐ Introduce new content
☐ Extending/reinforcing new content
☐ Practice problem solving
☐ Other, please specify ______________________

How many days of NON-Classroom Challenge instruction did you devote to this particular mathematical content prior to teaching this Classroom Challenge?

When was the last day of NON-Classroom Challenge instruction on this particular mathematical content?

- ○ Earlier this week
- ○ Last week
- ○ Within the past few weeks
- ○ Over a month ago

To what extent did you follow the detailed Classroom Challenge lesson plan instruction?

Not at all	Somewhat	Mostly	Completely
○	○	○	○

Which of the following activities did you do as part of Classroom Challenge instruction? (check all that apply)

- ☐ Pre-assessment
- ☐ Small-group collaborative work
- ☐ Whole-class plenary
- ☐ Post-assessment

If you did not assign a post-assessment, which of the following best characterizes your reasoning (check all that apply)

- ☐ I ran out of class time
- ☐ I plan to assign it tomorrow
- ☐ It seemed redundant
- ☐ My students understood the material
- ☐ It was too difficult
- ☐ Other, please specify ______________________

Consider the total amount of class time spent on Classroom Challenge instruction. What proportion of time was spent on the following classroom activities? (Total should add up to 100%)

	0	10	20	30	40	50	60	70	80	90	100	
Pre-assessment												0
Small-group collaborative work												0
Whole-class discussion												0
Individual work												0
Student presentations												0
Teacher-led review of content/ concepts												0
Post-assessment												0
Other___________________												0
Total:												0

Pre-Assessment

When did students complete the pre-assessment?

○ In class at the start of Classroom Challenge

○ Other

How much time did you spend reviewing students’ answers to the pre-assessment?

0 min	1–5 min	6–15 min	16–30 min	31–60 min	>1 hour
○	○	○	○	○	○

How did you review students’ answers to the pre-assessment?

○ Alone

○ With a colleague

○ With the class

○ Other

Which of the following characterizes the feedback you gave students on their pre-assessment?

- ☐ No feedback provided because Classroom Challenge instruction addressed misconceptions
- ☐ Commented on papers
- ☐ Graded papers
- ☐ Wrote questions on papers
- ☐ Reviewed common errors at start of class
- ☐ No feedback provided because of time constraints

To what extent do you agree or disagree with the following statements?

	Strongly disagree	Disagree	Agree	Strongly agree
Before starting the Classroom Challenge, I had a very strong sense of students' misconceptions on this topic.	○	○	○	○
My understanding of students' misconceptions comes from studying their answers on the pre-assessment.	○	○	○	○
It was difficult for me to identify students' misconceptions from the pre-assessment.	○	○	○	○
I relied primarily on the lesson's suggested questions/comments when responding to pre-assessments.	○	○	○	○

Small-group Collaborative Work

When you heard students struggle in small groups, what did you do? (check all that apply)

- ☐ Listened but did not intervene
- ☐ Offered hints and suggestions
- ☐ Raised questions
- ☐ Provided the answer
- ☐ Asked another student to explain concept
- ☐ Stopped class and reviewed concept

What percentage of students struggled to understand the underlying mathematical concept?

<5%	5–25%	25–50%	50–75%	75–99%	100%	Not sure
○	○	○	○	○	○	○

Whole-class Plenary

For each of the types of questioning described below, please indicate whether or not it was incorporated into today's lesson. Each type is accompanied by several examples to illustrate what kinds of questions are included in that category.

	Yes	No
IRE (Initiate-Respond-Evaluate): (Yes/No questions, questions that ask students to recall facts or definitions)	○	○
Self-Reflection: (Why do you think that? Why is that true? How did you reach that conclusion?)	○	○
Reflection-on-Others: (Do you agree? Does anyone have a different way to explain it? Would you ask the rest of the class that question?)	○	○
Pattern-Finding and Conjecturing: (How did you predict the next case? What is similar and what is different about your solution and his/hers? Do you see a pattern?)	○	○
Mathematical Reasoning: (Does that always work? Is that true for all cases? Can you think of a counter example?)	○	○

What percentage of students presented their solutions to the whole class?

<5%	5–25%	25–50%	50–75%	75–99%	100%	Not sure
○	○	○	○	○	○	○

What percentage of students articulated the reasoning behind their solutions to the whole class?

<5%	5–25%	25–50%	50–75%	75–99%	100%	Not sure
○	○	○	○	○	○	○

Post Assessment

When did students complete the post-assessment?

○ In class at the end of the Classroom Challenge
○ Homework
○ Other, please specify ____________________

What percent of your students do you think gained a strong grasp of the material by the end of the lesson?

<5%	5–25%	25–50%	50–75%	75–99%	100%	Not sure
○	○	○	○	○	○	○

Please indicate the approximate date of your next Classroom Challenge. We recognize that this may change. (mm/dd/yyyy)

☐

Please scan and upload a full class set of student work on the Classroom Challenge. We would like both the Classroom Challenge pre-assessments and post-assessments. You can attach PDFs or Word files. If you would prefer to send us hard copies, please email Debbie La Torre Matrundola at latorre@cse.ucla.edu.

If you would like to upload the student work later, you can reenter the log and click "Skip Log to Upload Files" on the first page.

Full class set of Classroom Challenge pre-assessments

Browse

Full class set of Classroom Challenge post-assessments

Browse

Additional student work (optional)

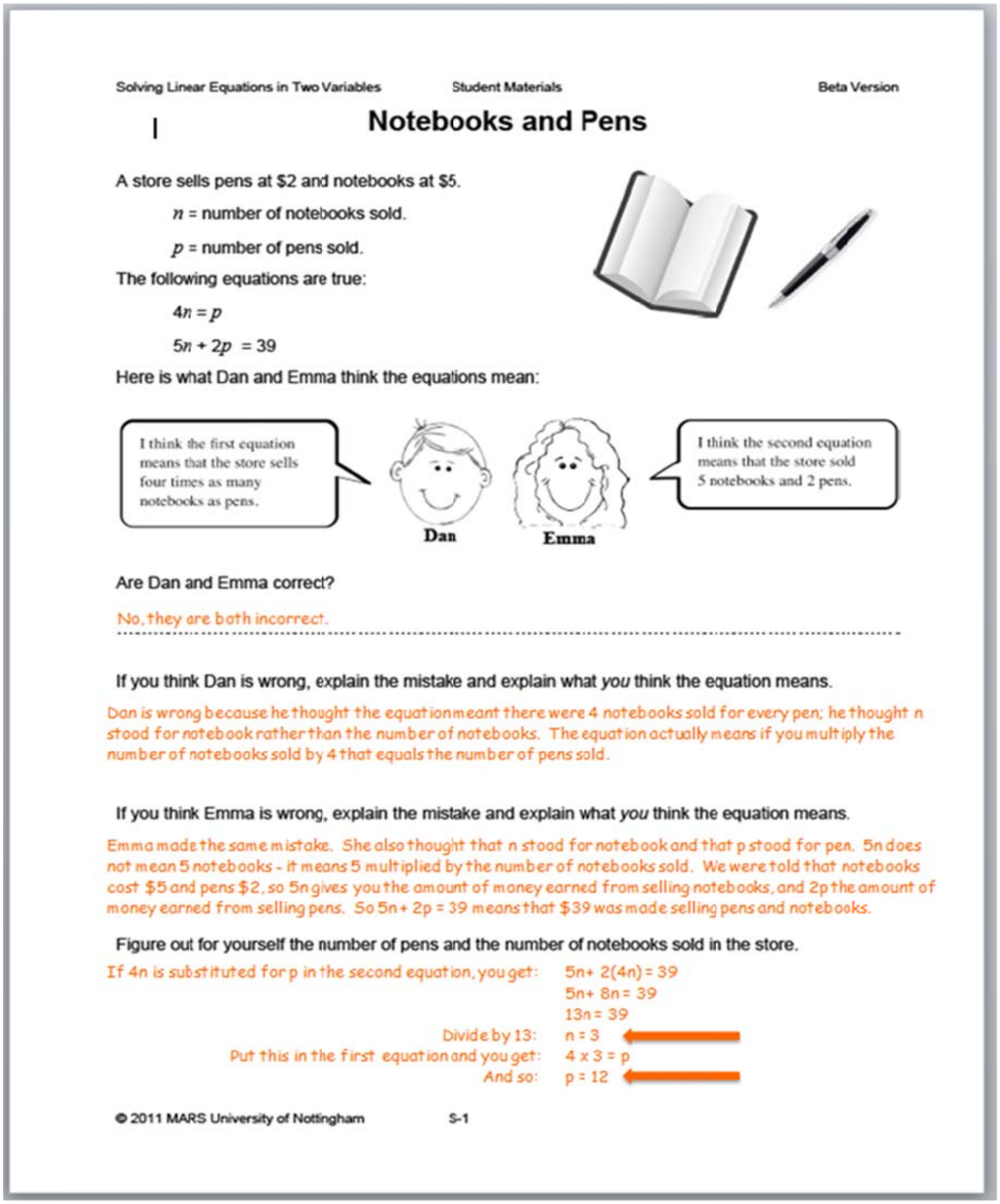
Browse

ADDITIONAL COMMENTS:

We are very interested in your feedback. Please let us know if you have any questions or concerns about this log. Thank you!

Exhibit A2: Artifact Exemplars and Scoring Rubrics

FAL 03, Solving Linear Equations in Two Variables
Scoring Exemplar



Solving Linear Equations in Two Variables Student Materials Beta Version

Notebooks and Pens

A store sells pens at $2 and notebooks at $5.

n = number of notebooks sold.

p = number of pens sold.

The following equations are true:

$4n = p$

$5n + 2p = 39$

Here is what Dan and Emma think the equations mean:

I think the first equation means that the store sells four times as many notebooks as pens.

I think the second equation means that the store sold 5 notebooks and 2 pens.

Dan

Emma

Are Dan and Emma correct?

No, they are both incorrect.

If you think Dan is wrong, explain the mistake and explain what *you* think the equation means.

Dan is wrong because he thought the equation meant there were 4 notebooks sold for every pen; he thought n stood for notebook rather than the number of notebooks. The equation actually means if you multiply the number of notebooks sold by 4 that equals the number of pens sold.

If you think Emma is wrong, explain the mistake and explain what *you* think the equation means.

Emma made the same mistake. She also thought that n stood for notebook and that p stood for pen. 5n does not mean 5 notebooks - it means 5 multiplied by the number of notebooks sold. We were told that notebooks cost $5 and pens $2, so 5n gives you the amount of money earned from selling notebooks, and 2p the amount of money earned from selling pens. So 5n + 2p = 39 means that $39 was made selling pens and notebooks.

Figure out for yourself the number of pens and the number of notebooks sold in the store.

If 4n is substituted for p in the second equation, you get: $5n + 2(4n) = 39$
$5n + 8n = 39$
$13n = 39$
Divide by 13: $n = 3$
Put this in the first equation and you get: $4 \times 3 = p$
And so: $p = 12$

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FAL 03, Solving Linear Equations in Two Variables
Quality Rubric

Item: Notebooks and Pens-01
Prompt: Are Dan and Emma correct?

[unscored]

Item: Notebooks and Pens-02
Prompt: If you think Dan is wrong, explain the mistake and explain what *you* think the equation means.

Accuracy/Precision	**Explanation** (Dan's mistake)	**Explanation** (interpretation of equation)
• (1) The student has concluded that Dan is wrong. • (0) The student has concluded that Dan is right, or leaves blank.	• (3) The student explicitly describes Dan's misinterpretation (e.g. "He thought *n* stood for *notebook* rather than *number of notebooks*"). • (2) The student mentions that Dan has misinterpreted *n*, but the explanation lacks specificity or clarity. • (1) The explanation demonstrates no evidence of understanding of Dan's misinterpretation. • (0) The student does not explain Dan's mistake.	• (3) The student correctly interprets the equation (e.g. "If you multiply the number of notebooks sold by 4 that equals the number of pens sold") • (2) The student's explanation shows some evidence of a correct interpretation of the equation (e.g. the explanation is partially correct or uses ambiguous or confusing language). • (1) The interpretation demonstrates no evidence of understanding. • (0) The student does not interpret the equation.
Accuracy/ Precision Score	**Explanation Score**	**Explanation Score**

Item: Notebooks and Pens-03
Prompt: If you think Emma is wrong, explain the mistake and explain what *you* think the equation means.

Accuracy/Precision	**Explanation** (Emma's mistake)	**Explanation** (interpretation of equation)
• (1) The student has concluded that Emma is wrong. • (0) The student has concluded that Emma is right, or leaves blank.	• (3) The student explicitly describes Emma's misinterpretation (e.g. "She thought that *n* stood for notebook and that *p* stood for pen"). • (2) The student mentions that Emma has misinterpreted *n* and *p,* but the explanation lacks specificity or clarity. • (1) The explanation demonstrates no evidence of understanding of Emma's misinterpretation. • (0) The student does not explain Emma's mistake.	• (3) The student correctly interprets the equation (e.g. "$39 was made selling pens and notebooks"). • (2) The student's explanation shows some evidence of a correct interpretation of the equation (e.g. the explanation is partially correct or uses ambiguous or confusing language). • (1) The interpretation demonstrates no evidence of understanding. • (0) The student does not interpret the equation.
Accuracy/ Precision Score ☐	**Explanation Score** ☐	**Explanation Score** ☐

Item: Notebooks and Pens-04
Prompt: Figure out for yourself the number of pens and the number of notebooks sold in the store.

Accuracy/Precision
• (2) The solution is correct (e.g. "3 notebooks and 12 pens were sold"). • (1) There is evidence of a viable solution strategy (e.g. the student has attempted to solve with substitution, but has made an algebra or arithmetic error). • (0) There is no evidence of a viable solution strategy or no solution was written.
Accuracy/Precision Score ☐

FAL 03, Solving Linear Equations in Two Variables
Common Issues (Misconceptions) Rubric

Item: Notebooks and Pens-01
Prompt: Are Dan and Emma correct?

[unscored]

Item: Notebooks and Pens-02
Prompt: If you think Dan is wrong, explain the mistake and explain what *you* think the equation means.

Code	**Common Issue**	**Example of Present Common Issue**	**Is the Common Issue present? (Yes/No)**
Variable Misrepresentation	Student assumes that the letter stands for an object not a number.	Student says that the statements are correct.	

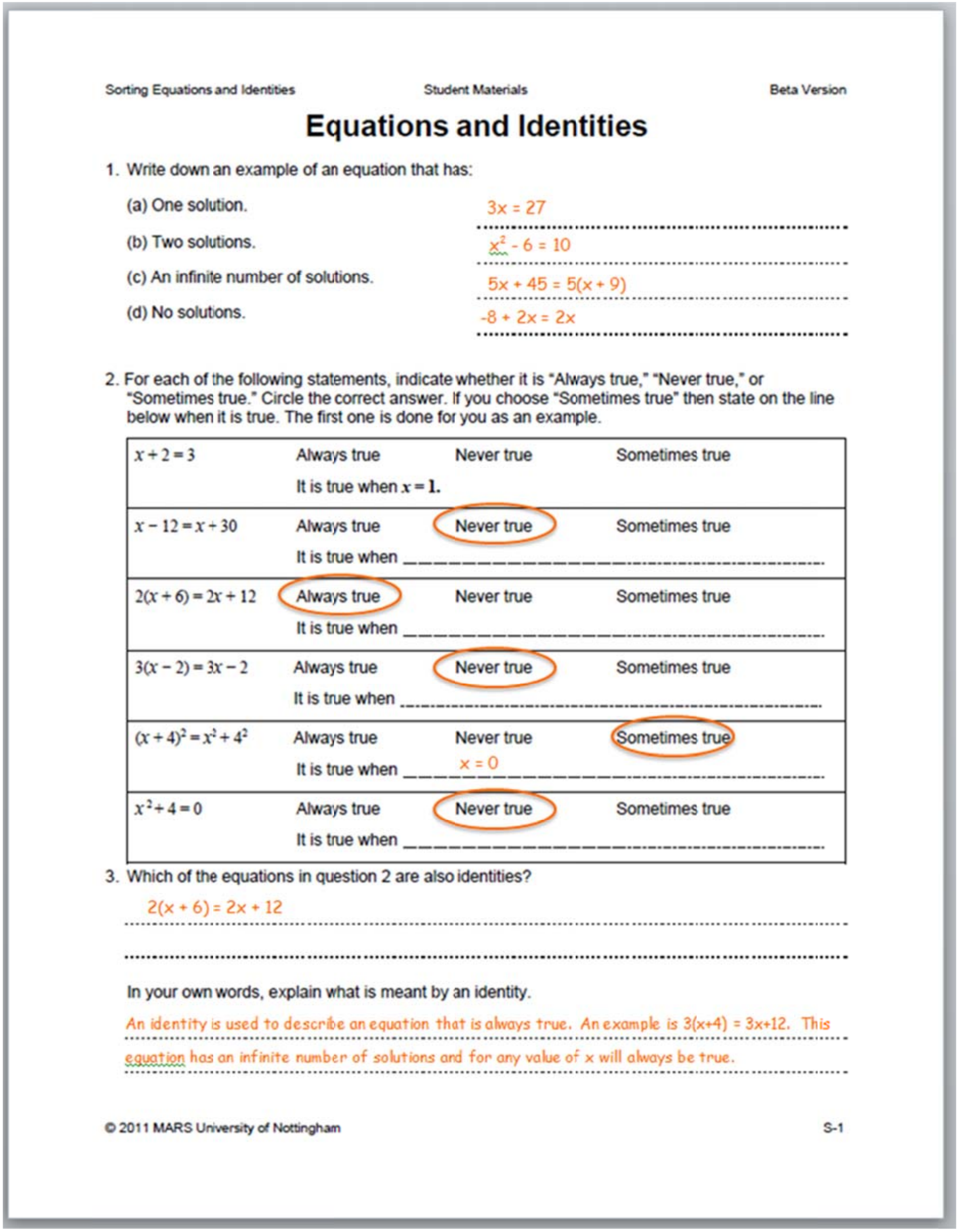
Item: Notebooks and Pens-03
Prompt: If you think Emma is wrong, explain the mistake and explain what *you* think the equation means.

Code	**Common Issue**	**Example of Present Common Issue**	**Is the Common Issue present? (Yes/No)**
Variable Misrepresentation	Student assumes that the letter stands for an object not a number.	Student says that the statements are correct.	

Item: Notebooks and Pens-04
Prompt: Figure out for yourself the number of pens and the number of notebooks sold in the store.

Code	**Common Issue**	**Example of Present Common Issue**	**Is the Common Issue present? (Yes/No)**
Uses Single Equation	Student only uses one equation.	Student finds a value or values for *n* and *p* that fits one equation but not the other, such as $n = 1$ and $p = 4$ for the first equation.	
Guess and Check	Student produces unsystematic guess and check work.	Student works out three or four seemingly unconnected combinations of values for *n* and *p*.	
Algebraic Mistake	Student makes algebraic mistakes.	Student makes a mistake when manipulating the algebra in the equations.	

FAL 13, Sorting Equations and Identities
Scoring Exemplar



Sorting Equations and Identities Student Materials Beta Version

Equations and Identities

1. Write down an example of an equation that has:

(a) One solution. $3x = 27$

(b) Two solutions. $x^2 - 6 = 10$

(c) An infinite number of solutions. $5x + 45 = 5(x + 9)$

(d) No solutions. $-8 + 2x = 2x$

2. For each of the following statements, indicate whether it is "Always true," "Never true," or "Sometimes true." Circle the correct answer. If you choose "Sometimes true" then state on the line below when it is true. The first one is done for you as an example.

$x + 2 = 3$	Always true	Never true	Sometimes true
	It is true when $x = 1$.		
$x - 12 = x + 30$	Always true	[✓ Never true]	Sometimes true
	It is true when		
$2(x + 6) = 2x + 12$	[✓ Always true]	Never true	Sometimes true
	It is true when		
$3(x - 2) = 3x - 2$	Always true	[✓ Never true]	Sometimes true
	It is true when		
$(x + 4)^2 = x^2 + 4^2$	Always true	Never true	[✓ Sometimes true]
	It is true when $x = 0$		
$x^2 + 4 = 0$	Always true	[✓ Never true]	Sometimes true
	It is true when		

3. Which of the equations in question 2 are also identities?

$2(x + 6) = 2x + 12$

In your own words, explain what is meant by an identity.

An identity is used to describe an equation that is always true. An example is $3(x+4) = 3x+12$. This equation has an infinite number of solutions and for any value of x will always be true.

FAL 13, Sorting Equations and Identities
Quality Rubric

Item: Equations and Identities-01
Prompt: Write down an example of an equation that has:

(a) One solution.

Accuracy/Precision

- (1) The student's response is correct (i.e. an equation with one solution).
- (0) The student's response is incorrect (e.g. an equation with no or multiple solutions, an expression instead of an equation).

Accuracy/Precision Score

(b) Two solutions.

Accuracy/Precision

- (1) The student's response is correct (i.e. an equation with two solutions).
- (0) The student's response is incorrect (e.g. an equation with fewer or more than 2 solutions, an expression instead of an equation).

Accuracy/Precision Score

(c) An infinite number of solutions.

Accuracy/Precision

- (1) The student's response is correct.
- (0) The student's response is incorrect (e.g. an equation with a finite number of solutions, an expression instead of an equation).

Accuracy/Precision Score

(d) No solutions.

Accuracy/Precision

- (1) The student's response is correct (i.e. a equation with no solutions).
- (0) The student's response is incorrect (e.g. an equation with one or more solutions, an expression instead of an equation).

Accuracy/Precision Score

Item: Equations and Identities-02

Prompt: For each of the following statements, indicate whether it is 'Always true,' 'Never true,' or 'Sometimes true.' Circle the correct answer. If you choose 'Sometimes true' then state on the line below when it is true. The first one is done for you as an example.

(i) $x + 2 = 3$

[unscored-example item]

(ii) $x - 12 = x + 30$

Accuracy/Precision

- (1) The student has circled 'Never true.'
- (0) The student has circled a different response or has left the item blank.

Accuracy/Precision Score ☐

(iii) $2(x + 6) = 2x + 12$

Accuracy/Precision

- (1) The student has circled 'Always true.'
- (0) The student has circled a different response or has left the item blank.

Accuracy/Precision Score ☐

(iv) $3(x - 2) = 3x - 2$

Accuracy/Precision

- (1) The student has circled 'Never true.'
- (0) The student has circled a different choice or has left the item blank.

Accuracy/Precision Score ☐

(v) $(x + 4)^2 = x^2 + 4^2$

Accuracy/Precision

- (2) The student has circled 'Sometimes true' and written the solution $x = 0$.
- (1) The student has circled 'Sometimes true' but has not provided the solution $x = 0$ **or**
- (1) The student has not circled 'Sometimes true' but has provided the solution $x = 0$.
- (0) The student has circled a different choice or has left the item blank.

Accuracy/Precision Score ☐

(vi) $x^2 + 4 = 0$

Accuracy/Precision

- (1) The student has circled 'Never true.'
- (0) The student has circled a different choice or has left the item blank.

Accuracy/Precision Score ☐

Item: Equations and Identities-03(i)
Prompt: Which of the equations in question 2 are also identities?

Accuracy/Precision

- (2) The student has listed only $2(x + 6) = 2x + 12$.
- (1) The student has listed $2(x + 6) = 2x + 12$ and one additional equation.
- (0) The student has not listed $2(x + 6) = 2x + 12$ or has listed more than one incorrect equation.

Accuracy/Precision Score ☐

Item: Equations and Identities-03(ii)
Prompt: In your own words, explain what is meant by an identity.

Explanation

- (3) The student describes identities as equations that are always true and provides an example.
- (2) The student response indicates correct understanding of identities, but lacks precision or completeness (e.g. "they are always true").
- (1) The student response provides no evidence of correct understanding of identities.
- (0) The student gives no explanation.

Explanation Score ☐

FAL 13, Sorting Equations and Identities
Common Issues (Misconceptions) Rubric

Item: Equations and Identities-01
Prompt: Write down an example of an equation that has…

Code	**Common Issue**	**Example of Present Common Issue**	**Is the Common Issue present? (Yes/No)**
Variable Missing	Student fails to include a variable in the equation	Student writes $5+5=10$ as an example of an equation with one solution in part (a) **or** Student writes $5+6=10$ as an example of an equation with no solutions in part (d).	
Expression vs. Equation	Student thinks expressions and equations are the same thing.	Student writes $y+3$ for an equation with an infinite number of solutions in part (c).	
Non-Integer Solutions	Student provides a quadratic with non-integer solutions as an example of an equation with no solutions.	Student writes $x^2 + 8x + 13 = 0$ as an example of an equation with no solutions in part (d).	

Item: Equations and Identities-02
Prompt: For each of the following statements, indicate whether it is ‘Always true,’ ‘Never true,’ or ‘Sometimes true.’ Circle the correct answer. If you choose ‘Sometimes true’ then state on the line below when it is true. The first one is done for you as an example.

Code	**Common Issue**	**Example of Present Common Issue**	**Is the Common Issue present? (Yes/No)**
Distributive Property	Student assumes that $3(x - 2)$ is the same as $3x - 2$.	Student classifies $3(x - 2) = 3x - 2$ as “Always true.”	
Exponent over Addition	Student assumes that $(x + 4)^2$ is the same as $x^2 + 4^2$	Student classifies $(x + 4)^2 = x^2 + 4^2$ as “Always true.”	
Squaring a Negative	Student assumes that $–(x^2)$ is the same as $(-x)^2$.	Student classifies $x^2 + 4 = 0$ as “Sometimes true” and provides the case, $x = -2$.	

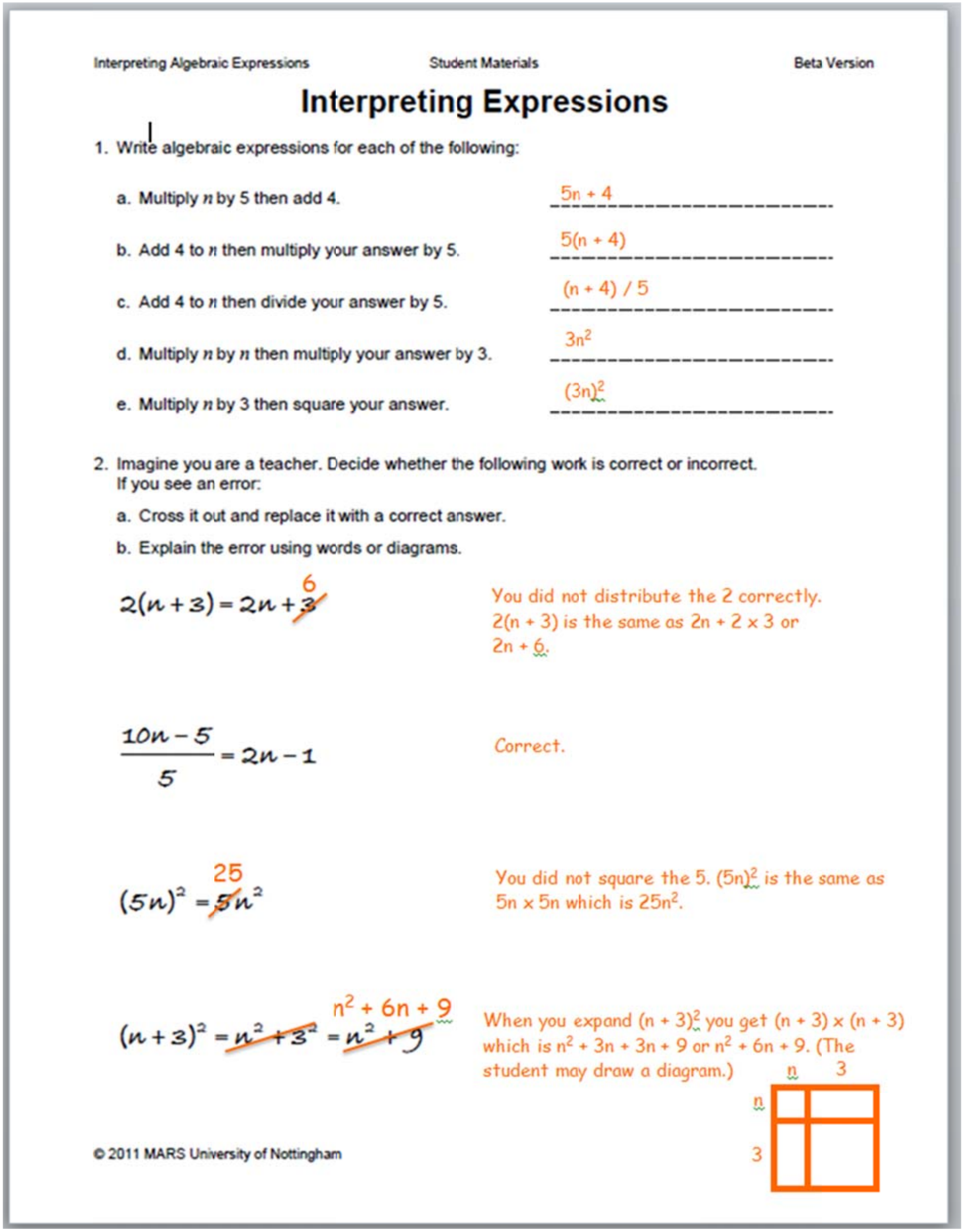
Item: Equations and Identities-03(i)
Prompt: Which of the equations in question 2 are also identities?

[unscored]

Item: Equations and Identities-03(ii)
Prompt: In your own words, explain what is meant by an identity.

[unscored]

FAL 16, Interpreting Algebraic Expressions
Scoring Exemplar



Interpreting Algebraic Expressions　　Student Materials　　Beta Version

Interpreting Expressions

1. Write algebraic expressions for each of the following:

a. Multiply n by 5 then add 4.	5n + 4
b. Add 4 to n then multiply your answer by 5.	5(n + 4)
c. Add 4 to n then divide your answer by 5.	(n + 4) / 5
d. Multiply n by n then multiply your answer by 3.	$3n^2$
e. Multiply n by 3 then square your answer.	$(3n)^2$

2. Imagine you are a teacher. Decide whether the following work is correct or incorrect.
If you see an error:

a. Cross it out and replace it with a correct answer.

b. Explain the error using words or diagrams.

$$2(n+3)=2n+\overset{6}{\cancel{3}}$$

You did not distribute the 2 correctly. 2(n + 3) is the same as 2n + 2 x 3 or 2n + 6.

$$\frac{10n-5}{5}=2n-1$$

Correct.

$$(5n)^2=\overset{25}{\cancel{5}}n^2$$

You did not square the 5. $(5n)^2$ is the same as 5n x 5n which is $25n^2$.

$$(n+3)^2=\cancel{n^2+3^2}=\overset{n^2+6n+9}{\cancel{n^2+9}}$$

When you expand $(n + 3)^2$ you get (n + 3) x (n + 3) which is n^2 + 3n + 3n + 9 or n^2 + 6n + 9. (The student may draw a diagram.)

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FAL 16, Interpreting Algebraic Expressions
Quality Rubric

Item: Interpreting Expressions-01
Prompt: Write algebraic expressions for each of the following:

(a) Multiply *n* by 5 then add 4.

Accuracy/Precision	
- (1) The student's response is correct (i.e. $5n+4$ or an equivalent form). - (0) The student's response is incorrect.	
Accuracy/Precision Score	

(b) Add 4 to *n* then multiply your answer by 5.

Accuracy/Precision	
- (1) The student's response is correct (i.e. $5(n+4)$ or an equivalent form). - (0) The student's response is incorrect.	
Accuracy/Precision Score	

(c) Add 4 to *n* then divide your answer by 5.

Accuracy/Precision	
- (1) The student's response is correct (i.e. $(n+4)/5$ or an equivalent form). - (0) The student's response is incorrect.	
Accuracy/Precision Score	

(d) Multiply *n* by *n* then multiply your answer by 3.

Accuracy/Precision	
- (1) The student's response is correct (i.e. $3n^2$ or an equivalent form). - (0) The student's response is incorrect.	
Accuracy/Precision Score	

(e) Multiply n by 3 then square your answer.

Accuracy/Precision

- (1) The student's response is correct (i.e. $(3n)^2$ or an equivalent form).
- (0) The student's response is incorrect.

Accuracy/Precision Score

Item: Interpreting Expressions-02[1]
Prompt: Imagine you are a teacher. Decide whether the following work is correct or incorrect. If you see an error: (a) Cross out the expression on the right and replace it with the expression that is equivalent to the one on the left. (b) Explain the error using words or diagrams.

(i) $2(n + 3) = 2n + 3$

Accuracy/Precision

- (1) The student corrects the error by replacing 3 on the RHS with 6.
- (0) The student does not correct the error.

Accuracy/Precision Score

Explanation

- (3) The student's explanation displays understanding of the distributive property (e.g. "You did not distribute the 2 correctly").
- (2) The student's explanation displays limited understanding of the distributive property.
- The student's explanation displays no understanding of the distributive property.
- No explanation is provided.

Explanation Score

(ii) $\frac{10n-5}{5} = 2n - 1$

Accuracy/Precision

- (1) The student concludes the work is correct.
- (0) The student concludes the work is incorrect.

Accuracy/Precision Score

---

[1] In completing part (b), students may include area diagrams, correct algebraic steps, or other supports for their explanation. However, this grading rubric only considers *their written explanation*.

(iii) $(5n)^2 = 5n^2$

Accuracy/Precision

- (1) The student corrects the error by replacing 5 on the RHS with 25.
- (0) The student does not correct the error.

Accuracy/Precision Score ☐

Explanation

- (3) The student's explanation displays understanding of the distribution of exponents over multiplication.
- (2) The student's explanation displays limited understanding of the distribution of exponents over multiplication.
- The student's explanation displays no understanding of the distribution of exponents over multiplication.
- No explanation is provided.

Explanation Score ☐

(iv) $(n + 3)^2 = n^2 + 3^2 = n^2 + 9$

Accuracy/Precision

- (1) The student corrects the error by adding the term $6n$ to the RHS.
- (0) The student does not correct the error.

Accuracy/Precision Score ☐

Explanation

- (3) The student's explanation displays understanding of the expansion of squared binomials (e.g. "When you expand $(n+3)^2$ you get $(n+3)(n+3)$…").
- (2) The student's explanation displays limited understanding of the expansion of squared binomials.
- The student's explanation displays no understanding of the expansion of squared binomials.
- No explanation is provided.

Explanation Score ☐

FAL 16, Interpreting Algebraic Expressions
Common Issues (Misconceptions) Rubric

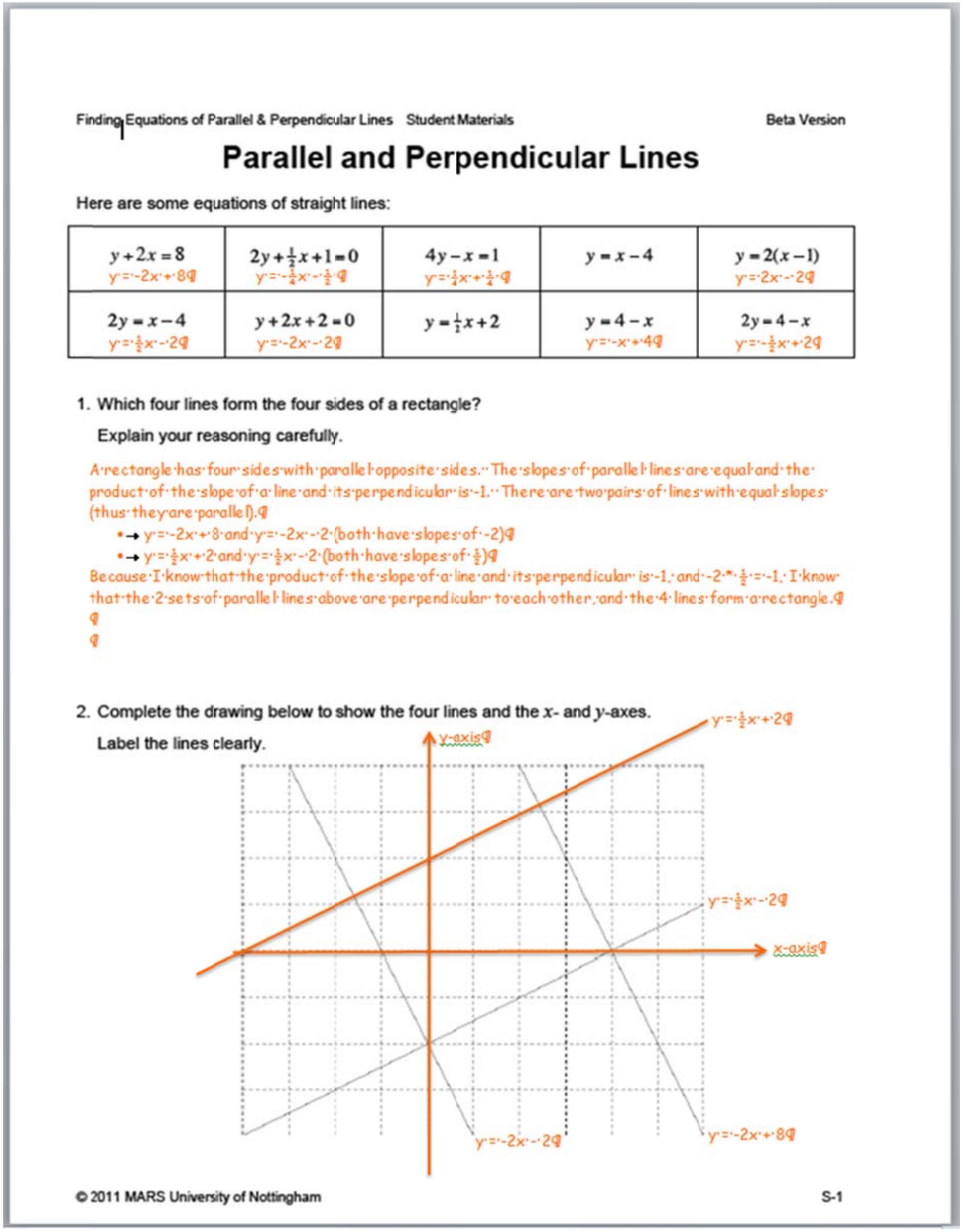
Item: Interpreting Expressions-01
Prompt: Write algebraic expressions for each of the following…

Code	**Common Issue**	**Example of Present Common Issue**	**Is the Common Issue present? (Yes/No)**
Order of Operations/ Parentheses	Student writes expressions left to right showing little understanding of the order of operations implied by the symbolic representation. or Student does not construct parentheses correctly or expands them incorrectly.	Q1b. Student writes $4 + n \times 5$ instead of $5(n + 4)$ Q1c. Student writes $4 + n \div 5$ instead of $\frac{4+n}{5}$	

Item: Interpreting Expressions-02a
Prompt: Imagine you are a teacher. Decide whether the following work is correct or incorrect. If you see an error: (a) Cross it out and replace it with a correct answer.

Code	**Common Issue**	**Example of Present Common Issue**	**Is the Common Issue present? (Yes/No)**
Order of Operations/ Parentheses	Student does not construct parentheses correctly or expands them incorrectly.	Any of the following are not indicated as incorrect: • $2(n + 3) = 2n + 3$ • $(5n)^2 = 5n^2$ • $(n + 3)^2 = n^2 + 3^2$	

FAL 22, Finding Equations of Parallel and Perpendicular Lines
Scoring Exemplar



Finding Equations of Parallel & Perpendicular Lines Student Materials Beta Version

Parallel and Perpendicular Lines

Here are some equations of straight lines:

$y+2x=8$ $y = -2x + 8$	$2y+\frac{1}{2}x+1=0$ $y = -\frac{1}{4}x - \frac{1}{2}$	$4y-x=1$ $y = \frac{1}{4}x + \frac{1}{4}$	$y=x-4$	$y=2(x-1)$ $y = 2x - 2$
$2y=x-4$ $y = \frac{1}{2}x - 2$	$y+2x+2=0$ $y = -2x - 2$	$y=\frac{1}{2}x+2$	$y=4-x$ $y = -x + 4$	$2y=4-x$ $y = -\frac{1}{2}x + 2$

1. Which four lines form the four sides of a rectangle?

   Explain your reasoning carefully.

A rectangle has four sides with parallel opposite sides. The slopes of parallel lines are equal and the product of the slope of a line and its perpendicular is -1. There are two pairs of lines with equal slopes (thus they are parallel).

- → $y = -2x + 8$ and $y = -2x - 2$ (both have slopes of -2)
- → $y = \frac{1}{2}x + 2$ and $y = \frac{1}{2}x - 2$ (both have slopes of $\frac{1}{2}$)

Because I know that the product of the slope of a line and its perpendicular is -1, and $-2 * \frac{1}{2} = -1$, I know that the 2 sets of parallel lines above are perpendicular to each other, and the 4 lines form a rectangle.

2. Complete the drawing below to show the four lines and the x- and y-axes.

   Label the lines clearly.

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FAL 22, Finding Equations of Parallel and Perpendicular Lines
Quality Rubric

Item: Parallel and Perpendicular Lines-01
Prompt: Which four lines form the four sides of a rectangle? Explain your reasoning carefully.

Accuracy/Precision

Score one point for each of the following correct lines: (0-4 points possible):

- $y+2x=8$ **or** $y=-2x+8$
- $y+2x+2=0$ **or** $y=-2x-2$
- $2y=x-4$ **or** $y=\frac{1}{2}x-2$
- $y=\frac{1}{2}x+2$

Accuracy/Precision Score

Explanation

- (3) The student provides a clear, well-supported explanation with explicit reference to the geometric properties of rectangles and the relationships between slopes of parallel and perpendicular lines.
- (2) The student displays some understanding of the relevant mathematical concepts (the geometric properties of rectangles and the relationships between slopes of parallel and perpendicular lines), but does not provide a clear, well-supported explanation.
- (1) An explanation is provided, but it does not display understanding of the relevant mathematical concepts (the geometric properties of rectangles and the relationship between slopes for parallel and perpendicular lines).
- (0) There is no explanation.

Explanation Score

Item: Parallel and Perpendicular Lines-02
Prompt: Complete the drawing below to show the four lines and the *x*- and *y*-axes. Label the lines clearly.

Accuracy/Precision

Score one point for each of the following (0-7 points possible):

- The student correctly draws the missing line, $y=\frac{1}{2}x+2$.
- The student correctly draws the x-axis.
- The student correctly draws the y-axis.
- The student correctly labels $y=-2x+8$ ($y+2x=8$ *also acceptable*)
- The student correctly labels $y=-2x-2$ ($y+2x+2=0$ *also acceptable*)
- The student correctly labels $y=\frac{1}{2}x-2$ ($2y=x-4$ *also acceptable*)
- The student correctly labels $y=\frac{1}{2}x+2$

Accuracy/Precision Score

FAL 22, Finding Equations of Parallel and Perpendicular Lines
Common Issues (Misconceptions) Rubric

Item: Parallel and Perpendicular Lines-01
Prompt: Which four lines form the four sides of a rectangle? Explain your reasoning carefully.

Code	**Common Issue**	**Example of Present Common Issue**	**Is the Common Issue present? (Yes/No)**
Rectangle Properties	Student does not use geometric properties of a rectangle in solution.	Student does not mention that a rectangle has two pairs of parallel sides **or** Student does not mention that adjacent sides of a rectangle are perpendicular.	
Slope Properties	Student does not identify parallel / perpendicular lines by their slopes.	Student does not select pairs of parallel lines **or** Student does not select parallel pairs that are perpendicular to each other.	
Slope from Equation	Student demonstrates limited understanding of the link between the slope and the form of the equation of a straight line.	Student identifies slopes for equations in which y is given explicitly in terms of x ($y=mx+b$) but not for other equations **or** Student reads the number in front of x as if it were the slope in all equations.	

Item: Parallel and Perpendicular Lines-02
Prompt: Complete the drawing below to show the four lines and the *x*- and *y*-axes. Label the lines clearly.

[unscored]

Exhibit A3:

MDC Teacher Survey 2013

[login]

Before you begin, note that the math tools provided to you by the Gates Foundation are referred to by many names.

We use the phrase Formative Assessment Lessons (MDC Lessons) to refer to the math tools
that were developed by the Shell Centre (whose name appears on the course materials) as part of the Mathematic Design Collaborative (MDC).

You may recall that these tools have four distinct parts:
the initial or pre-assessment, the collaborative activity; the whole class plenary and the post-assessment.

Some of the questions in the survey make reference to the Common Core State Standards (CCSS). In different states, this could be referred to differently, for example, in the state of Colorado, it is referred to as Colorado Academic Standards.

You are about to enter the survey. To go back a page, please use the

survey's red "Back" button, not your browser's back button.

Your answers will be saved each time you click "Next."

The survey takes about 30 minutes to complete. You may leave and return multiple times.

If you do return, after entering your login code, you will be placed in the screen you last visited.

Please select the best answer for each question. Some instructions are in *italics*.

TEACHER BACKGROUND INFORMATION

1. What is/are your current position(s)? *Please CHECK ALL that apply.*

☐$_a$ Classroom math teacher
☐$_b$ Special Education
☐$_c$ Department head
☐$_d$ Math coach
☐$_e$ Other*(please specify)* _______[100 characters]________

2. At which grade level(s) do you teach? *Please CHECK ALL that apply.*

☐$_a$ Middle school (6th – 8th grade)
☐$_b$ High school (9th – 12th grade)

3. In what content area(s) do you teach? *Please CHECK ALL that apply.*

☐$_a$ Pre-Algebra
☐$_b$ Algebra I
☐$_c$ Geometry
☐$_d$ Algebra II
☐$_e$ Pre-Calculus
☐$_f$ Calculus
☐$_g$ Probability and Statistics
☐$_h$ Other *(please specify)* _______[100 characters]________

4. To the nearest year, how long have you …

a) … been a teacher? _________ year(s) [integer, 0-99]

b) … taught in your current school? _________ year(s) [integer, 0-99]

c) … taught in your current district? _________ year(s) [integer, 0-99]

	Yes	No
5. Do you teach ELL students?	○$_1$	○$_0$
6. Do you teach special education students?	○	○
7. Do you teach students who are struggling in Math?	○	○
8. Do you teach students with advanced mathematical levels?	○	○

9. How would you describe your participation in the MDC initiative?

○$_1$ Required
○$_2$ Voluntary
○$_3$ I have not taught an MDC Lesson in **2012-2013** [End of survey; go to Reg Close]
○$_4$ I opted out of participating in **2012-2013** *(please specify a reason for opting out)* ______[1000 characters]_______ [End of survey; go to Reg Close]

10. Is this your first year in the MDC initiative? ○$_1$ Yes [skip to Q12] ○$_0$ No

11. How many MDC Lessons did you teach **last** year (**2011-12**)? ____[integer, 0-99]_____ MDC Lesson(s)

Please enter a 0 if you did not teach any MDC Lessons ***last*** *year (**2011-12**).*

12. How many MDC Lessons will you have taught in total during the **current** school year (**2012-13**)? ___[integer, 0-99]___ MDC Lesson(s)

13. My involvement with the MDC initiative has included the following activities: *Please CHECK ALL that apply.*

- ☐$_a$ Teaching the MDC Lessons
- ☐$_b$ Aligning MDC Lessons to the course content/pacing guide
- ☐$_c$ Coaching others on how to use MDC Lessons
- ☐$_d$ Presenting at an MDC Lesson professional development session

14. How many MDC Lessons do you have access to? *Check ONLY ONE that applies*

- ○$_1$ 1-5 MDC Lessons
- ○$_2$ 6-10 MDC Lessons
- ○$_3$ 11-20 MDC Lessons
- ○$_4$ more than 20 MDC Lessons
- ○$_5$ Don’t know

15. How do you access the MDC Lessons? *Please CHECK ALL that apply.*

○$_1$ They are emailed to me by district administrator.
○$_2$ They are saved on the district website.
○$_3$ They are on the Shell Centre Website.
○$_4$ Hard copies are provided during professional development.
○$_5$ Other

SUPPORT FOR USING MDC LESSONS

16. Indicate whether the following people visited your classroom when you were teaching an MDC Lesson.
[randomize options, letters don't appear]

		Visited	Did not visit
a.	District or network MDC project lead	○$_1$	○$_0$
b.	Principal	○	○
c.	Instructional coach/department head	○	○
d.	Teacher colleague	○	○

BELIEFS ABOUT TEACHING MATHEMATICS SKILLS

Q17 is about teaching mathematics.

17. Please indicate the degree to which you agree or disagree with the following statements:

I believe the following strategies are effective ways of strengthening my students' mathematical understanding:

	Agree	Agree Somewhat	Disagree Somewhat	Disagree
a. Teacher taking on the role of "facilitator" or "coach"	○$_1$	○$_2$	○$_3$	○$_4$
b. Peer-to-peer problem-solving	○	○	○	○
c. Asking students guiding questions	○	○	○	○
d. Providing class time for students to persevere through difficult math problems	○	○	○	○

PURPOSE OF INITIATIVE

18. Please indicate the degree to which you agree or disagree with the following statements:

Math MDC Lessons are effective in…

a. … improving students' ability to think mathematically.	○	○	○	○
b. … providing a curricular resource for teachers in addressing the Common Core State Standards.	○	○	○	○
c. … encouraging teachers to adjust their pedagogy in math instruction from a focus on process to a focus on building conceptual understanding.	○	○	○	○
d. … making instruction more engaging for students.	○	○	○	○
e. … using formative assessment to identify student strengths and weaknesses and to inform instruction.	○	○	○	○

TEACHER PERCEPTIONS OF TOOL UTILITY

19. Please indicate whether using the MDC Lessons has helped you in the following ways during MDC Lesson use.

During MDC Lesson instruction, using the MDC Lessons has helped me …

	Yes	No
a) … find effective strategies for teaching my subject content.	○$_1$	○$_0$
b) … learn new ways to include formative assessment in my classes.	○	○
c) … learn detailed information about my students’ mathematical strengths and weaknesses.	○	○
d) … provide students with more detailed feedback about their work.	○	○
e) … implement the Common Core State Standards.	○	○
f) …create an environment that promotes mathematical discourse.	○	○
g) … better engage students.	○	○

	Agree	Agree Somewhat	Disagree Somewhat	Disagree
20. Please indicate the degree to which you agree or disagree with the following statements. MDC Lessons help me differentiate instruction …				
[skip next item if Q5 = no]				
a. … for ELL students.	○$_1$	○$_2$	○$_3$	○$_4$
[skip next item if Q6 = no]				
b. … for special education students.	○	○	○	○
[skip next item if Q7 = no]				
c. … for students who struggle with math.	○	○	○	○
[skip next item if Q8 = no]				
d.… for students with advanced math abilities.	○	○	○	○
21. The MDC Lessons are flexible enough to fit the needs of all my students.	○	○	○	○

*Question 22a-c is about the **most recent** MDC Lesson you taught.*

22. Please indicate the degree to which you agree or disagree with the following statements:

	Agree	Agree Somewhat	Disagree Somewhat	Disagree
a. Based on the information collected from using the MDC Lesson, I adjusted my instruction to meet the needs of individual students.	○$_1$	○$_2$	○$_3$	○$_4$
b. I knew where to fit the MDC Lesson in the unit.	○	○	○	○
c. The pre-assessment revealed my students' misconceptions to me.	○	○	○	○

23. Please indicate the degree to which you agree or disagree with the following statements:

a. Using the MDC Lessons raised my expectations for students' mathematical work.	○	○	○	○
b. The MDC Lessons have become an important part of my instructional practice.	○	○	○	○

24. Select the phrase that best completes the sentence:

I use the MDC instructional strategies …

○$_1$ …often ○$_2$ …sometimes ○$_3$ …rarely

… during non-MDC instruction.

STUDENT IMPACT

25. Compared to my usual instruction, during the MDC Lessons, my students …

○$_1$ … are more engaged. ○$_2$ … show the same level of engagement. ○$_3$ … are less engaged.

26. Please indicate the degree to which you agree or disagree with the following statements.

	Agree	Agree Somewhat	Disagree Somewhat	Disagree
a. The MDC Lessons have improved my students' mathematical reasoning.	○$_1$	○$_2$	○$_3$	○$_4$
b. The MDC Lessons are supporting my students' college-readiness.	○	○	○	○

*Question 27a-c asks you to reflect back on your **most recent** experience implementing an MDC Lesson during the current school year (**2012-13)**.*

27a. When I taught the most recent MDC Lesson, the **majority** of my students improved their content knowledge.

○$_1$ Yes ○$_0$ No

27b. When I taught my most recent MDC Lesson, the **majority** of my students improved their conceptual understanding.

○$_1$ Yes ○$_0$ No

TOOL USE (FOI Questions)

28. To what extent did you follow the MDC Lessons Teacher Guide when implementing instruction?

○$_1$ Completely
○$_2$ Mostly
○$_3$ Somewhat
○$_4$ Not at all

29. How many class periods did you spend implementing a typical MDC Lesson in the current school year **(2012-13)**? ________ class periods
[integer, 1-99]

30. What percent of class time did you spend on each of the following MDC components during a typical MDC Lesson in the current school year **(2012-13)**?

Pre-assessment	[Enter number]
Small-group collaborative work	[Enter number]
Whole-class plenary/discussion	[Enter number]
Post-assessment	[Enter number] [limit the sum of the numbers in this ques to 100]

31. About how long did you spend reviewing your class's answers to the MDC pre-assessment? ___________ minutes [integer, 1-99]

32. Please indicate, across all the MDC lessons you taught in the current school year (2012-13), how frequently you responded to the pre-assessment in the following ways.

	Almost always	Often	Sometimes	Almost never
a. Little feedback provided because of time constraints				
b. Wrote comments on most individuals' pre-assessments	○$_1$	○$_2$	○$_3$	○$_4$
c. Wrote questions on most individuals' pre-assessments	○	○	○	○
d. Reviewed common errors at start of class	○	○	○	○

33. Please select the phrase that best reflects your practice:

When students are working on the collaborative portion of the FALs, …

○$_1$ … I *typically* let students choose their own partners or group.

○$_2$ … I *typically* assign students to homogeneous math ability groups.

○$_3$ … I *typically* assign students to heterogeneous math ability groups.

34. Please indicate the degree to which you use the following strategies while implementing the collaborative activity portion of your MDC Lessons in the current school year **(2012-13)**.

[randomize options, letters don't appear]

	Always	Often	Sometimes	Never
a. observed and listened but did not offer feedback	○$_1$	○$_2$	○$_3$	○$_4$
b. offered hints and suggestions	○	○	○	○
c. raised questions	○	○	○	○
d. provided the answer	○	○	○	○
e. asked another student to explain the concept	○	○	○	○
f. spent time re-teaching the concept	○	○	○	○

Q35-38 are about the ***<u>most recent</u>*** *MDC Lessons you taught.*

35. Reflecting on the **<u>most recent</u>** MDC Lesson, when did students complete the post-assessment?

○$_1$ In class, at the end of the plenary/class discussion
○$_2$ As homework
○$_3$ Other *(please specify)* ______[1000 characters]_______
○$_4$ I did not use the post-assessment

36. Which <u>one</u> of the following reasons <u>best</u> describes why you did not use the post-assessment in your **most recent** MDC Lesson? [Only displayed if teacher selects 4 on Q35]

○$_1$ I ran out of time.
○$_2$ It seemed redundant.
○$_3$ My students understood the material.
○$_4$ It was too hard.
○$_5$ Other *(please specify)* ______[1000 characters]_______

37. What percent of your students do you think gained a strong grasp of the material by the end of the MDC Lesson?

○$_{1}$ 100%
○$_{2}$ 75-99%
○$_{3}$ 50-74%
○$_{4}$ 25-49%
○$_{5}$ 5-24%
○$_{6}$<5%
○$_{-99}$ Not sure

38. How effective were each of the following components of the MDC Lesson in promoting student learning?

		Very Effective	Effective	Somewhat Effective	Not Effective
a.	Pre-assessment	○$_{1}$	○$_{2}$	○$_{3}$	○$_{4}$
b.	Small-group collaborative work	○	○	○	○
c.	Whole Class plenary/discussion	○	○	○	○
d.	Post-assessment	○	○	○	○

POTENTIAL BARRIERS TO TOOL USE

39. Please indicate the degree to which you agree or disagree with the following statements.

	Agree	Agree Somewhat	Disagree Somewhat	Disagree
a. I had sufficient time to plan for the lessons.	○1	○2	○3	○4
b. I felt adequately prepared to effectively use the lessons.	○	○	○	○
c. I had sufficient time to prepare for the pre-assessment.	○	○	○	○
d. Using the MDC Lessons takes too much time away from covering required curriculum topics.	○	○	○	○
e. The preparation required for the MDC Lesson collaborative activity is an impediment to using the lesson.	○	○	○	○
f. During the collaborative portion of the MDC Lesson, it is difficult for me to interact with every group.	○	○	○	○

SCALING OF MDC INITIATIVE

*Q40 is about using the MDC Lessons next year (**2013-14**).*

40. Please indicate the degree to which you agree or disagree with the following statements:

	Agree	Agree Somewhat	Disagree Somewhat	Disagree
a) I would like to have access to more MDC Lessons next year.	○$_1$	○$_2$	○$_3$	○$_4$
b) I look forward to teaching MDC Lessons next year.	○	○	○	○
c) I plan to improve how I teach the MDC Lessons next year.	○	○	○	○

41. Please indicate the degree to which you agree or disagree with the following statements below:

a) My participation in the MDC initiative is worth the time and effort involved.	○	○	○	○
b) I see the ideas and practices of the MDC initiative gaining traction in my school.	○	○	○	○
c) I have noticed an increase in the number of teachers using the MDC Lessons in my school since last year.	○	○	○	○
d) There are other curricular initiatives or programs in the district that address some of the same purposes as MDC.	○	○	○	○
e) The other curricular initiatives or programs in the district create competing priorities with the MDC initiative.	○	○	○	○
f) The district has the commitment to sustain the MDC initiative.	○	○	○	○

42. Have you shared any of your MDC Lessons with a teacher who is not participating in the MDC initiative? ○$_1$ Yes ○$_0$ No

SCHOOL LEADERSHIP

Q43 is about administrators at your school and district.

43. Please indicate the degree to which you agree or disagree with the following statements.

	Agree	Agree Somewhat	Disagree Somewhat	Disagree	Don't Know
My **school administrators** … [randomize options, letters don't appear]					
a. … have a firm understanding of the MDC Lessons.	○$_1$	○$_2$	○$_3$	○$_4$	○$_{-99}$
b. … have made formative assessment a priority at my school.	○	○	○	○	○
c. … encouraged me to participate in the MDC initiative.	○	○	○	○	○
d. … have provided me with feedback about my instruction of the MDC Lessons.	○	○	○	○	○
e. … have provided ongoing support for the implementation of the MDC Lessons.	○	○	○	○	○
f. … expressed concerns that the MDC Lessons are taking time away from other instructional priorities.	○	○	○	○	○
g. … have attended professional development about the MDC Lessons.	○	○	○	○	○
h. … have communicated how the MDC Lessons are aligned with other school initiatives.	○	○	○	○	○
My **district administrators** … [randomize options, letters don't appear]					
i. … support the MDC initiative.	○	○	○	○	○
j. … encourage my participation in the MDC initiative.	○	○	○	○	○
k. … provide ongoing support for the implementation of the MDC Lessons.	○	○	○	○	○
l. … have a firm understanding of the MDC Lessons.	○	○	○	○	○
m. …have attended professional development about the MDC Lessons.	○	○	○	○	○

ALIGNMENT

44. Please indicate the degree to which you agree or disagree with the following statements.

	Agree	Agree Somewhat	Disagree Somewhat	Disagree
a. The MDC Lessons align well with my school's curriculum.	○1	○2	○3	○4
b. The MDC Lessons help prepare my students for the current state assessment(s).	○	○	○	○
c. The MDC Lessons align with the Common Core State Standards.	○	○	○	○
d. I see the **unique value** of the MDC Lessons to address the Common Core State Standards.	○	○	○	○

COLLABORATION

Questions 45-46 are about your interactions with your MDC colleagues.

45. Do you and your MDC colleagues have regularly scheduled common planning time to discuss MDC?

○1 Yes ○0 No

	Agree	Agree Somewhat	Disagree Somewhat	Disagree
46. I would describe my MDC colleagues as collaborative.	○1	○2	○3	○4

47. About how often do you have **<u>scheduled meetings</u>** (as opposed to informal discussions) with your MDC colleagues to discuss student work, instructional strategies, or teaching approaches? [skip if Q45=no]

○$_1$ At least once a week
○$_2$ Every other week
○$_3$ Once a month
○$_4$ Once per quarter/trimester/semester
○$_5$ Never

48. About how often do you have **<u>informal discussions</u>** (as opposed to scheduled meetings) with your MDC colleagues to discuss student work, instructional strategies, or teaching approaches?

○$_1$ At least once a week
○$_2$ Every other week
○$_3$ Once a month
○$_4$ Once per quarter/trimester/semester
○$_5$ Never

	Agree	Agree Somewhat	Disagree Somewhat	Disagree
49. Collaboration with my MDC colleagues helps me to … [randomize options, letters don't appear]				
a. …more effectively use the MDC formative assessment strategies.	○$_1$	○$_2$	○$_3$	○$_4$
b. …better support student learning.	○	○	○	○
c. …use the MDC Lessons in my class.	○	○	○	○
d. …review pre-assessments.	○	○	○	○
e. …facilitate collaborative group work.	○	○	○	○
f. …facilitate the plenary or whole-class discussion.	○	○	○	○
g. …identify common math misconceptions.	○	○	○	○
h. …determine where to use an MDC Lesson in a unit.	○	○	○	○
i. …develop feedback questions.	○	○	○	○
j. …determine how to group students.	○	○	○	○
k. …review post-assessments.	○	○	○	○

WORKING WITH EXPERIENCED MDC COLLEAGUES

50. Are there teachers in your school or district who used the MDC Lessons **last** year (**2011-2012)**? ○$_1$ Yes ○$_0$ No [skip to Q53]

51. Did you work with a colleague more experienced with MDC **this** year (**2012-2013**)? ○$_1$ Yes ○$_0$ No [skip to Q53]

52. How much did working with an experienced MDC colleague help you to use MDC Lessons?

○$_1$ a great deal
○$_2$ a fair amount
○$_3$ some
○$_4$ not much
○$_5$ not at all

PROFESSIONAL DEVELOPMENT

53. Have you participated in formal professional development sessions related to MDC during the **current** school year (**2012-13**)?

○$_1$ Yes ○$_0$ No [skip to Q61]

54. Which PD providers facilitated the MDC professional development you attended this year **(2012-13)**? *Please CHECK ANY that applies*

- ☐$_a$ State or regional staff
- ☐$_b$ External partner (e.g., SREB, Ann Shannon, Math Solutions)
- ☐$_c$ District or network staff
- ☐$_d$ School-based staff
- ☐$_e$ I don't remember who facilitated the PD this year

55. How many formal, scheduled MDC professional development sessions have you attended **this** year (**2012-13)**? ___[integer, 1-99]___ session(s)

56. Please indicate whether you participated in the following **types of MDC professional development sessions**.

	Participated	Did not participate
a. One-on-one classroom visits	○$_1$	○$_0$
b. Coaching	○	○
c. Webinars	○	○
d. Small group meetings	○	○
e. School-wide meetings	○	○
f. District-wide meetings	○	○
g. Cross-district meetings	○	○

57. Please indicate whether the MDC professional development sessions you participated in was effective or not effective.

	Effective	Not Effective
a. [fill choice from previous item here]	○$_1$	○$_0$
b. [fill choice from previous item here, etc., etc.]	○	○

58. Please indicate whether the MDC professional development sessions you have participated in contained the following **types of content**:

	PD contained this content	PC did not contain this content
a. Using MDC Lessons as a way to implement the Common Core State Standards	○$_1$	○$_0$
b. Administering the pre-assessment	○	○
c. Identifying common misconceptions through the pre-assessment results	○	○
d. Developing feedback questions	○	○
e. Facilitating small group work with guiding questions	○	○
f. Facilitating whole group plenary discussions	○	○
g. Placing lessons at the appropriate point in the unit	○	○
h. Determining how to use the post-assessment results to guide continued instruction in the unit	○	○
i. Differentiating MDC lesson instruction to meet student needs	○	○
j. Implementing MDC lessons with ELL students.	○	○
k. Implementing MDC lessons with special education students.	○	○
l. Implementing MDC lessons with students who are struggling with Math.	○	○
m. Implementing MDC lessons with students with advanced mathematical levels.	○	○

Q59 asks about MDC professional development that would support your implementation of the MDC initiative.

59. Please indicate whether you would like more professional development on …

	Yes	No
a. …using MDC Lessons as a way to implement the Common Core State Standards	○$_1$	○$_0$
b. …administering the pre-assessment.	○	○
c. …identifying common misconceptions through the pre-assessment results.	○	○
d. …developing feedback questions.	○	○
e. …facilitating small group work with guiding questions.	○	○
f. …facilitating whole group plenary discussions.	○	○
g. …placing lessons at the appropriate point in the unit.	○	○
h. ... determining how to use the post-assessment results to guide continued instruction in the unit.	○	○
i. …differentiating lesson instruction to meet student needs	○	○
j. …implementing lessons with special education students	○	○
k. …implementing lessons with ELL students	○	○
l. …implementing lessons with students who are struggling in Math	○	○
m. …differentiating lesson with students with advanced mathematical levels	○	○

60. Are you compensated for attending professional development sessions? ○$_1$ Yes ○$_0$ No

61. What additional supports and training would help you use the MDC Lessons? *Please use the field below to describe.*

[limit 1000 characters]

62. Surveys are not perfect. Maybe we missed some things that you think are important about the Gates MDC initiative. Below, we invite you to write your assessment and comments about the initiative as you have experienced it.

[limit 1000 characters]

These last few questions are about you.

63. Are you certified to teach mathematics? ○$_1$ Yes ○$_0$ No

64. Are you a member of National Council of Teachers of Mathematics (NCTM)? ○$_1$ Yes ○$_0$ No

65. What is your race/ethnicity? *Please CHECK ONE that apply.*

- ☐$_a$ Native American
- ☐$_b$ Asian/Pacific Islander
- ☐$_c$ Black or African American
- ☐$_d$ Hispanic or Latino
- ☐$_e$ White or Caucasian
- ☐$_f$ Multiracial
- ☐$_g$ Other *(please specify)* ______[100 characters]_______

[Go to “Regular Close”]

= = = = = = = = = = = = = = = =

REGULAR CLOSE

Thank you very much for the time and thought you have put into completing this survey.

To ensure anonymity, your responses will be combined with those from teachers of numerous schools.

Your responses will help to inform implementation of the Math Design Collaborative.

= = = = = = = = = = = = = = = =

DON’T AGREE CLOSE

We are sorry you have chosen not to participate in the survey.

Thank you for visiting *Research for Action’s and the National Center for Research on Evaluation, Standards and Student Testing’s* survey on the Gates Math initiative.

= = = = = = = = = = = = = = = =

ERROR MESSAGE IF AN ANSWER IS LEFT BLANK:

You have not given an answer for a question on this screen.

Do you want to go back to give an answer or continue with the survey?

○ I want to go back to answer the question.

○ I want to continue without answering the question.

Exhibit A4: MDC CRESST Assessment: Short Teacher Survey

1. **What date(s) were the enclosed assessments administered? ____________**

2. **How much total time did students spending taking the assessments? _____** minutes

Please answer the following questions about your instruction in the 2012–13 school year. Answers should reflect your instruction for the classroom in which you are administering the enclosed assessments.

3. **Place an X in the box next to each Formative Assessment Lesson (FAL) you taught this school year in this class. (For your convenience, the lesson number is included in parentheses where applicable.)**

	Comparing Investments (37)
	Creating and Solving Equations (44)
	Defining Regions Using Inequalities (14)
	Equations of Circles 1 (34)
	Estimating and Approximating: The Money Munchers (15)
	Evaluating Statements about Probability (21)
	Ferris Wheel (23)
	Finding Equations of Parallel and Perpendicular Lines (22)
	Forming Quadratics (20)
	Functions and Everyday Situations (46)
	Generalizing Patterns: Table Tiles (9)
	Interpreting Algebraic Expressions (16)
	Interpreting Distance-Time Graphs (2)
	Interpreting Statistics: A Case of Muddying the Waters (12)
	Lines and Linear Equations (62)
	Manipulating Polynomials (45)

	Manipulating Radicals (40)
	Mean, Median, Mode, and Range
	Modeling Situations with Linear Equations (5)
	Modeling: Having Kittens (39)
	Modeling: Rolling Cups (17)
	Operations and Radicals
	Optimization Problems: Boomerangs (1)
	Rational and Irrational Numbers 1 (27)
	Rational and Irrational Numbers 2 (31)
	Representing Data Using Box Plots (26)
	Representing Data Using Frequency Graphs (25)
	Representing Polynomials (41)
	Solving Linear Equations in One Variable (70)
	Solving Linear Equations in Two Variables (3)
	Solving Quadratic Equations: Cutting Corners (43)
	Sorting Equations and Identities (13)

4. **How many FALs which do not appear on the list below did you teach in this class? _____**

5. **Please indicate the degree of emphasis you placed on each of the following standards during your 2012–13 instruction in this class, by placing an X in the appropriate column.**

	No Emphasis	Slight Emphasis	Moderate Emphasis	Sustained Emphasis
a. Interpret the structure of expressions.				
b. Rewrite rational expressions.				
c. Write expressions in equivalent forms to solve problems.				
d. Create equations that describe numbers or relationships				
e. Solve systems of equations				
f. Use coordinates to prove simple geometric theorems algebraically				
g. Analyze functions using different representations				

6. **If there were any problems with the administration of the assessments, or you have any other comments, please use the space below.**

____

____

____

____

____

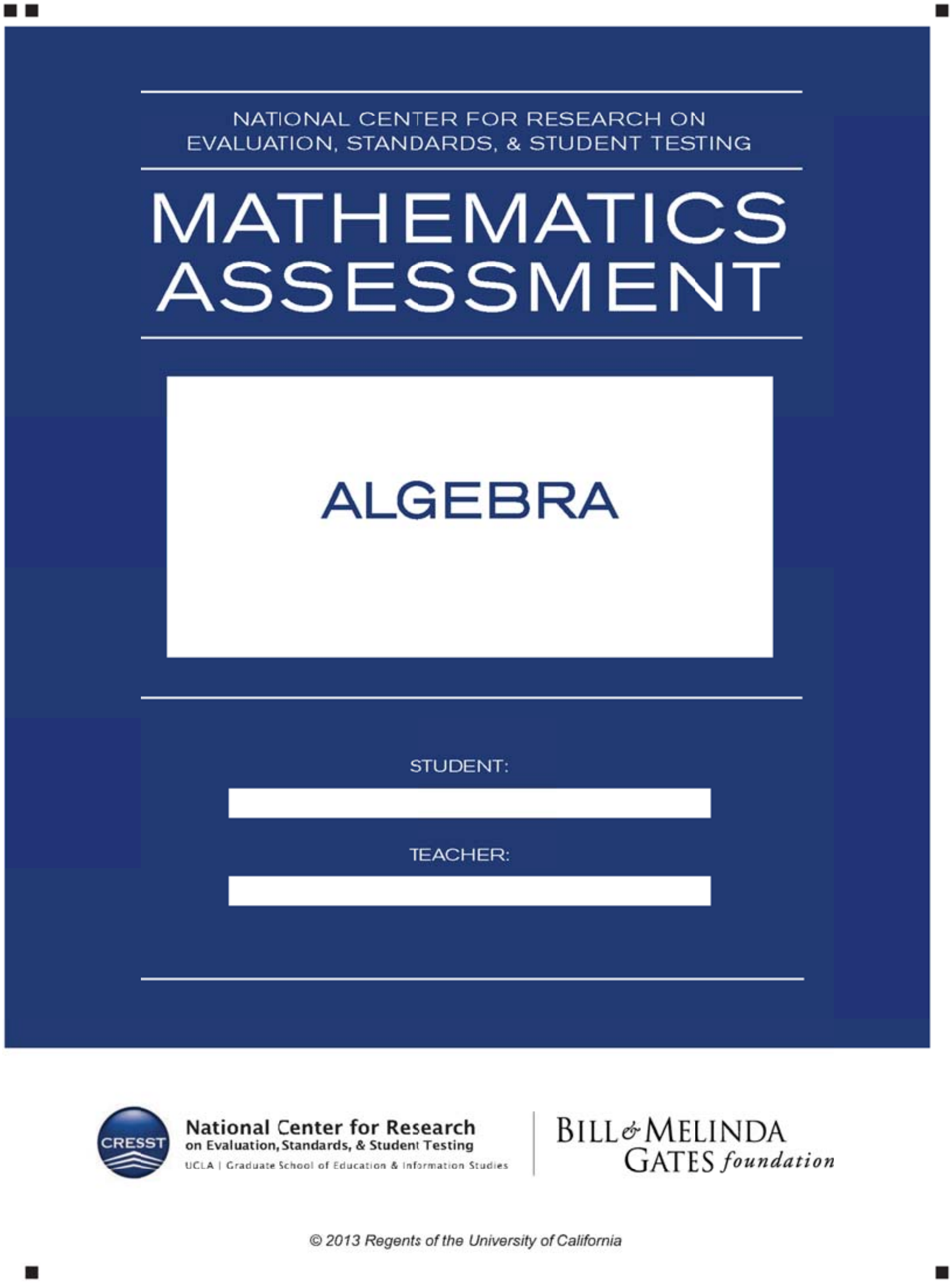
____

____

____

____

Exhibit A5: CRESST Math Assessment



NATIONAL CENTER FOR RESEARCH ON
EVALUATION, STANDARDS, & STUDENT TESTING

MATHEMATICS
ASSESSMENT

ALGEBRA

STUDENT:

TEACHER:

National Center for Research
on Evaluation, Standards, & Student Testing
UCLA | Graduate School of Education & Information Studies

BILL & MELINDA
GATES *foundation*

Instructions

Read and answer the following questions. If you are asked to explain something, make sure you **use words** and not only calculations in your explanation.

1) Which of the following statements is true about this equation?

$2(x - 4) = 2x - 8$

Ⓐ This equation has exactly one solution.

Ⓑ This equation has exactly two solutions.

Ⓒ This equation has no solutions.

Ⓓ This equation has an infinite number of solutions.

2) Which equation does not have a solution?

Ⓐ $x^2 = (x + 2)(x - 2)$

Ⓑ $(x)^2 = x^2$

Ⓒ $(2x - 3)(x - 2) = 0$

Ⓓ $x = 5$

CONTINUE ➡

3) On the line next to each equation, give the solution to the equation or write "no solution" if the equation has no solution.

a) Equation 1: $x - 7 = 7 - x$ ______________________________

b) Equation 2: $x^2 = (x + 5)(x - 5)$ ______________________________

4) Write a number in the box below to make this equation an identity.

$5(x - 3) + 3 = 3x - \boxed{} + 2x$

5) Explain why the expression $y^2 + 6^2$ is not equivalent to the expression $(y + 6)^2$.

CONTINUE ➡

6) Which expression is equivalent to the expression $(x+3)^2 + 2x(x-1)$?

Ⓐ $3x^2 + 8$

Ⓑ $3x^2 + 6x + 8$

Ⓒ $3x^2 - 2x + 9$

Ⓓ $3x^2 + 4x + 9$

7) Which expression is equivalent to the expression $8n$ - 24?

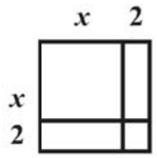
Ⓐ $4(2n - 6) + 2$

Ⓑ $(n+2)^2 + 4(n-7)$

Ⓒ $\frac{5n\ -\ 40}{2} + \frac{1}{2}(11n) - \frac{4n}{n}$

Ⓓ $\frac{16n}{2} - 4(n) + \frac{4}{n} + 1$

8) Your friend Jay says that this area diagram corresponds to expression $x^2 + 4x + 4$.



Shade the box (or boxes) that correspond to the $4x$ term.

CONTINUE

9) Brian makes x dollars working at a car wash. Brian's mom agreed to match the amount he earns at the car wash if Brian mows the lawn. Brian's dad agreed to give Brian three dollars if Brian washes dishes after dinner. Write an expression for the total amount of dollars Brian earns for working at a car wash, mowing the lawn, and washing dishes in terms of x.

10) Noelle is an animal lover who has d number of dogs and c number of cats. Noelle has 2 more cats than dogs.

Using that information, determine which of the two expressions below is larger and CIRCLE that expression. Explain your reasoning on the lines below the expressions.

$c + d$ and $2c$

CONTINUE ➡

Use the scenario below to answer questions 11 - 13.

A store sells popsicles for \$3 and chocolates for \$4.

p = numbers of popsicles sold
c = number of chocolates sold

The following equations are true:

Equation 1: $6c = p$
Equation 2: $3p + 4c = 88$

11) On the lines below, explain the meaning of Equation 2.

____

____

____

12) Which of the following sets of values satisfies Equation 1?

Ⓐ $c = 12,\ p = 2$
Ⓑ $c = 4,\ p = 19$
Ⓒ $c = 3,\ p = 18$
Ⓓ $c = 13,\ p = 12$

13) Which of the following sets of values satisfies Equation 1 and Equation 2?

Ⓐ $c = 4,\ p = 20$
Ⓑ $c = 3,\ p = 18$
Ⓒ $c = 5,\ p = 30$
Ⓓ $c = 4,\ p = 24$

CONTINUE ➡

14) Write an equation for the following statement:

There are 6 times as many rabbits as foxes in the forest.

Use r for the number of rabbits and f for the number of foxes in your equation.

15) Determine the values of x and y that simultaneously satisfy both of these equations.

$x + 4 = 3y$

$6x - 4y = 32$

$x =$ ______________ $y =$ ______________

16) The y-intercept of line $y = -3x - 5$ is _______.

17)

$$y = \frac{1}{3}x + 2 \qquad y = -\frac{3}{1}x + 2$$

The lines represented by these equations:

Ⓐ are parallel

Ⓑ are the same line

Ⓒ are perpendicular

Ⓓ intersect at an angle other than 90°

CONTINUE ➡

18)

$$y - 8 = \frac{1}{4}x \qquad 2y - \frac{1}{2}x = 3$$

The lines represented by these equations:

- Ⓐ are parallel
- Ⓑ are the same line
- Ⓒ are perpendicular
- Ⓓ intersect at an angle other than 90°

19) **a) The slope of line $5y + 3x = 15$ is ________________.**

b) Explain how you determined the slope of the line.

CONTINUE ➡

20) Write the equation for the line that passes through (-1, 5) and is perpendicular to line $x + 4y = -6$.

21) What is the vertex of the graph for the quadratic equation below?

$$y = x^2 + 6x - 7$$

- Ⓐ (0, -7)
- Ⓑ (5, 0)
- Ⓒ (-3, -16)
- Ⓓ (9, -12)

22) Ava serves a volleyball. The height of the ball can be described by $h = -t^2 + 2t + 13$, where h represents the height of the volleyball (in feet) and t represents time (in seconds).

What is the maximum height that the volleyball reaches?

- Ⓐ 10 feet
- Ⓑ 12 feet
- Ⓒ 14 feet
- Ⓓ 16 feet

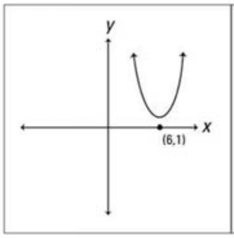
CONTINUE ➡

23) The roots of equation $y = x^2 + x \quad 6$ are (____, ____) and (____, ____).

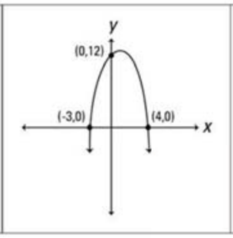
24) The vertex of equation $y = -2(x \quad 5)^2 \quad 9$ is (____, ____).

Use these 4 quadratic equations and 4 sketches of the graphs of quadratic equations to answer question 25.

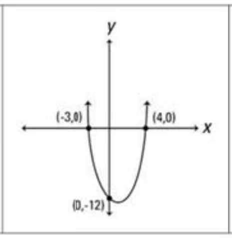
Ⓐ $y = -x^2 + x + 12$ Ⓑ $y = (x \quad 6)(x + 1)$ Ⓒ $y = (x + 3)(x \quad 4)$ Ⓓ $y = (x \quad 6)^2 + 1$



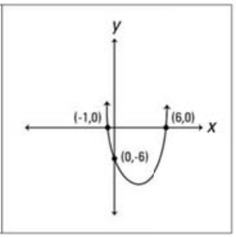
Graph 1



Graph 2



Graph 3



Graph 4

25) Equation A matches Graph _____ because:

Exhibit A6: CRESST Math Assessment Explanation Rubrics

Question 5

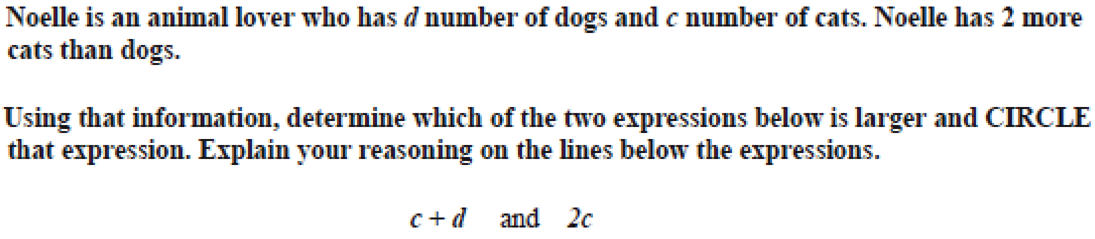
Explain why the expression $y^2 + 6^2$ is not equivalent to the expression $(y + 6)^2$.

Sample Answer: $y^2 + 6^2$ simply takes both terms and squares them, whereas $(y + 6)^2$ squares not only both terms but results in an additional term. Instead of just squaring the y and the 6, $(y + 6)^2$ is equivalent to $(y+6)(y+6)$. Therefore, while $y^2 + 6^2$ simplifies to $y^2 + 36$, $(y + 6)^2$ simplifies to $y^2 + 12y + 36$.

Score	Description	Notes
2	Correct and complete explanation	*Example:* The expressions are not equivalent because the parentheses around $y + 6$ in the expression $(y + 6)^2$ indicate that the entire expression $y + 6$ is squared, and that results in $y^2 + 12y + 6^2$ or $y^2 + 12y + 36$, not $y^2 + 6^2$.
1	Partially correct explanation/incomplete explanation or an explanation that isn't completely clear	*Notes:* It is not sufficient for students to just point out surface feature differences without explaining how those surface feature differences impact the expressions. *Example:* $(y + 6)^2$ means that the whole expression is squared. *Example:* The exponent is outside the parentheses in the expression $(y + 6)^2$, while the exponent is after each term in $y^2 + 6^2$.
0	Incorrect, too unclear, or too incomplete	*Example:* $(y + 6)^2$ has parentheses while $y^2 + 6^2$ does not have parentheses.

** If students leave a question blank or write ? or IDK, write "BL" as the score. If students used primarily numbers and/or symbols (instead of words) to correctly show their procedure, write "num". If students incorrectly show their procedure with numbers, count that as a 0.*

Question 10



Noelle is an animal lover who has d number of dogs and c number of cats. Noelle has 2 more cats than dogs.

Using that information, determine which of the two expressions below is larger and CIRCLE that expression. Explain your reasoning on the lines below the expressions.

$c + d$ and $2c$

Sample Answer:2c should be circled. If Noelle has 2 more cats than dogs, that means that $d = c - 2$. Therefore $c + d$ is equivalent to $c + c - 2$, which results in $2c - 2$, which is smaller than $2c$.

This question wasn't written with 2 distinct parts, but we will score them that way. Part a will be the score that indicates whether they circled the correct expression. Part b will be the score for their explanation.

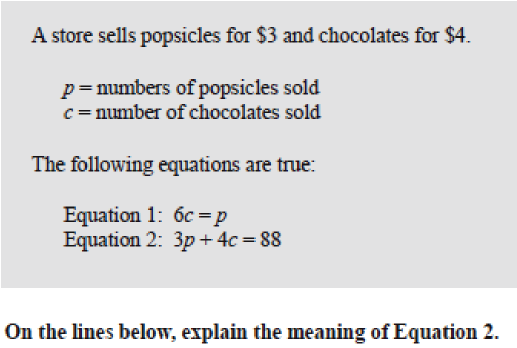
a) Only 2c should be circled. Give 1 point if it is circled. 0 for all other answers.

b)

Score	Description	Notes
2	Student correctly explains how he/she uses the information about Noelle having 2 more cats than dogs to substitute values in the expressions to correctly determine that $c + d$ is larger (this may or may not involve using equations) OR Student uses another method to clearly explain how he/she determined that $c + d$ is larger	*Note:* A student should be clear about how he/she has used the information about Noelle having 2 more cats than dogs. If the student explains a method of substitution, the student may explain how this information was used in two different ways…by substituting into c or d in the two expressions. *Example:* We know that $d = c - 2$. Therefore $c + d$ is equivalent to $c + c - 2$, which results in $2c - 2$. That is smaller than $2c$, so $2c$ is the larger expression. *Example:* We know that $c = d + 2$. Therefore $c + d$ is equivalent to $d + 2 + d$, which results in $2d + 2$. If we substitute $d + 2$ for c in $2c$, we get $2(d + 2)$ or $2d + 4$. Because $2d + 4$ is larger than $2d + 2$, 2c is larger than $c + d$. Example: c $c + d$ is the same as $c + c - 2$ or $2c – 2$, which is smaller than 2c. So $2c$ is larger than $c + d$. *Example:* If Noelle has 2 more cats than dogs, that means that c (the number of cats) is always larger than d (the number of dogs), so $2c$, which is $c + c$, will always be larger than $c + d$. (Note: it's sufficient if the student doesn't break $2c$ down into $c + c$)
1	Student gives a partially correct explanation, an explanation that isn't completely clear, or an incomplete explanation	*Example:* $c + d$ is equivalent to $c + c - 2$, which results in $2c - 2$. *Note:* If the student is on the right path with his/her explanation but makes a minor mistake, he/she can also receive a 1. *Note:* If the student explains how he/she plugs in numbers to find out which is bigger, he/she could get partial credit if they clearly explain the relationships between the expressions
0	Incorrect, too unclear to understand, or too incomplete	*Note:* If the student just reiterates information from the question (e.g., "because Noelle has 2 more cats than dogs"), that's a 0.

** If students leave a question blank or write ? or IDK, write "BL" as the score. If students used primarily numbers and/or symbols (instead of words) to correctly show their procedure, write "num". If students incorrectly show their procedure with numbers, count that as a 0.*

Question 11



A store sells popsicles for $3 and chocolates for $4.

p = numbers of popsicles sold
c = number of chocolates sold

The following equations are true:

Equation 1: $6c = p$
Equation 2: $3p + 4c = 88$

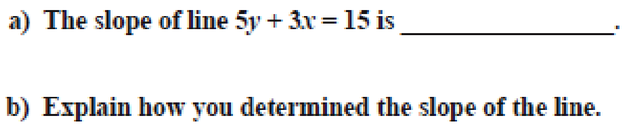
On the lines below, explain the meaning of Equation 2.

Sample Answer: Equation 2 states that the total amount of money earned in sales of *p* number of popsicles at $3 and *c* number of chocolates at $4 was $88.

Score	Description	Notes
2	Student must be clear: About the relationship between 3 and *p* and the relationship between 4 and *c* AND About operations (addition and equals signs) between terms	*Note:* Make sure students are clear on the multiplicative relationships (e.g., *p* number of popsicles at $3 or 3 times the number of popsicles, not 3 popsicles). Also, they don't have to explicitly mention the addition and equals signs, but the relationships should be clear in their explanation. *Note:* Although it is not critical that the student specifies that 88 is 88 dollars, the student's explanation needs to be clear that 88 is the total or the result of summing the other terms. *Example:* Equation 2 states that the total amount of money earned in sales of *p* number of popsicles at $3 and *c* number of chocolates at $4 is $88.
1	Partially correct explanation/incomplete explanation or an explanation that isn't completely clear	*Example:* The total amount of money earned from 3 popsicles and 4 number chocolates is $88. *Example:* 3 times *p* plus 4 times *c* equals 88 *Example:* You add the amount earned from *p* number of popsicles and *c* number of chocolates.
0	Incorrect, too unclear, or too incomplete	*Example:* 3 popsicles and 4 chocolates

** If students leave a question blank or write ? or IDK, write "BL" as the score.*

Question 19


a) The slope of line $5y + 3x = 15$ is ______________.

b) Explain how you determined the slope of the line.

Rubric for part a):

Score	Description	Notes
1	Students must answer -3/5	
0	Incorrect or too unclear to understand	*Note: (-3/5)x is incorrect.*

** If students leave a question blank or write ? or IDK, write "BL" as the score.*

Rubric for part b):

Note: Students should have answered -3/5 for part a, so they may not specifically mention -3/5 in their answer to part b. That's fine as long as it's clear what they were talking about.

Sample Answer: The equation can be expressed in slope-intercept form, $y = mx + b$, with m representing the slope. In that form, the line is $y = (-3/5)x + 3$. Therefore, -3/5 is the slope.

Score	Description	Notes
2	Student gives a correct and complete explanation	*Note:* Students don't necessarily have to use the term "slope-intercept form", if they are clear about what they mean. *Note:* Students must be clear about which coefficient they are referring to in order to get a score of 2. *Note:* Students could describe substitution as a method of finding the slope, but they need to give sufficient details to evaluate that method. *Example:* The equation is rewritten as $y = (-3/5)x + 3$. In that form, the term multiplied with the x is the slope, so -3/5 is the slope. *(Because we care more about method and explanation for part b, they can get credit if they correctly explained what they did but made a calculation error when they rewrote the equation in slope-intercept form. They would miss part a, but we wouldn't penalize them in part b as long as they give a correct explanation. Also, many students will say the term "next to" or with the "x". That is fine as long as it's clear what they are referring to.)* *Example:* I rewrote the equation in slope-intercept form, and -3/5 is the slope because it is the "m" term in the equation. *(Students would get credit even if they don't specifically mention -3/5 because it's known that "m" is the slope in slope-intercept form.)* *Example:* I rewrote the equation in terms of y. In the equation $y = (-3/5)x + 3$, -3/5 is the slope. *(If the student talks about solving or rewriting the equation in terms of y, it's important that it's evident where the -3/5 came from. In this case, it's clear because the student gave the equation that results when the equation is rewritten in terms of y.)* *Example:* I plugged in a 0 and a 1 for x and got y values of 3 and 12/5 for y. Then I used those values in this formula for slope, $m = y_2 - y_1 / x_2 - x_1$ to find the slope. *(Student provides values for two points [may include minor calculation errors for one of the two points] and formula for using points to calculate slope [or simply set up the expression correctly using the two points])*

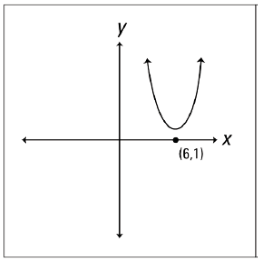
Score	Description	Notes
1	Student gives a partially correct explanation, an explanation that isn't completely clear, or an incomplete explanation	*Example:* I solved for *y* and got -3/5. *(If they say all this but say it equals (-3/5)x instead of -3/5, you can still give them a 1 because they are showing some understanding of the process (even though they are not completely correct about the slope)* *Example:* I wrote the equation in terms of *y* and found m. *(It's not clear what they are talking about because "m" only means something if we're referring to slope-intercept form.)* *Example:* I rewrote the equation in slope-intercept form and got the slope. *(It's unclear how the student got the slope from slope-intercept form.)* *Example:* I plugged in a 0 and a 1 for *x* and got *y* values of 3 and 12/5 for *y*. Then I used these values to calculate the slope. *(Student knows how to use line equation to find two points, but does not give the formula for calculating slope from these two points or show calculation of slope by using these numbers in the formula. If the student had done either, the student would have received a 2.)* *Example*: I plugged in a 0 and a 1 for *x* and got *y* values and used y_2-y_1/x_2-x_1 *(Student does not specify the y values or how to calculate them using the equation for the line; basically, the student knows that values can be calculated using the line equation and that two points with x and y values are needed to calculate slope.)* *Example*: I found two points on the line and used $m = y_2-y_1/x_2-x_1$ *(Student does not specify the y values or how to calculate using the equation for the line.)*
0	Incorrect, too unclear to understand, or too incomplete	*Example:* I solved for *y* and found the slope. *Example:* I rewrote the equation, and -3/5 is the slope. *Example:* I used slope-intercept form. *Example:* I plugged in a 0 and a 1 for *x* and calculated the slope.

** If students leave a question blank or write ? or IDK, write "BL" as the score. If students used primarily numbers and/or symbols (instead of words) to correctly show their procedure, write "num". If students incorrectly show their procedure with numbers, count that as a 0.*

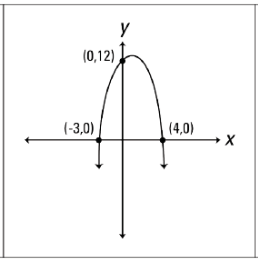
Question 25

Use these 4 quadratic equations and 4 sketches of the graphs of quadratic equations to answer question 25.

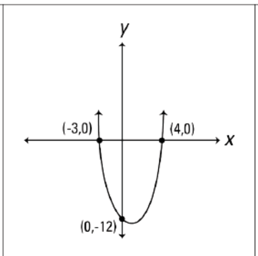
🅐 $y = \text{-}x^2 + x + 12$ 🅑 $y = (x - 6)(x + 1)$ 🅒 $y = (x + 3)(x - 4)$ 🅓 $y = (x - 6)^2 + 1$



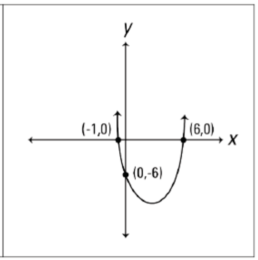
Graph 1



Graph 2



Graph 3



Graph 4

!
!
Equation!A!matches!Graph!____!because:!

Sample Answer: 2, it opens downwards because the value of the *a* term is negative

Although this question isn't split into parts, we're going to grade this as if there are two parts.

Rubric for part a):

Score	Description	Notes
1	Student correctly writes "2" for Graph 2.	
0	Incorrect or too unclear.	*Note: Many students used letters instead of numbers for the graphs because they got confused. Although they may mean Graph 2 when they write Graph B, we can't assume that.*

** If students leave a question blank or write ? or IDK, write "BL" as the score. If students do something other than write 2 (e.g., they draw an arrow to Graph 2), give them credit if their answer is clear but also make a note about it in a notes column.*

Rubric for part b):

Score	Description	Notes
2	Student gives a clear explanation. This may include: Explaining that the figure opens downwards because the *a* term is negative (or explaining that there is a negative in front of the x^2 term, meaning the figure should have a maximum/open downwards) OR Explaining that the figure crosses the *y*-axis at (0,12) because substituting 0 for *x* in the equation results in 12 for *y* (or explaining that the *c* term in the equation is the *y*-intercept)	*Note:* *To get a 2, it is important that the student explains how they know something rather than simply stating how they know something so it's clear how they determined their answer.* *Note:* *If a student makes a big mistake with important terminology (e.g., explaining that the vertex is at (0,12), he/she cannot receive full credit even if the explanation is otherwise correct.* *Note:* *Ideally, the student should relate the graph to the equation and not just refer to one or the other (but this may not always be the case).*
1	Partially correct explanation/incomplete explanation or an explanation that isn't completely clear	*Example:* The equation and figure both have a *y*-intercept at (0,12). *(Student didn't explain how he/she knows that. More explanation would be needed to know that the student didn't just choose to describe the graph.)* *Example:* I know the figure should cross the *x*-axis at (-3,0) and (4,0) because $y = -x^2 + x + 12$ is equivalent to $y = -(x-4)(x+3)$. If you then set *y* to 0, *x* equals 4 and -3. *(This is a good description, but it is not sufficient for full credit because more than one choice includes a graph that crosses at those points.)* *Example:* The graph I chose is the only one with a maximum. *(Not explicit enough about why they wanted a graph with a maximum.)* *Example:* I chose that graph because the sign in front of x^2 is negative. *(Not explicit enough about why that would lead to a graph that opens downwards/has a maximum.)*
0	Incorrect, too unclear, or too incomplete	*Example:* The equation and figure both intercept the *x*-axis at (-3,0) and (4,0). *Note:* *(If a student says he/she graphed the equation to determine which graph matched the equation but showed no evidence of graphing, give it a 0.)* *Example:* It is negative. *(Too unclear)*

** If students leave a question blank or write ? or IDK, write "BL" as the score. If students used primarily numbers and/or symbols (instead of words) to correctly show their procedure, write "num". If students incorrectly show their procedure with numbers, count that as a 0.*

Appendix B: MDC Teacher Log Descriptives

Table B1

Days Spent on Mathematics Activities

Days spent teaching	*n*	Mean	*SD*	Minimum	Maximum
Classroom Challenge	27	1.93	0.57	1.00	3.00
Prior instruction on math concepts covered by Classroom Challenge	27	4.64	4.01	0.50	15.00

Table B2

Extent to Which Teachers Followed the Detailed Lesson Plans

n	Mean	*SD*	Minimum	Maximum
27	3.10	0.23	2.80	3.75

Note. 1 = *not at all*, 2 = *somewhat*, 3 = *mostly*, and 4 = *completely*.

Table B3

Average Proportion of Time Spent on the Different Classroom Challenge Activities

Activities	*n*	Mean	*SD*	Minimum	Maximum
Pre-assessment	27	11.24	3.95	5.00	20.00
Small-group collaborative work	27	34.48	8.66	20.00	48.50
Whole-class discussion	27	18.58	4.93	10.75	31.25
Individual work	27	7.53	4.59	0.00	15.00
Student presentations	27	7.41	4.48	0.00	16.00
Teacher-led review of content/concepts	27	9.39	4.43	0.00	19.25
Post-assessment	27	11.08	3.42	5.00	20.00
Other, please specify	27	0.26	0.65	0.00	2.00

Note. The means represent the average proportion of time spent by each teacher across the study rather than per log. Proportions on each log were measured in 10% increments for a total of 100% per log.

Table B4

When Students Completed the Pre-Assessment

Variable	*n*	Mean	*SD*	Minimum	Maximum
In class at start of Classroom Challenge	27	0.37	0.38	0	1
Other	27	0.63	0.38	0	1

Note. Other responses ranged from one day to one week prior to the start of the Classroom Challenge.

Table B5

Time Spent Reviewing Students' Answers to the Pre-Assessment

Variable	*n*	Mean	*SD*	Minimum	Maximum
0 min	27	0.01	0.04	0.00	0.20
1–5 min	27	0.15	0.28	0.00	1.00
6–15 min	27	0.25	0.37	0.00	1.00
16–30 min	27	0.34	0.36	0.00	1.00
31–60 min	27	0.19	0.27	0.00	1.00
>1 hour	27	0.04	0.11	0.00	0.50

Note. Means represent percentages.

Table B6

How Reviewed Students' Answers to the Pre-Assessment

Method	*n*	Mean	*SD*	Minimum	Maximum
Alone	27	0.49	0.40	0.00	1.00
With a colleague	27	0.38	0.41	0.00	1.00
With the class	27	0.06	0.17	0.00	0.75
Other	27	0.05	0.13	0.00	0.50

Note. Means represent percentages.

Table B7

Understanding of Student Misconceptions

Attitudes	*n*	Mean	*SD*	Minimum	Maximum
Understanding comes from studying their answers on the pre-assessment.	27	2.79	0.54	1.00	3.57
Difficult to identify from the pre-assessment.	27	1.93	0.39	1.00	3.00

Note. 1 = *strongly disagree*, 2 = *disagree*, 3 = *agree*, and 4= *strongly agree*.

Table B8

Types of Feedback Given to Students on Their Pre-Assessments

Feedback type	*n*	Mean	*SD*	Minimum	Maximum
No feedback because Classroom Challenge instruction addressed misconceptions	27	0.46	0.39	0.00	1.00
Commented on papers	27	0.14	0.30	0.00	1.00
Graded papers	27	0.01	0.04	0.00	0.20
Wrote questions on papers	27	0.06	0.13	0.00	0.50
Reviewed common errors at start of class	27	0.58	0.35	0.00	1.00
No feedback provided because of time constraints	27	0.06	0.20	0.00	1.00

Note. Responses are not mutually exclusive.

Table B9

Techniques to Handle Students Who Struggled During Small-Group Work

Variable	*n*	Mean	*SD*	Minimum	Maximum
Listened but did not intervene	27	0.41	0.36	0.00	1.00
Offered hints and suggestions	27	0.45	0.39	0.00	1.00
Raised questions	27	0.93	0.17	0.33	1.00
Provided the answer	27	0.02	0.06	0.00	0.25
Asked another student to explain concept	27	0.78	0.32	0.00	1.00
Stopped class and reviewed concept	27	0.30	0.37	0.00	1.00

Note. Responses are not mutually exclusive.

Table B10

Types of Questioning Incorporated Into the Whole-Class Plenary

Variable	*n*	Mean	*SD*	Minimum	Maximum
IRE (Initiate-Respond-Evaluate): (Yes/No questions, questions that ask students to recall facts or definitions)	27	0.64	0.38	0.00	1.00
Self-Reflection: (Why do you think that? Why is that true? How did you reach that conclusion?)	27	1.00	0.00	1.00	1.00
Reflection-on-Others: (Do you agree? Does anyone have a different way to explain it? Would you ask the rest of the class that question?)	27	0.98	0.08	0.60	1.00
Pattern-Finding and Conjecturing: (How did you predict the next case? What is similar and what is different about your solution and his/hers? Do you see a pattern?)	27	0.77	0.25	0.00	1.00
Mathematical Reasoning: (Does that always work? Is that true for all cases? Can you think of a counter example?)	27	0.84	0.26	0.00	1.00

Note. 0 = *no* and 1 = *yes*.

Table B11

Percentage of Students Who Presented to the Whole Class

Student presentations to whole class	*n*	Mean	*SD*	Minimum	Maximum
Present their solutions	27	2.07	0.51	1.00	3.00
Articulate the reasoning behind their solutions	27	2.25	0.64	1.00	4.00

Note. 1 = *<5%*, 2 = *5–25%*, 3 = *25–50%*, 4 = *50–75%*, 5 = *75–99%*, 6 = *100%*.

Table B12

When Students Completed the Post-Assessment

Variable	*n*	Mean	*SD*	Minimum	Maximum
In class at the end of the Classroom Challenge	27	0.82	0.32	0.00	1.00
Homework	27	0.01	0.08	0.00	0.40
Other, please specify	27	0.17	0.31	0.00	1.00

Note. Means represent percentages.

Table B13

Perceptions About Percentage of Students Who Struggled to Understand the Underlying Mathematical Concepts

n	Mean	*SD*	Minimum	Maximum
27	3.02	0.75	2.00	5.00

Note. 1 = *<5%*, 2 = *5–25%*, 3 = *25–50%*, 4 = *50–75%*, 5 = *75–99%*, 6 = *100%*.

Table B14

Perceptions About Percentage of Students Who Gained a Strong Grasp of the Material by the End of Challenge

n	Mean	*SD*	Minimum	Maximum
27	3.85	0.70	2.33	5.00

Note. 1 = *<5%*, 2 = *5–25%*, 3 = *25–50%*, 4 = *50–75%*, 5 = *75–99%*, 6 = *100%*.

Appendix C: MDC Teacher Survey Descriptives

Table C1

Q3: Content Areas Participants Teach

Content areas	*n*	MDC teachers (%)
Pre-algebra	3	8.3
Algebra 1	35	97.2
Geometry	14	38.9
Algebra 2	10	27.8
Pre-calculus	1	2.8
Calculus	0	0.0
Probability and statistics	2	5.6
Other	6	16.7

Note. n = 36.

Table C2

Q4: Years of Teaching Experience

Type of experience	*n*	Mean	*SD*	Minimum	Maximum
Years of teaching	36	8.72	5.49	2.00	21.00
Years taught in current school	36	5.86	3.33	2.00	13.00
Years taught in current district	36	6.96	4.09	2.00	16.00

Table C3

Q5–8: Teaching of Different Student Populations

	Yes		No	
Student population	*n*	%	*n*	%
ELL students	23	63.9	13	36.1
Special education students	33	91.7	3	8.3
Students struggling in math	36	100.0	0	0.0
Students with advanced mathematics levels	24	66.7	12	33.3

Note. n = 36.

Table C4

Q9: Type of Participation in the MDC Initiative

Type of participation	*n*	MDC teachers (%)
Required	23	63.9
Voluntary	12	33.3
Other	1	2.8

Note. *n* = 36.

Table C5

Q11–12: MDC Lessons Taught by School Year

School year	*n*	Mean	*SD*	Minimum	Maximum
2011–2012	31	4.74	1.82	2.00	8.00
2012–2013	35	5.97	2.80	2.00	12.00

Table C6

Q44: MDC Lesson Alignment

Question	*n*	Mean	*SD*
a. The MDC Lessons align well with my school's curriculum.	35	2.37	0.69
b. The MDC Lessons help prepare my students for the current state assessment(s).	35	2.09	0.82
c. The MDC Lessons align with the CCSS.	35	2.57	0.61
d. I see the unique value of the MDC Lessons to address the CCSS.	35	2.31	0.53

Note. 0 = *disagree*, 1 = *disagree somewhat*, 2 = *agree somewhat*, and 3 = *agree*.

Table C7

Q28: Fidelity to the MDC Lessons Teacher Guide

Extent followed	*n*	MDC teachers (%)
Completely	5	14.3
Mostly	28	80.0
Somewhat	2	5.7

Note. *n* = 35.

Table C8

Q29: Class Periods Spent Implementing a Typical MDC Lesson (2012–2013)

Question	*n*	Mean	*SD*	Minimum	Maximum
Class periods	35	3.31	3.64	1.00	18.00

Table C9

Q33: Practice Used When Assigning Students to Collaborative Groups

Practice	*n*	MDC teachers (%)
Students choose their own partners/groups	8	22.9
Assign students to homogeneous math ability groups	20	57.1
Assign students to heterogeneous math ability groups	7	20.0

Note. *n* = 35.

Table C10

Q35–36: Use of Post-assessments During Most Recent MDC Lessons Taught

Post assessments	*n*	MDC teachers (%)
When students completed the post-assessment (*n* = 35)		
In class, at the end of the plenary/class discussion	31	88.6
As homework	0	0.0
Did not use the post-assessment	4	11.4
Reasons didn’t use post-assessment (*n* = 4)		
Ran out of time	2	50.0
Seemed redundant	0	0.0
Students understood the material	0	0.0
Too hard	0	0.0
Reason – Other	2	50.0

Note. Only teachers who indicated that they did not use the post-assessment were asked to state a reason.

Table C11

Q17: Teacher Perceptions About the Effectiveness of Strategies for Strengthening Mathematical Understanding

Question	*n*	Mean	*SD*
a. Teacher taking on the role of “facilitator” or “coach”	35	2.83	0.38
b. Peer-to-peer problem solving	35	2.77	0.43
c. Asking students guiding questions	35	2.91	0.37
d. Providing class time for students to persevere through difficult math problems	35	2.66	0.68

Note. 0 = *disagree*, 1 = *disagree somewhat*, 2 = *agree somewhat*, and 3 = *agree*.

Table C12

Q19: Teacher Perceptions of Whether MDC Lessons Helped Them

	Yes		No	
Question	*n*	%	*n*	%
a. Find effective strategies for teaching my subject content	32	88.9	4	11.1
b. Learn new ways to include FA in my classes	32	88.9	4	11.1
c. Learn detailed info about students’ math strengths and weaknesses	29	80.6	7	19.4
d. Provide students with more detailed feedback about their work	25	69.4	11	30.6
e. Implement the CCSS	28	77.8	8	22.2
f. Create an environment that promotes math discourse	31	86.1	5	13.9
g. Better engage students	27	75.0	9	25.0

Note. n = 36.

Table C13

Q18: Teacher Perceptions of the Effectiveness of MDC Lessons

Question	*n*	Mean	*SD*
a. Improve students’ ability to think mathematically	35	2.63	0.55
b. Provide a curricular resource for teachers in addressing CCSS	35	2.43	0.56
c. Encourage teachers to adjust pedagogy in math from focus on process to building conceptual knowledge	35	2.69	0.47
d. Make instruction more engaging for students	35	2.57	0.56
e. Use FA to identify student strengths and weaknesses and to inform instruction	35	2.60	0.60

Note. 0 = *disagree*, 1 = *disagree somewhat*, 2 = *agree somewhat*, and 3 = *agree*.

Table C14

Q39: Potential Barriers to Use of MDC Lessons

Barriers	*n*	Mean	*SD*
a. Had sufficient time to plan for lessons	35	2.31	0.68
b. Felt adequately prepared to effectively use the lessons	35	2.34	0.72
c. Had sufficient time to prepare for the pre-assessment	35	2.46	0.70
d. Using MDC takes too much time away from covering required curriculum topics	35	1.49	0.85
e. Prep required for the MDC collaborative activity is an impediment to using the lesson	35	1.71	0.86
f. During the collaborative portion of MDC, it is difficult to interact with every group	35	1.49	0.92

Note. 0 = *disagree*, 1 = *disagree somewhat*, 2 = *agree somewhat*, and 3 = *agree*.

Table C15

Q16: Individuals Who Visited Teachers' Classrooms During MDC Lessons

	Yes		No	
Individuals	*n*	%	*n*	%
a. District or network MDC project lead	25	71.4	10	28.6
b. Principal	14	40.0	21	60.0
c. Instructional coach/department head	27	77.1	8	22.9
d. Teacher colleague	33	94.3	2	5.7

Note. n = 35.

Table C16

Q43: Administration and MDC Lessons

Question	*n*	Mean	*SD*
School administrators			
a. Have a firm understanding of the MDC Lessons	31	1.61	0.99
b. Have made FA a priority at my school	34	2.18	0.83
c. Encouraged me to participate in MDC	34	2.44	0.82
d. Provided me with feedback about my instruction of MDC Lessons	34	1.32	1.22
e. Concerned that the MDC Lessons are taking time away from other instructional priorities	33	0.52	0.91
f. Attended PD about the MDC Lessons	23	1.13	0.97
g. Communicated how the MDC lessons are aligned with other school initiatives	26	1.58	1.14
District administrators			
h. Support the MDC initiative	32	2.68	0.54

Note. 0 = *disagree*, 1 = *disagree somewhat*, 2 = *agree somewhat*, and 3 = *agree*.

Table C17

Q45: Teacher Collaboration During MDC Implementation

	Yes		No	
Teacher collaboration	*n*	%	*n*	%
Regularly scheduled common planning time with colleagues to discuss MDC	21	60.0	14	40.0

Note. n = 35.

Table C18

Q47–48: MDC Meetings to Discuss Student Work, Instructional Strategies, or Teaching Approaches

	Scheduled		Informal	
Frequency	*n*	%	*n*	%
At least once a week	2	9.5	15	42.9
Every other week	4	19.0	12	34.3
Once a month	8	38.1	3	8.6
Once per quarter/trimester/semester	7	33.3	5	14.3

Note. Scheduled meetings (*n* = 21), informal meetings (*n* = 35).

Table C19

Q46 & Q49: Perceptions of Teacher Collaboration During MDC Implementation

Question	*n*	Mean	*SD*
Teacher collaboration			
Describes MDC colleagues as collaborative	35	2.66	0.59
Benefits of collaboration with MDC colleagues			
a. More effectively use the MDC FA strategies	35	2.71	0.46
b. Better support student learning	35	2.57	0.66
c. Develop the MDC lessons in my class	35	2.54	0.70
d. Review pre-assessments	35	2.54	0.70
e. Facilitate collaborative group work	35	2.57	0.66
f. Facilitate the plenary or whole-class discussion	35	2.46	0.66
g. Identify common math misconceptions	35	2.63	0.65
h. Determine where to use an MDC lesson in a unit	35	2.80	0.41
i. Develop feedback questions	35	2.69	0.63
j. Determine how to group students	35	1.91	1.04
k. Review post-assessments	35	2.51	0.78

Note. 0 = *disagree*, 1 = *disagree somewhat*, 2 = *agree somewhat*, and 3 = *agree*.

Table C20

Q53: Teacher Participation in MDC Professional Development

	Yes		No	
Question	*n*	%	*n*	%
Participated during the 2012–2013 school year	27	75.0	9	25.0

Note. n = 36.

Table C21

Q55: Level of Participation in Formal MDC Professional Development Sessions

Question	*n*	Mean	*SD*	Minimum	Maximum
Sessions attended during the 2012–2013 school year	27	2.93	1.52	1.00	8.00

Table C22

Q58: Content Included in MDC Professional Development Sessions in Which Teachers Participated

Question	Yes		No	
	n	%	*n*	%
a. Using MDC Lessons as a way to implement the CCSS	18	66.7	9	33.3
b. Administering the pre-assessment	21	77.8	6	22.2
c. Identifying common misconceptions through the pre-assessment results	26	96.3	1	3.7
d. Developing feedback questions	27	100.0	0	0.0
e. Facilitating small group work with guiding questions	25	92.6	2	7.4
f. Facilitating whole group plenary discussions	22	81.5	5	18.5
g. Placing lessons at the appropriate point in the unit	19	70.4	8	29.6
h. Determining how to use the post-assessment results to guide continued instruction in the unit	19	70.4	8	29.6
i. Differentiating MDC lesson instruction to meet student needs	14	51.9	13	48.1
j. Implementing MDC lessons with ELL students	4	14.8	23	85.2
k. Implementing MDC lessons with special education students	9	33.3	18	66.7
l. Implementing MDC lessons with students who are struggling with math	15	55.6	12	44.4
m. Implementing MDC lessons with students with advanced math levels	12	44.4	15	55.6

Note. n = 27.

Table C23

Q56–57: Types and Perceived Effectiveness of Professional Development in Which Teachers Participated

Type	Yes, participated		If participated, perceived effectiveness			
			Yes		No	
	n	%	*n*	%	*n*	%
a. One-on-one classroom visits	20	74.1	18	90.0	2	10.0
b. Coaching	22	81.5	22	100.0	0	0.0
c. Webinars	2	7.4	1	50.0	1	50.0
d. Small group meetings	25	92.6	25	100.0	0	0.0
e. Schoolwide meetings	23	85.2	20	87.0	3	13.0
f. Districtwide meetings	23	85.2	17	73.9	6	26.1
g. Cross-district meetings	11	40.7	9	81.8	2	18.2

Note. Only teachers who indicated that they participated in a specific type of PD were asked about the effectiveness. *n* = 27.

Table C24

Q25: Student Engagement During MDC Lessons

	MDC teachers	
Effect on engagement	*n*	%
More engaged	14	38.9
Same level of engagement	18	50.0
Less engaged	3	8.3

Note. n = 54.

Table C25

Q26: Teacher Perceptions on Impact on Students in General

Impact on students	*n*	Mean	*SD*
a. Improved my students' mathematical reasoning	35	2.17	0.71
b. Supporting my students' college-readiness	35	2.17	0.71

Note. 0 = *disagree*, 1 = *disagree somewhat*, 2 = *agree somewhat*, and 3 = *agree*.

Table C26

Q27: Teacher Perceptions on Impact on Students During Last MDC Lesson

	Yes		No	
Impact on students	*n*	%	*n*	%
a. Majority of students improved their content knowledge	29	82.9	6	17.1
b. Majority of students improved their conceptual understanding	29	82.9	6	17.1

Note. n = 35.

Appendix D: Analysis of MDC Student Work Artifacts

Table D1

Goals and Standards for FALs Included in MDC Analysis

FAL	Goals	Standards	Practices	Items
FAL03	• Solving a problem using two linear equations with two variables. • Interpreting the meaning of algebraic expressions.	Algebra: • CED: Create equations that describe numbers or relationships. • REI: Solve systems of equations.	2. Reason abstractly and quantitatively. 3. Construct viable arguments and critique the reasoning of others.	Accuracy: 3 Explanation: 4 Misconceptions: 4
FAL13	• Recognize the differences between equations and identities. • Substitute numbers into algebraic statements in order to test their validity in special cases. • Resist common errors when manipulating expressions such as $2(x – 3) = 2x – 3$; $(x + 3)^2 = x^2 + 3^2$. • Carry out correct algebraic manipulations.	Algebra: • SSE: Interpret the structure of expressions. Write expressions in equivalent forms to solve problems. • REI: Solve equations and inequalities in one variable.	3. Construct viable arguments and critique the reasoning of others. 7. Look for and make use of structure.	Accuracy: 10 Explanation: 1 Misconceptions: 6
FAL16	• Recognizing the order of algebraic operations. • Recognizing equivalent expressions. • Understanding the distributive laws of multiplication and division over addition (expansion of parentheses).	Algebra: • SSE: Interpret the structure of expressions. • APR: Rewrite rational expressions.	2. Reason abstractly and quantitatively. 7. Look for and make use of structure.	Accuracy: 9 Explanation: 3 Misconceptions: 1
FAL22	• Find, from their equations, lines that are parallel and perpendicular. • Identify and use intercepts. • It also aims to encourage discussion on some common misconceptions about equations of lines.	Geometry: • PE: Use coordinates to prove simple geometric theorems algebraically. Functions: • IF: Analyze functions using different representations.	1. Make sense of problems and persevere in solving them. 3. Construct viable arguments and critique the reasoning of others. 7. Look for and make use of structure.	Accuracy: 2 Explanation: 1 Misconceptions: 3

Appendix E: Quasi-Experimental Analysis of MDC Effects

Table E1

MDC Effects on ACT PLAN Total Scores, Including Interaction Effects (Models 1 and 2)

ACT PLAN mathematics (total)	Model 1 coefficient (*SE*)	Model 2 coefficient (*SE*)
MDC treatment	0.092 (0.031)*	0.110 (0.022)*
School effectiveness	0.284 (0.092)*	0.300 (0.093)*
Teacher effectiveness	0.199 (0.101)	0.154 (0.094)
MDC treatment by teacher effectiveness interaction	0.251 (0.173)	0.285 (0.158)
Treatment by demographic characteristic interactions		
Gender	0.002 (0.026)	0.00 (0.029)
Special education	0.042 (0.034)	0.055 (0.037)
Free/reduced price lunch eligible	0.013 (0.028)	0.012 (0.027)
Prior achievement	0.040 (0.021)	0.023 (0.017)

Note. Fixed effects for demographic predictors not shown.
$*p \leq .05$. $**p \leq .01$.

Table E2

Models 1 and 2 With Demo Interactions: Final Estimation of Fixed Effects on Math PLAN Algebra Score With Robust Standard Errors

Fixed effect	Model 1 coefficient (*SE*)	Model 2 coefficient (*SE*)
Level 1 variables		
Female	0.022 (0.015)	0.022 (0.018)
White	-0.058 (0.050)	-0.058 (0.053)
Hispanic	-0.087 (0.064)	-0.126 (0.066)
Black	0.021 (0.057)	0.013 (0.061)
Asian	0.000 (0.075)	-0.019 (0.087)
English language learner	-0.114 (0.069)	-0.073 (0.074)
Special education	0.019 (0.026)	0.032 (0.026)
Free/reduced price lunch eligible	-0.003 (0.015)	-0.002 (0.015)
Prior achievement	0.434 (0.008)**	0.435 (0.008)**
Level 2 variables		
MDC treatment	0.128 (0.035)**	0.130 (0.026)**
School effectiveness	0.273 (0.110)*	0.309 (0.103)**
Teacher effectiveness	0.113 (0.094)	0.060 (0.087)
Missing teacher effectiveness	0.018 (0.022)	0.014 (0.020)
MDC treatment by teacher effectiveness interaction	0.342 (0.197)	0.420 (0.178)*
Treatment by demographic characteristic interactions		
Female	-0.010 (0.030)	0.005 (0.036)
Special education	0.040 (0.040)	0.070 (0.045)
Free/reduced price lunch eligible	0.019 (0.029)	0.027 (0.029)
Prior achievement	0.041 (0.017)*	0.030 (0.016)

*$p \leq .05$. **$p \leq .01$.