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BENCHMARKS FOR DEEPER LEARNING ON NEXT GENERATION TESTS: A STUDY OF PISA

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JULY 2016

CRESST REPORT **855**

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A Study of PISA**

CRESST Report 855

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July 2016

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The work reported herein was supported by grant number 2012-8075 from The William and Flora Hewlett Foundation with funding to the National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

The findings and opinions expressed in this report are those of the authors and do not necessarily reflect the positions or policies of The William and Flora Hewlett Foundation.

To cite from this report, please use the following as your APA reference: Herman, J. L., La Torre, D., Epstein, S., & Wang, J. (2016). *Benchmarks for deeper learning on next generation tests: A study of PISA* (CRESST Report 855). Los Angeles: University of California, Los Angeles, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

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Acknowledgments

We wish to acknowledge the many individuals who contributed to this study and made it possible.

First, we are grateful to those individuals who were instrumental in helping us gain access to the Programme for International Student Assessment (PISA) Reading Literacy and Mathematics Literacy tests. We thank Andreas Schleicher, Director for the Directorate of Education and Skills at the Organisation for Economic Co-operation and Development (OECD), for his support, and Michael Davidson, then Senior Analyst at OECD, for facilitating our request to the PISA Governing Board. We also thank our colleagues at the National Center for Education Statistics (NCES) for endorsing our study and their Governing Board for granting our request.

Colleagues at NCES could not have been more helpful or efficient in arranging our access to the PISA items and associated materials and in coordinating logistics for our panel meetings. We would especially like to thank Dana Kelly, Branch Chief, and Patrick Gonzales, a research analyst at NCES, as well as Anindita Sen, Senior Researcher, and Teresa Kroeger, then a Research Assistant at the American Institutes for Research (AIR) for their help with these arrangements.

The study panels included an exceptional group of expert educators and researchers who brought their deep knowledge of reading and mathematics to the deliberations. We thank them for their patience in complying with study procedures, for the care that they took in conducting the panel tasks, and for their insights and wisdom in helping us to complete our study.

Finally, we thank Barbara Chow, Education Director, and Denis Udall, Program Officer at the William and Flora Hewlett Foundation, for their support of this project and their unwavering commitment to deeper learning for all children.

BENCHMARKS FOR DEEPER LEARNING ON NEXT GENERATION TESTS: A STUDY OF PISA

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Abstract

This report presents the results of expert panels' item-by-item analysis of the 2015 PISA Reading Literacy and Mathematics Literacy assessments and compares study findings on PISA's representation of deeper learning with that of other related studies. Results indicate that about 11% to 14% of PISA's total raw score value for reading and mathematics literacy respectively are devoted to deeper learning, defined as items addressing depth of knowledge (DOK) Levels 3 or 4, based on Norman Webb's framework (Webb, Alt, Ely, & Vesperman, 2005). These levels are compared to those in the Common Core State Standards (CCSS) and in recent tests of the CCSS. Study results suggest the complexity of establishing deeper learning benchmarks.

Introduction

College and career ready standards have been adopted by states across the country. Common Core State Standards (CCSS) or not, these standards reflect a general consensus that to be prepared for success in college and work, students need to master core academic content and to be able to use their knowledge and skills to think critically, communicate effectively, and solve complex, real-life problems (National Research Council, 2012; William and Flora Hewlett Foundation, n.d.). In both English language arts (ELA) and mathematics, students need to be engaged by the content and they need to attain deeper learning.

These college and career ready expectations carry with them the need for not only new pedagogies to support student success, but also new assessments of student learning that can provide valid measures of, and motivation for, student success in the standards. Ample research, for example, demonstrates the powerful signal that accountability tests send to schools about what the standards mean as well as what, and how, students should be taught (Hamilton, Stecher & Yuan, 2008; Herman, 2010). In response to pressure to improve test scores, schools tend to align their curriculum to focus on what is tested: What is tested is what is taught, and added attention is paid to where test scores show weaknesses. Further, teachers not only tend to teach what is tested, but how it is tested: Test formats and demands serve as the model for instruction. As a result, new assessments of college and career ready standards will play an important role in how these standards are implemented. To play a productive role, the tests must reflect both the content and deeper learning goals of the standards.

However, what does it mean for tests to reflect deeper learning? Historically, state accountability tests have focused predominantly on low-level learning and have given scant, if any, attention to students' ability to apply, synthesize, communicate, and use their knowledge to solve complex problems (Webb, 2002a; Yuan & Le, 2012). Clearly, if new exams of college and career readiness are to send a strong signal about the importance of deeper learning and encourage its teaching, they must give more attention to higher levels of thinking and problem solving. There currently is no established benchmark to evaluate the cognitive rigor of new tests and to hold them accountable for the assessment of deeper learning. Assessment experts have offered opinions on what such benchmarks should be, ranging from one third to half of the test. For example, based on existing state and other expert analyses of DOK in the CCSS and that estimated in nationally prominent assessments, Herman and Linn (2013) recommended that for ELA, 50% of the total score value should reflect deeper learning, while in mathematics, 30% of total score value should be at this level.

Funded by the William and Flora Hewlett Foundation, the following study provides one source of evidence to help establish a benchmark. The study examines the depth of knowledge evident in the Programme for International Student Assessment (PISA), the highly regarded international assessment of reading and mathematics literacy used for cross-country comparisons. PISA serves as a focal point because of its high visibility internationally and its reputed attention to students' problem solving and ability to apply their knowledge in everyday situations.

The study examines two PISA assessments fielded in 2015, Reading Literacy and Mathematics Literacy, and addresses the following questions:

1. To what extent does PISA assess deeper learning in reading literacy and mathematics literacy?
2. How does PISA's attention to deeper learning compare with that reflected in the CCSS and projected for the new CCSS-aligned year-end tests developed by ACT Aspire, the Partnership for Assessment of Readiness for College and Careers (PARCC), and the Smarter Balanced Assessment Consortium (Smarter Balanced)?
3. What are study implications for establishing benchmarks for deeper learning?

We start by providing background information on PISA and our study methodology. We then present separate results for the Reading Literacy and Mathematics Literacy assessments. We also compare these results with those from other related studies. Finally, we present our conclusions and suggest implications for establishing benchmarks for deeper learning.

Background on PISA

PISA is conducted every three years to evaluate and compare educational systems across the world in the core topics of reading, mathematics, and science in addition to optional, additional select topics that vary across administration years. Rather than a direct test of school curriculum at a particular grade, PISA targets 15-year-old students' ability to apply their knowledge to real-life issues and to participate in society (OECD, 2013a). This age is the focus for PISA since it is when compulsory school attendance ends in many countries.

PISA is administered to students in randomly sampled schools in each country, carefully selected to represent demographically each country's full population of 15-year-olds (OECD, 2013a). An internationally developed content framework guides the development of each assessment. The frameworks organize each content domain to be assessed relative to key dimensions that define the content and how it will be assessed, while assuring broad coverage of the subject. The framework also specifies both the total number of items that will comprise each assessment and how the items are to be distributed across dimensions. The framework, as the following elucidates, has been uniquely developed to serve PISA and does not, nor is it intended to, reflect college and career ready standards.

PISA defines reading literacy as “understanding, using, reflecting on and engaging with written texts, in order to achieve one's goals, to develop one's knowledge and potential, and to participate in society” (OECD, 2013c, p. 9). Three major dimensions are used to organize the reading literacy domain:

- **Situation:** The range of broad contexts or purposes for which reading takes place, which includes (1) personal, (2) public, (3) occupational, and (4) educational contexts.
- **Text:** The range of material that is read, which includes (1) text display space (whether fixed or dynamic text—all in the current assessment is fixed, static text); (2) text format (whether continuous or non-continuous text and whether it involves multiple texts or a single text that includes multiple kinds of objects); and (3) text type (whether text involves description, narration, exposition, argumentation, instruction, or transaction).
- **Aspect:** Cognitive engagement with a text, which includes (1) access and retrieve (specific information from the text), (2) integrate and interpret (form an understanding from relationships within the text or texts), and (3) reflect and evaluate (require readers to relate knowledge outside the text to what they are reading).

PISA defines students' mathematical literacy as “an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognize the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective

citizens” (OECD, 2013b, p. 5). The framework uses three dimensions to define the domain for assessment:

- **Mathematical process and capabilities:** These enable students to “connect the context of the problem with mathematics and thus solve the problem” (OECD, 2013b, p. 9), which includes (1) formulating situations mathematically; (2) employing mathematical concepts, facts, procedures, and reasoning; (3) interpreting, applying, and evaluating mathematical outcomes; and (4) fundamental underlying capabilities including communication, mathematizing, representation, reasoning and argument, using symbolic, formal, and technical language and operations, and using mathematical tools.
- **Mathematical content knowledge:** This is categorized as (1) change and relationships, (2) space and shape, (3) quantity, and (4) uncertainty and data.
- **Problem contexts:** These contexts include (1) personal, (2) occupational, (3) societal, and (4) scientific.

The 2015 PISA Reading Literacy and Mathematics Literacy assessments are composed of 92 and 70 items respectively. Both tests are computer administered and use multiple choice and open response item types. Matrix sampling is used in administering the tests, such that the full set of items is systematically distributed across a number of test forms, with each student taking only one, two-hour form. Responses are aggregated across students to provide country-level estimates of performance. More than 500,000 students in 65 economies¹ participated in the 2012 PISA assessment and more than 70 economies were scheduled to take the 2015 assessment (For more information, see <http://www.oecd.org/pisa/aboutpisa/>).²

Study Methodology

The study used Norman Webb’s DOK framework (Webb, Alt, Ely, & Vesperman, 2005) to examine the representation of deeper learning in PISA. Past and present state tests have used this metric, so study results can be used to examine if and how they compare to one another and with PISA.

Expert panels of high school teachers, curriculum specialists, and other subject matter and learning experts were convened to conduct an item-level review of each PISA assessment, as the following describes.

¹ PISA uses the term “economy” to denote the locales that participate in the assessment. In general, these are countries, but there are smaller locales that also participate. For example, China, Hong Kong, Macao, and Shanghai participate as separate economies.

² In the United States, data collection took place during October and November of 2015.

DOK Framework and Deeper Learning

Webb's framework (Webb et al., 2005) defines four levels to characterize the DOK and thinking that students are required to apply to respond correctly to an item and/or to attain full credit for the response:

- DOK1: Recall of a fact, term, concept, or procedure: basic comprehension
- DOK2: Application of concepts and/or procedures involving some mental processing
- DOK3: Applications requiring abstract thinking, reasoning, and/or more complex inferences
- DOK4: Extended analysis or investigation that requires synthesis and analysis across multiple contexts and nonroutine problems and applications

We have argued elsewhere that DOK3 and DOK4 represent important aspects of deeper learning, because to answer items or tasks at these levels students have to apply and synthesize their knowledge and engage in critical thinking and reasoning (Herman & Linn, 2013). Further, both levels have been grossly underrepresented in most prior state tests. For example, RAND's analysis of the DOK assessed in released items from the 17 states reputed to have the most challenging state assessments, showed that virtually all of the multiple choice and open response items in mathematics were categorized as DOK1 or DOK2, with similar results for the multiple choice items of reading and writing (Yuan & Le, 2012). The situation was better for states with open response items: more than half the open response reading tasks were at or above DOK3. The eight states that directly assessed writing had open response writing prompts that were nearly uniformly classified at DOK3 or DOK4.

Review Panel Recruitment

Expert panelists were recommended and recruited through trusted colleagues and respected organizations known for their expertise in the CCSS in ELA or mathematics (e.g., Student Achievement Partners, Curtis Mathematics Center, UCLA's Center X, and America Achieves). We solicited nominations of individuals who had prior experience teaching high school ELA and/or mathematics, were highly knowledgeable about the CCSS in one or both content areas, had prior experience in test development and/or alignment studies, and/or had work experience with special populations. Furthermore, all applicants were asked to complete a questionnaire regarding their background and experiences in each of these areas, as well as indicating any additional teaching experience and their current work positions (see Appendix A).

The final panelists were selected to assure that all members had strong qualifications and each panel included members who had experiences across educational settings (e.g., high school educators, district specialists, university researchers and professors) and were geographically

distributed. The names and affiliations of all panelists can be found in Figure 1, while individual biographies can be found in Appendix B.

Reading literacy	Mathematics literacy
<ul style="list-style-type: none"> • Katherine Allebach Franz, M.A.Ed., Minneapolis Public Schools • Katrina Boone, M.A.T., Shelby County High School • Mark Conley, Ph.D., University of Memphis • Linda Friedrich, Ph.D., National Writing Project • P. David Pearson, Ph.D., University of California, Berkeley • Martha Thurlow, Ph.D., NCEO/University of Minnesota • Sheila Valencia, Ph.D., University of Washington • Karen Wixson, Ph.D., University of North Carolina at Greensboro 	<ul style="list-style-type: none"> • Christopher Affie, M.A., The Gilbert School • Patrick Callahan, Ph.D., California Mathematics Project • Phil Daro, B.A., University of California, Berkeley • Wally Etterbeek, Ph.D., California State University, Sacramento • David Foster, B.A., Silicon Valley Mathematics Initiative • Curtis Lewis, Ph.D., Henry Ford Academy: School for Creative Studies (Middle and High School) • Barbara Schallau, M.A., East Side Union High School District • Guillermo Solano-Flores, Ph.D., University of Colorado Boulder

Figure 1. Reading and mathematics literacy panelists.

Review Panel Training

Synchronous and asynchronous trainings were conducted for the reading and mathematics panels during the month prior to the rating sessions. Panelists were provided with orientation materials concerning the logistics for the study, publicly released drafts of the PISA frameworks and associated documentation, and depth of knowledge frameworks.

Webinars. Webinar trainings were conducted with each panel to ensure that all participants had an understanding of the study purpose and procedures, the PISA test structure, and the content-specific applications of DOK for mathematics and reading (see Webb, 2002b). As part of the process of familiarizing panelists with the content-specific frameworks (see Appendix C), the webinars provided an initial opportunity for panelists to apply and discuss their ratings of items from the Web Alignment Tool (WAT) Training Tutorial developed by the Wisconsin Center of Education Research (see <http://wat.wceruw.org/tutorial/index.aspx>).

Practice ratings. To begin establishing interrater reliability and to identify the need for additional training, during the period between the webinars and the on-site rating sessions, all panelists were asked to rate released items from prior PISA administrations. These ratings were completed online using Qualtrics web forms similar to those used for the formal rating sessions (see Appendix C). The reading web form included 21 items spanning four units, while the

mathematics web form included 13 items spanning six units.³ Each web form included categories for panelists to rate item DOK, the primary CCSS domain, construct-irrelevant obstacles, and any notes they might have concerning these obstacles. The reading web form also included a category to rate text complexity at the item level and the mathematics web form also included a category to indicate evidence of a primary mathematical practice.⁴

Data Collection and Panel Process

Rating sessions for the reading and mathematics panels were conducted separately for two days each at an American Institutes for Research (AIR) facility in Washington, DC, where the PISA measures are securely held. Two members of the CRESST research team who have expertise in Webb’s DOK framework facilitated the rating sessions. In order to ensure confidentiality, staff from AIR also supervised these sessions and panelists were required to provide notarized affidavits of nondisclosure prior to being given electronic access to the test items as well as notebooks containing further documentation. Each notebook included supplemental materials (i.e., a statement of confidentiality concerning secure items, instructions for assessing the electronic items, item classifications by framework characteristics, and item allocations by cluster), hard copies of the assessment items, and coding guides and answer keys for all human-scored items (see Appendix C for the Table of Contents).

Session structure and procedures. Each on-site panel meeting began with introductions, a review of the study purpose, and an overview of the session agenda (see Appendix C). Once this was completed, results from the practice ratings were discussed and further training was conducted on the content-specific DOK framework for the session. Because of the results of the practice ratings, particular attention was paid during this follow-up training to helping panelists differentiate reliably between DOK2 and DOK3 as well as between DOK3 and DOK4.

Once re-training was complete, panelists were oriented to the test software and the materials in their notebooks, and were given a review of the Qualtrics web form and procedures for coding. As with the practice ratings, all panelists were asked to rate the following at the item level: DOK, CCSS domain, construct-irrelevant obstacles, and in the case of mathematics, the primary CCSS practice. Reading panelists also coded the text complexity of each reading stimuli

³ The computer-based PISA test forms are each constructed to include four clusters of items spanning the major subject area for that testing cycle (e.g., science in 2015) as well as one or more of the other content areas. Items within each cluster are then organized into units that each contain a common theme and text or stimulus, depending upon the content area. For the 2015 test cycle in the United States, the reading sub-measure included 92 items spanning 23 units and 6 clusters and the mathematics sub-measure included 70 items spanning 40 units and 6 clusters.

⁴ After practice coding, it was decided to rate the text complexity of each stimuli for reading literacy. The ordering of the categories in the web form was also updated to improve functionality.

(see Appendix C for details of all variables coded by panelists). The subsequent panel time was organized into six rating sessions, each corresponding to the rating of one cluster of items. For each of these sessions, panelists first individually rated all items within an assigned cluster. Following individual ratings, panelists' ratings of each item were shared and their rationales for the ratings discussed, facilitated by one or both members of the research team. Subsequent to the discussion of each item, panelists had the opportunity to revise their ratings if their perspective had changed based on the discussion.

The whole panel rated and discussed Cluster 01 in the first rating session. For the remaining sessions, participants were organized into two sub-panels of four each to balance the sequence of review of the various clusters and to facilitate more extensive discussion (see Table 1). These subsequent sessions were structured so that Group A reviewed items in order from Cluster 02, while Group B worked in the opposite order beginning with Cluster 06. The sub-panels were composed to ensure a balance of individuals with classroom content teaching experience, expert knowledge in the CCSS, and experience with test development or alignment. A second round of consensus making was then conducted with the whole group for Clusters 02 through 06 on the second afternoon (see Appendix C for the session agendas).

Members of the CRESST research team also recorded other variables of interest for the analysis. These included an examination of the reading units to determine text type, as well as information from the notebooks concerning representing reading and mathematics framework categories, including content aspect/process, item format, score type, and score points (see Appendix C for details of these variables).

Table 1

Characteristics of the Reading and Mathematics Panels

	Reading			Mathematics			Total
	Group A	Group B	Total	Group A	Group B	Total	
Gender							
Female	2	4	6	0	1	1	7
Male	2	0	2	4	3	7	9
Region							
Midwest	1	1	2	0	1	1	3
Northeast	0	0	0	1	0	1	1
South	2	1	3	0	0	0	3
West	1	2	3	3	3	6	9
Primary expertise							
Assessment	1	1	2	1	0	1	3
CCSS	2	1	3	2	1	3	6
K-12 educator	1	1	2	1	2	3	5
Special needs	0	1	1	0	1	1	2
Total	4	4	8	4	4	8	16

In lieu of a formal panelist evaluation, each two-day meeting culminated with a debriefing. As with the inclusion of multiple rounds of rating and discussion, this was done to gain qualitative evidence concerning the validity of the rating process. In addition, the final debriefing session was used to elicit panelists' impressions about the representation of deeper learning in the reading and mathematics measures, respectively.

Analysis

Consistent with other studies of cognitive complexity, descriptive statistics were used to address the primary research question concerning the extent to which PISA assesses deeper learning in the two focal content areas of reading and mathematics. Histograms were created and measures of central tendency and dispersion were calculated to provide a representation of the distribution of responses across each test for each variable (e.g., DOK, CCSS domain, and text complexity) as well as for each value. Crosstabs were used to examine the relationship between DOK and the other variables of interest. Composite ratings were created showing the distribution of modal responses for each value by each rater. In addition, responses concerning construct-irrelevant obstacles were examined qualitatively.

Reliability. Interrater reliability was assessed by examining the distribution of ratings (i.e., units) across raters and by computing intraclass correlations (ICCs) for ordinal data and kappa (*K*) correlations for nominal data (see Table 2). As would be expected based on the process of using multiple rounds of discussion for the rating of DOK, overall reliability was extremely high for both reading and mathematics. When examining the distribution of units across raters, consensus was reached for DOK for the vast majority of reading items (84.8%) and for two thirds of the mathematics items (67.1%). In addition, the ICC for DOK was very high when averaged across raters (Reading = .99, Mathematics = .98). Furthermore, reliability was generally high for text complexity with a mean agreement level of 83.5% and an ICC of .89. It should also be noted that while variance was primarily at the item level for the reading and mathematics ratings of DOK, ratings of text complexity varied substantially from rater to rater (see Table 3). Even so, a majority of panelists (five or more) agreed on the modal rating for each text.

Table 2

Indices of Reliability Across Reading Literacy and Mathematics Literacy Panels

	# of options	Mean % agreement across items	% items with perfect agreement	Mean <i>K</i> across rater pairs	Mean rater ICC
Reading					
CCSS domain	3	85.6	47.8	.32	--
DOK	4	95.9	84.8	--	.99
Text complexity	3	83.5	24.0	--	.89
Mathematics					
CCSS domain	6	67.3	8.6	.39	--
DOK	4	90.9	67.1	--	.98
CCSS mathematical practice	2	77.7	11.4	.33	--

Note. Since “Range of reading and level of text complexity” received no ratings, only three reading domains were included in the reliability analyses.

Table 3

Item Variances for Reading Literacy and Mathematics Literacy Panels

Variable	<i>n</i>	Item variance		Rater variance		Error variance	
		Amount	%	Amount	%	Amount	%
Reading							
DOK	92	0.339	90.9	0.001	0.3	0.033	8.9
Text complexity	25	0.129	47.8	0.013	4.7	0.128	47.5
Mathematics							
DOK	70	0.371	83.2	0.001	0.2	0.074	16.6

Study Results

The following section presents findings for PISA’s Reading Literacy and Mathematics Literacy assessments. For each assessment, we first provide descriptive data on test content as context for study results and then present data on the primary study question: PISA’s representation of deeper learning as viewed through the lens of DOK and that of panelists’ qualitative impressions. Detailed results at the rater level can be found in Appendices D and E. In viewing these results, it is important to recognize that PISA makes no claims about its representation of high levels of DOK, and item DOK level plays no role in the creation of their assessments.

PISA Reading Literacy Results

Reading literacy results reported here summarize panelists’ ratings of the 92 items comprising the full PISA item pool. As noted earlier, these items are organized into six clusters for assignment to test forms, with each cluster composed of four to five units, and each unit constituted by one to four texts on a related topic and three to six text-related questions. Of the total item pool, 86 items are scored dichotomously (0 or 1 point) while the remaining six items are scored polychotomously (0, 1, or 2 points).

Item characteristics. Table 4 summarizes the characteristics of the texts that serve as the stimulus for the PISA reading literacy units. The table shows that over half of the reading items (57.6%) used continuous texts, which normally consist of sentences organized into paragraphs, while approximately one third (31.5%) used non-continuous texts, which are phrases or sentences organized into a matrix format (e.g., lists, tables, graphs, and advertisements). Other text formats were less common, with only 7.6% of items including a mix of continuous and non-

continuous texts, and 3.3% of units consisting of multiple independent texts that may complement or contradict each other.⁵

Table 4
Frequencies of the Item Characteristics of the Reading Literacy Units (N = 92)

Variable	<i>n</i>	%
Text format		
Continuous	53	57.6
Non-continuous	29	31.5
Mixed	7	7.6
Multiple	3	3.3
Item format (CBA)		
Simple multiple choice	32	34.8
Complex multiple choice	11	12.0
Open response	49	53.3
Aspect		
Access and retrieve	28	30.4
Integrate and interpret	44	47.8
Reflect and evaluate	20	21.7
Scoring (CBA)		
Computer scored	49	53.3
Human scored	43	46.7

In addition, Table 4 summarizes the characteristics used in structuring and scoring the items. More specifically, over half of the items (53.3%) used an open response format, about one third (34.8%) consisted of a simple multiple choice format (i.e., a list of provided answers), and only 12.0% were structured as complex multiple choice items (e.g., yes/no, true/false questions). In about half of the reading items (47.8%) the intent was for students to Integrate and Interpret information from the text, about one third (30.4%) required students to Access and Retrieve specific information from the text, while the remaining items (21.7%) required students to Reflect and Evaluate on what they read in relation to other outside knowledge. Finally, slightly more items were designated as computer (53.3%) rather than human scored (46.7%).

⁵ See pages 17 and 18 of the 2015 Reading Framework (OECD, 2013c) for detailed descriptions of the four text formats.

Mean average text complexity was 1.95 ($SD = 0.38$), indicating that texts were at a grade level appropriate for 15-year-olds (e.g., approximately ninth grade). Examining panelists' modal ratings for each item, more than three quarters (76.0%) of the units consisted of texts rated as being at grade level, while only five units had texts (20.0%) rated as below and one unit (4.0%) had texts rated as above grade level (see Figure 2).

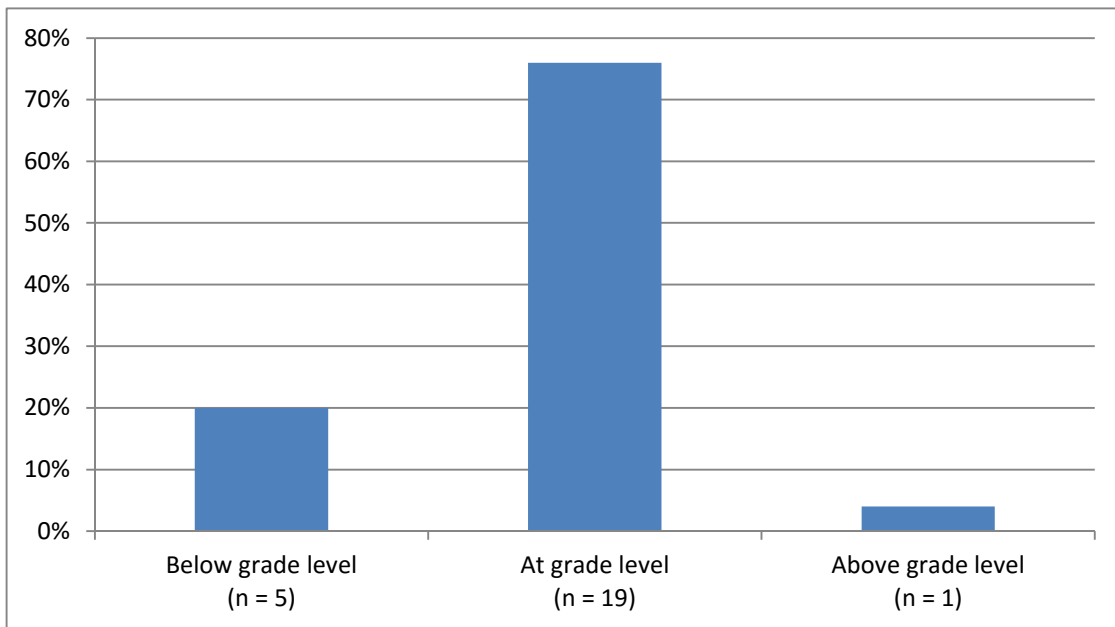


Figure 2. Modal text complexity ratings for the reading literacy stimuli ($N = 25$).

CCSS reading domains addressed. Although we did not expect PISA to be aligned with the CCSS, the research team did ask panelists to evaluate the reading domain each item principally addressed to provide a general sense of PISA test content. As the data in Figure 3 show, the vast majority of reading items (89.1%) were characterized as addressing the first reading domain, Key Ideas and Details, which is to be expected given PISA's focus on students' ability to use their reading in real-life applications. Based on panelists' ratings, Craft and Structure was the focus of seven items (7.6%), and Integration of Knowledge and Ideas the focus of three items (3.3%). No items were rated as principally addressing the Range of Reading and Level of Text Complexity domain.

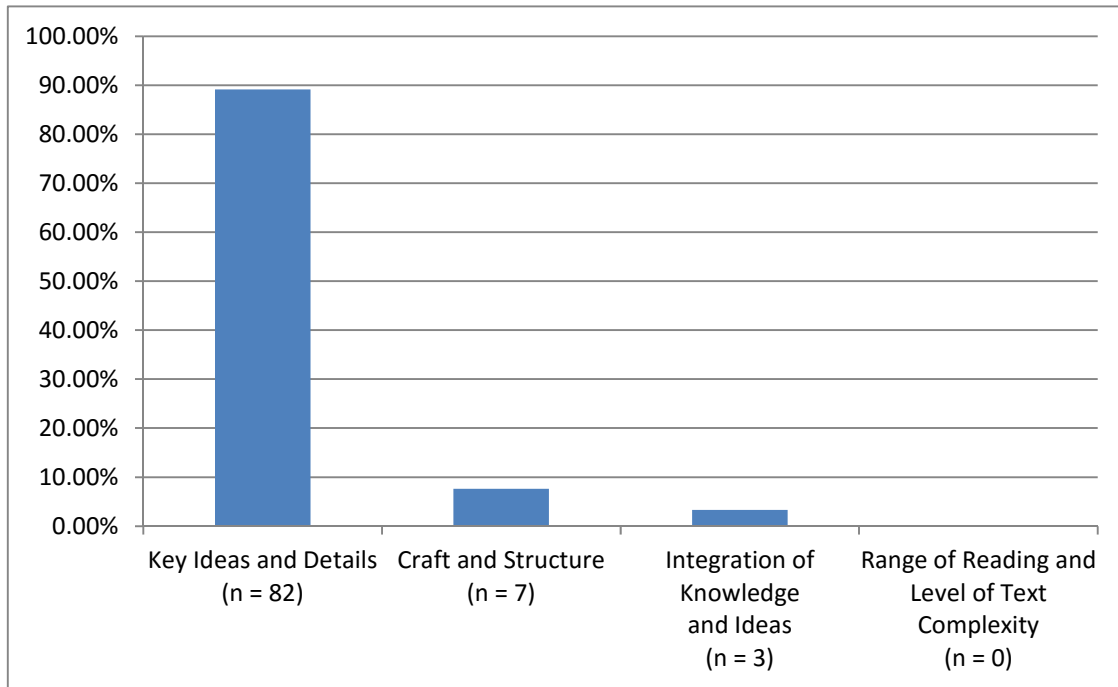


Figure 3. CCSS domains assessed for the reading literacy items ($N = 92$).

Construct-irrelevant obstacles. PISA reading literacy items were rated as generally free from construct-irrelevant obstacles (73.9%) that might impede students' understanding of the questions being asked or their ability to demonstrate their competencies. Only one of the items was identified as problematic by a majority of raters ($n = 6$) and for only six items (6.5%) did two or more raters note potential problems. These tended to focus on the clarity of the question posed in the item and/or concerns about whether an item was text-based or could be answered based only on background knowledge.

Depth of knowledge. Frequency and descriptive data were calculated on panelists' modal DOK ratings across all reading literacy items. Based on all indicators, the results indicate a modest level of cognitive demand on the test, with a mean DOK level across all items of 1.75 ($SD = 0.59$), and DOK2 representing both the median and mode.

The distribution of ratings, as shown in Figure 4, confirms a preponderance of items at DOK2 (57.6%). About one third of the items (33.7%) were rated as DOK1, only eight (8.7%) achieved a modal rating at DOK3, while none of the items were rated at DOK4. Based on the study definitions of what DOK levels reflect deeper learning, less than one tenth of the PISA reading literacy items meet this standard.

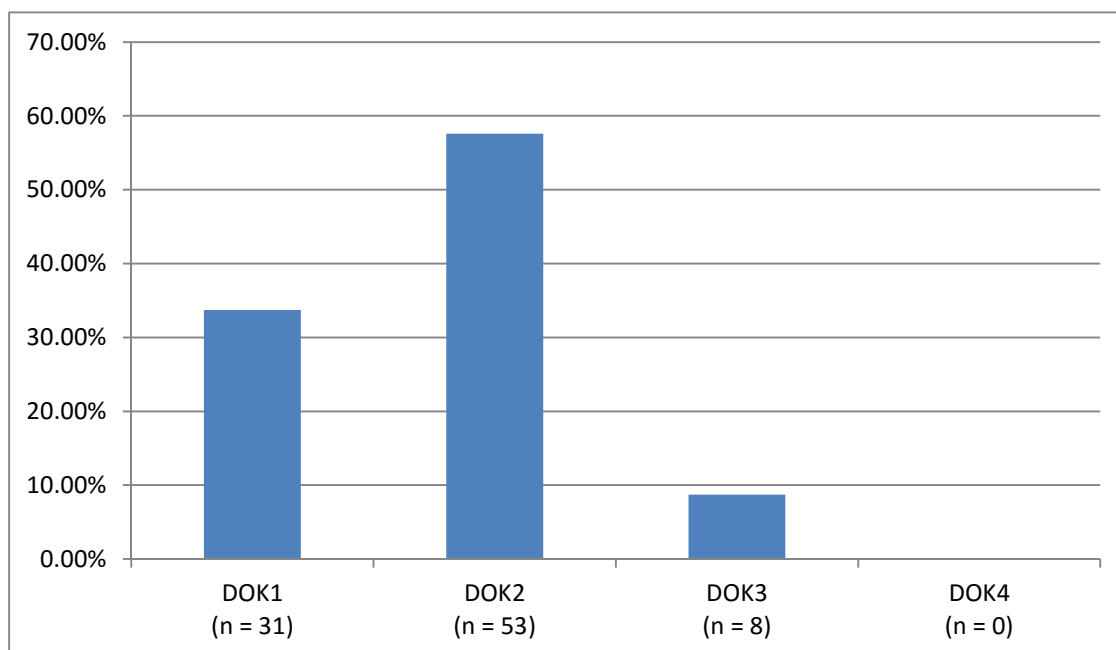


Figure 4. Percentage of reading literacy items at each DOK level ($N = 92$).

Because the scoring rubrics indicate that some items have higher values than others do—that is, some items are worth two points rather than one—simply examining the proportion of items at each level may not adequately describe the weighting given higher level DOK in PISA scores.⁶ We intuitively expected there to be a relationship between score type and DOK, with human-scored items eliciting higher levels of DOK than those that are automatically scored by computer. We also expected higher levels of DOK being accorded more score points than those at lower levels.

To explore these hypotheses we investigated possible relationships between score type (computer versus human scored, a proxy for open response items), score value, and DOK. As shown in Table 5, results show that all of the computer-scored items were rated as DOK1 or DOK2, with the majority at the latter (67.3%). A roughly similar proportion of human-scored items addressed DOK1, but the remaining were split between DOK2 and DOK3, with DOK3 accounting for 18.6% of the human-scored items.

Delving more deeply into the relationship between DOK level, open response items, and item score points, this table also shows the relationship between score value and DOK level. The vast majority of human-scored items worth one point were rated at DOK1 or DOK2, with only five of the one-point items rated at DOK3. In contrast, the relatively few two-point items were all

⁶ Although items may vary in their score values, the IRT scaling procedures used with PISA weight each item equally (OECD, personal communication, April 5, 2016). Nonetheless, the number of score points associated with an item often provides one indicator of its relative importance.

rated as DOK2 or DOK3 ($n = 3$, respectively). Because of this, we were able to conclude that the representation of higher level DOK is slightly larger when taking into account score points versus simple counts of reading items (11% and 9%, respectively). These results also highlight that PISA might not be getting full value from its open response items by failing to provide partial credit for so many reading literacy items.

Table 5

Distribution of DOK Level by Reading Literacy Score Type and Points (N = 92)

Type	# DOK1	# DOK2	# DOK3	#DOK4	# Total	% higher DOK
Item scoring						
Computer scored	16	33	0	0	49	0.0
Human scored	15	20	8	0	43	18.6
Total	31	53	8	0	92	8.7
Human scored points						
1 point	15	17	5	0	37	13.5
2 points	0	3	3	0	6	50.0
Total	15	20	8	0	43	18.6

Note. In the event that panelists were evenly split (4:4) concerning the DOK of an individual item, Panelist 1's rating was coded as the modal response.

Table 6

Distribution of DOK level by Reading Literacy Framework Aspect (N = 92)

Aspect	# DOK1	# DOK2	# DOK3	#DOK4	# Total	% higher DOK
Access and retrieve	18	10	0	0	28	0.0
Integrate and interpret	11	31	2	0	44	4.5
Reflect and evaluate	2	12	6	0	20	30.0
Total	31	53	8	0	92	8.7

Note. In the event that panelists were evenly split (4:4) concerning the DOK of an individual item, Panelist 1's rating was coded as the modal response.

Similarly, we examined the relationship between aspect of reading assessed, based on the PISA framework, and DOK. We expected Access and Retrieve items to elicit relatively lower levels of DOK, Integrate and Interpret items to occupy an intermediate position, and Reflect and Evaluate items to elicit the relatively highest levels of DOK. The data shown in Table 6 support the following suppositions: (1) The majority of Access and Retrieve items (64.3%) were rated at DOK1; (2) the majority of Integrate and Interpret items (70.4%) were rated at DOK2; and (3)

while the majority of Reflect and Evaluate items (60.0%) also were rated at DOK2, they were less likely than the Integrate and Interpret items to be rated DOK1 (10.0% and 25.0%) and more likely to garner DOK3 (30.0% and 4.5%).

General observations. During the debriefings, panelists were asked to reflect on their ratings and to discuss the session protocols. Some of the more salient issues voiced by panelists included the following: (1) Panelists noted struggling more in differentiating between DOK1 and DOK2 than with higher levels. They noted a number of items where the correct answer was a paraphrase of information explicitly mentioned in the text. In these cases, they struggled to differentiate whether items required a literal restating of a detail from the text or actually required students to make an inference across words, sentences, or paragraphs. In the end, panelists agreed that the distinction was a matter of professional judgment. (2) Another issue was how to classify an item that could potentially elicit a higher level DOK3 or DOK4 response, but the scoring rubric only required a DOK2 response for full credit. Panelists agreed that the expectations set forth in the rubric should govern the DOK rating. Although this decision partially led to a preponderance of DOK2 ratings, panelists noted that with slight changes in the rubrics, a number of items could have been moved to a DOK3. (3) Finally, panelists noted a surprising number of items that they felt were not text dependent. That is, students did not need to read or draw evidence from the text to get the answer correct, but could depend upon their prior knowledge. Panelists suggested that the PISA reading literacy items should give more attention to citing text and should take fuller advantage of cross-text comparisons.

PISA Mathematics Literacy Results

The 70 total items in PISA's Mathematics Literacy assessment are organized into six clusters, with each composed of five to nine units. Each unit presents a scenario that serves as the stimulus for one to four items.

Item characteristics. As shown in Table 7, of the total mathematics items, the majority (57.1%) used an open response format and one quarter (25.7%) required human scoring. The remaining items used either a simple (22.9%) or a complex (20.0%) multiple choice format: both of which were automatically computer scored. When examining the cognitive processes focused on in the PISA framework, the most common item type involves employing mathematical concepts (41.4%), with the remaining items fairly evenly distributed between the processes of formulating situations mathematically (31.4%) and interpreting outcomes (27.1%).

Table 7

Frequencies of the Text Characteristics of the Mathematics Literacy Units (N = 70)

Variable	<i>n</i>	%
Item format (CBA)		
Simple multiple choice	16	22.9
Complex multiple choice	14	20.0
Open response	40	57.1
Process		
Formulate	22	31.4
Employ	29	41.4
Interpret	19	27.1
Scoring (CBA)		
Computer scored	52	74.3
Human scored	18	25.7

CCSS content and practice domains. As with the reading literacy item set, we summarize the CCSS domains assessed in PISA as study context, with no expectation of alignment between the two. Within the limits of the consistency of panelists' content ratings, Figure 5 shows the distribution of items across domains, based on panelists' modal rating for each item. The data indicate that Functions (31.4%), Statistics (25.7%), and Geometry (21.4%) garner respectively the greatest attention, each representing more than one fifth of the total item set. Algebra (8.6%) and Numbers (11.4%) are each the topic of approximately one tenth of the items, and modeling was coded as the topic of only one item (1.4%). This distribution generally parallels PISA's content specifications, in which about a quarter of the assessment is targeted on Change and Relationships (roughly Functions), Shape and Space (roughly Geometry), Quantity (roughly combining Numbers and Algebra), and Uncertainty and Data (Statistics).

With regard to mathematical practices, the majority of panelists agreed that most items integrated both mathematical content and practice. More specifically, while the majority of raters agreed that 63 of the items (90.0%) included a mathematical practice, they did not agree on the specific practice incorporated for the individual items. By far, the most frequently cited practice (23.3%) was the omnibus "make sense of problems and persevere in solving them," while "reason abstractly and quantitatively" was the second most frequently cited practice (13.4%), followed by "look for and make use of structure," "construct viable arguments," and "model with

mathematics” (8.1%, 7.7%, and 7.5%). Other practices were each observed among less than 5% of the items.

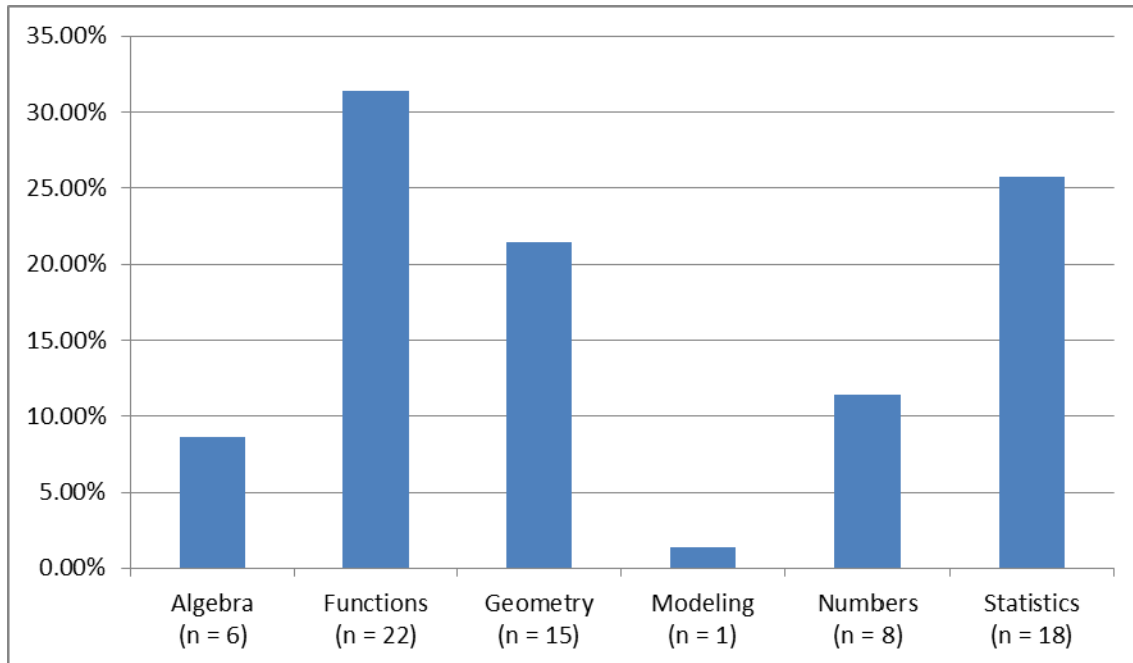


Figure 5. CCSS domains assessed for the mathematics literacy items ($N = 70$).

Construct-irrelevant obstacles. As with reading literacy, the mathematics literacy items were generally rated as free from construct-irrelevant characteristics that would impede students’ ability to show what they know ($n = 54, 77.1\%$). While individual raters noted scattered potential problems across the remaining item set, only one item (1.4%) had three panelists note a potential problem and this related to the quality of the visual (i.e., the alignment of axis labels). Only six other items (8.6%) had two panelists note a problem and nine items (12.9%) had one panelist note a potential problem.

Depth of knowledge. Frequency and descriptive data were calculated on panelists’ modal DOK ratings across all 70 mathematics literacy items. The data indicate a mean DOK level of 1.80 ($SD = 0.62$) over the entire item set, with a range of DOK1 to DOK3 and ratings of DOK2 representing both the median and mode.

The frequency distributions shown in Figure 6 indicate that more than half (51.4%) of the items were rated at DOK2, approximately one third at DOK1 (34.2%), and only 14.3% achieved a modal response of DOK3. Furthermore, no items achieved DOK4. Based on the definition used for this study, this would mean that less than one fifth of all mathematics literacy items represented deeper learning.

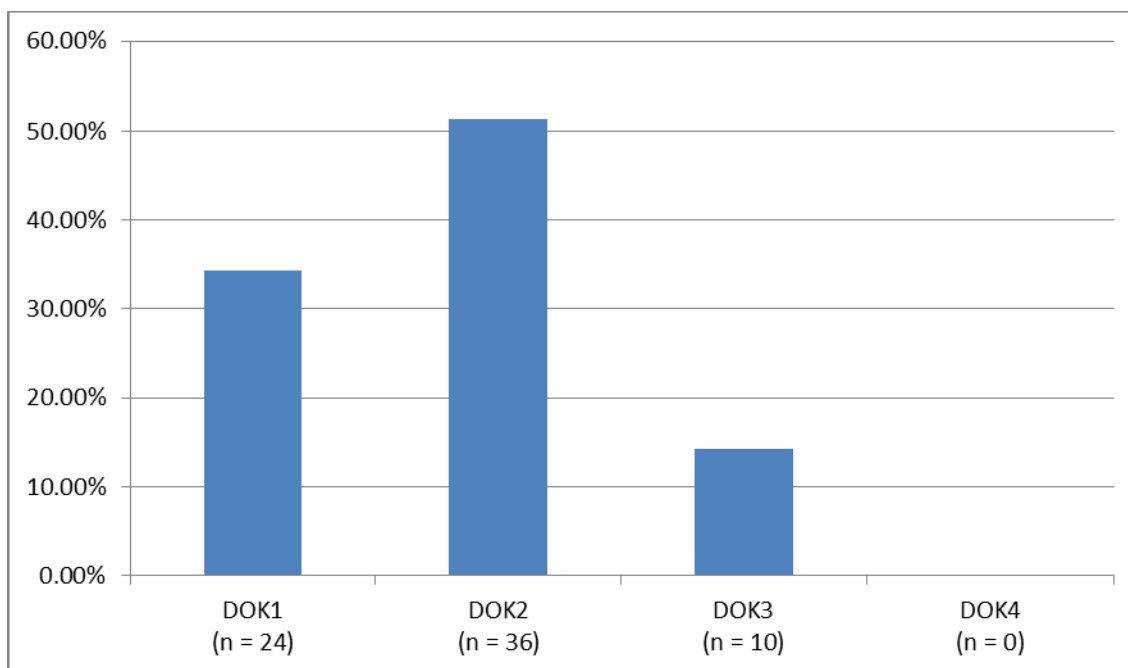


Figure 6. Percentage of mathematics literacy items at each DOK level ($N = 70$).

As with reading, we decided to investigate whether an association exists between higher level DOK mathematics items and higher score values. As shown in Table 8, in this case we found that all of the automatically scored mathematics items were worth one point ($n = 52$), as were the majority of human-scored items ($n = 12$), leaving only six human-scored items worth a possible two points. Only one of these two-point items was rated at DOK3, with the remaining five being rated at DOK2. Results also show that just over half of all items ($n = 36$) were rated at DOK2, whether computer or human scored. When examining the relationship between score values and DOK further, we also found that the representation of higher order DOK was equivalent whether examining the ratio of items or score points at DOK3 (14.3% and 14.5%, respectively).

We also examined the relationship between the mathematical process assessed, based on the PISA framework, and depth of knowledge. While we expected a similar trend as with the reading literacy items, the distribution of mathematical items across the processes was more complicated. More specifically, the data in Table 9 show the following: (1) The majority of both the Formulate (54.5%) and Employ items (58.6%) were rated at DOK2; (2) half of the DOK1 items (50.0%) were classified as Employ items as were just under half of the DOK2 items (47.2%); and (3) the DOK3 items were distributed between the Formulate ($n = 6$) and Interpret ($n = 4$) processes.

Table 8

Distribution of DOK Level by Mathematics Literacy Score Type and Points (N = 70)

Type	# DOK1	# DOK2	# DOK3	#DOK4	# Total	% higher DOK
Item scoring						
Computer scored	19	26	7	0	52	13.5
Human scored	5	10	3	0	18	16.7
Total	24	36	10	0	70	14.3
Human scored points						
1 point	5	5	2	0	12	16.7
2 points	0	5	1	0	6	16.7
Total	5	10	3	0	18	16.7

Table 9

Distribution of DOK Level by Mathematics Literacy Framework Process (N = 70)

Process	# DOK1	# DOK2	# DOK3	# DOK4	# Total	% higher DOK
Formulate	4	12	6	0	22	27.3
Employ	12	17	0	0	29	0.0
Interpret	8	7	4	0	19	21.0
Total	24	36	10	0	70	14.3

General observations. Mathematics panelists were also debriefed in order to gain qualitative evidence about the validity of the rating process. While panelists easily came to an agreement about what differentiated a DOK1 from a DOK2—items involving the routine application of mathematics concepts and procedures versus those requiring some transfer—they initially struggled in differentiating between DOK2 and DOK3, especially in regards to items requiring an explanation. What differentiated the latter, they concluded, was the extent of conceptual analysis and strategic thinking required. The panel agreed that DOK3 items require students to use and consider alternative mathematical structures to organize their approach to a problem and/or require explanations that examine a problem, solution, or approach. In contrast, panelists agreed that mathematics items requiring students to apply and communicate a set of known procedures on how to solve a problem would constitute DOK2. From this perspective, multistep problems could be classified at either of these two levels depending upon the conceptual analysis required to represent the problem and/or formulate a solution strategy.

Additional issues noted by mathematics panelists included the following. First, despite their breadth of knowledge and experience, they had difficulty assigning items to a primary CCSS domain, in that the concepts and procedures that students could use in the solution rarely fell neatly into one domain. Indeed, panelists felt that some of the PISA items could be solved using routine procedures from one domain or another (e.g., simple computation or applying an algebraic formula), while a few other items required students to think strategically to formulate one or more possible approaches to a solution. Second, while panelists were complimentary in their opinions about a number of the scenarios presented in the mathematics test, they did feel that some of the item prompts did not take full advantage of their respective scenarios for posing specific problems, in requiring students to construct viable mathematical arguments, or in using modeling. Finally, as with reading, panelists felt that the scoring rubrics sometimes lowered the potential depth of knowledge that items might otherwise elicit.

Comparison to Other Studies

In this section, we compare our results to a number of different studies. First, we consider the validity of our findings by comparing study results to a prior RAND study examining the depth of knowledge of PISA’s released items. We then examine expectations for deeper learning relative to others’ analyses of that evidence in the CCSS and new CCSS-aligned assessments.

Validity of Findings Relative to RAND Study

Although study panelists found the potential for assessing deeper learning in a number of additional items, actual representation in the 2015 assessments appear fairly modest: approximately 11% to 14% for reading and mathematics literacy, respectively. While we have confidence in our findings based on the caliber of our assembled reading and mathematics panels, the careful process used, and the reliability of results, it is interesting to compare study results to a prior RAND study of PISA’s DOK (Yuan & Le, 2014). The RAND study was based on earlier items that the OECD released to the public to describe and characterize their assessments.

Table 10

RAND Analysis of PISA Reading Literacy Released Items, Pre-2015

Item type	DOK1		DOK2		DOK3		DOK4	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Open response (<i>n</i> = 50)	20	40.0	6	12.0	24	48.0	0	0.0
Multiple choice (<i>n</i> = 60)	21	35.0	23	38.3	16	26.7	0	0.0
Total (<i>n</i> = 110)	41	37.3	29	26.4	40	36.4	0	0.0

Note. Adapted from *Measuring deeper learning through cognitively demanding test items: Results from the analysis of six national and international exams* (WR-967-WFHF), p. 35, by K. Yuan and V. Le, 2014, Santa Monica, CA: RAND Corporation.

Table 10 shows RAND’s results on the DOK of released reading literacy items (Yuan & Le, 2014). The results are similar to the current study in a number of respects: the relative attention to DOK1, the absence of tasks at DOK4, and the tendency for open response items to be rated at DOK3. However, the two studies show major differences in the relative attention to DOK2 and DOK3, and thus in the attention to deeper learning. The RAND study classifies more than one third of the items examined at DOK3, while the current study rated only 9% of the items at this level. We believe that this difference is attributable to a difference in methods. As described earlier, panelists in the current study examined both test items and relevant rubrics in rating item-level DOK and used the level credited by the rubric as the arbiter of their ratings. In contrast, we believe the RAND research only examined the items. Recall, also, that the current study identified instances where items might have elicited a higher DOK, but a deeper level response was not required by the scoring rubric for full credit. In other words, we believe that the difference in estimates for DOK2 and DOK3 are the result of RAND rating items based specifically on what students were asked to do, while the current study took into account the DOK reflected in the scoring rubrics.

In contrast, the data in Table 11 show striking similarities between the RAND analysis and the current study regarding the DOK distribution for the mathematics literacy items. In both studies, we see approximately one third of the items at DOK1, about half at DOK2, and about 14–17% at DOK3. No items in either study were classified as DOK4. Furthermore, in both studies a relationship can be found between item type and DOK levels. For example, in the RAND study (Yuan & Le, 2014), only open response items were rated as DOK3.

Table 11

RAND Analysis of PISA Mathematics Literacy Released Items, Pre-2015

Item type	DOK1		DOK2		DOK3		DOK4	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Open response (<i>n</i> = 68)	25	36.8	28	41.2	15	22.1	0	0.0
Multiple choice (<i>n</i> = 21)	4	19.0	17	81.0	0	0.0	0	0.0
Total (<i>n</i> = 89)	29	32.6	45	50.6	15	16.9	0	0.0

Note. Adapted from *Measuring deeper learning through cognitively demanding test items: Results from the analysis of six national and international exams* (WR-967-WFHF), p. 34, by K. Yuan and V. Le, 2014, Santa Monica, CA: RAND Corporation.

Comparison of Deeper Learning in PISA and Common Core State Standards

Table 12 shares data from expert consensus panels established by states and nationally prominent researchers to identify the DOK expectations for the middle and high school CCSS in ELA and mathematics. These sources include:

- David Conley and colleagues' (2011) study of the alignment between the CCSS and prior state standards at the high school level;
- The Florida State Department of Education (see Herman, Buschang, La Torre Matrundola, & Wang, 2013);⁷
- The Fordham study (Doorey & Polikoff, 2016) evaluating the content and quality of next generation tests;
- The Iowa State Department of Education (Niebling, 2012);
- Norman Webb's (2012a, 2012b) studies of the alignment between the CCSS and six nationally available high school tests; and
- WestEd's (2010) study of the alignment between the CCSS and the Massachusetts state standards.

What is striking in examining the data from these various sources is the variation in attention to deeper learning across content areas as well as in the conclusions made about deeper learning in the CCSS across studies composed of different panels of experts. More specifically, all of the studies in Table 12 show substantially higher levels of deeper learning in ELA than in mathematics. In contrast, results for the current study of PISA show a slightly higher representation of deeper learning for mathematics (14.3%) than for reading (8.7%). The current study also shows that PISA's representation of deeper learning in mathematics is slightly higher

⁷ Florida subsequently retreated from CCSS adoption but at the time of the analysis was a full adopter. Ratings of cognitive complexity for the Florida standards were calculated by Herman and colleagues (2013) from the CPALMS website (<http://www.cpalms.org/Downloads.aspx>).

than in three of the studies of middle school CCSS expectations and is similar or greater than in two of the high school studies. Although the results for PISA’s assessment of reading show relatively less attention to higher levels of deeper learning relative to the ELA CCSS, it is worth noting that the other studies also took into account writing and language.

Table 12

DOK Levels Reflected in Middle and High School CCSS by Source and Subject Area

DOK level	% DOK1	% DOK2	% DOK3	% DOK4	% higher DOK
ENGLISH LANGUAGE ARTS					
Middle school					
Florida (Herman et al., 2013)	1.1	37.4	52.6	8.9	61.5
Fordham (Doorey & Polikoff, 2016)	10.1	44.2	41.8	3.8	45.6
Iowa (Niebling, 2012)	22.5	24.4	32.5	20.6	53.0
WestEd (2010)	13.0	16.0	57.0	13.0	75.0
High school					
Conley et al. (2011)	4.5	9.0	52.2	34.3	86.5
Florida (Herman et al., 2013)	0.0	30.7	59.1	10.2	69.3
Iowa (Niebling, 2012)	19.7	29.5	32.5	18.3	50.8
Webb (2012a)	1.7	10.9	57.1	30.3	87.4
MATHEMATICS					
Middle school					
Florida (Herman et al., 2013)	11.8	75.6	12.6	0.0	12.6
Fordham (Doorey & Polikoff, 2016)	50.9	39.8	9.3	0.0	9.3
Iowa (Niebling, 2012)	48.3	41.9	9.8	0.0	9.8
WestEd (2010)	27.0	52.0	21.0	0.0	21.0
High school					
Conley et al. (2011)	21.2	53.9	19.7	4.7	24.4
Florida (Herman et al., 2013)	17.1	67.9	14.5	0.0	14.5
Iowa (Niebling, 2012)	46.4	42.6	10.9	0.2	11.1
Webb (2012b)	17.4	61.0	20.7	0.5	21.2

Note. Since the Iowa standards allow the assignment of more than one DOK level to each standard, the percentages reported are weighted.

Comparison to the Representation of Deeper Learning in the New Common Core Aligned Assessments

We raise, as a final point of comparison, the levels of deeper learning evident in recent CCSS-aligned tests including ACT Aspire, PARCC, and Smarter Balanced. The data in Table 13 shows the eighth grade results from a recent study conducted by Doorey and Polikoff (2016) of the quality of these three assessments.⁸ These ELA and mathematics results are presented because this grade most closely aligns to the PISA age target of 15-year-olds.

As with the results presented in the previous sections, considerable variation can be found across both subject areas as well as the three tests. However, in this case, results for PISA show relatively less attention to higher levels of deeper learning than do all of the new CCSS-aligned assessments, with the exception of Smarter Balanced’s mathematics assessment. It should be noted that the ELA assessments shown in Table 13 also target writing, language, and research, as well as reading, the focal content area in PISA. Furthermore, the PARCC and Smarter Balanced assessments include performance tasks, which PISA does not include for either reading or mathematics.

Table 13

DOK Levels in Three CCSS-Aligned Eighth Grade Assessments by Source and Subject Area

DOK level	% DOK1	% DOK2	% DOK3	% DOK4	% higher DOK
English language arts					
ACT Aspire	44.3	36.8	15.0	3.8	18.8
PARCC	1.6	29.1	46.4	22.9	69.3
Smarter Balanced	15.0	40.8	36.7	7.5	44.2
Mathematics					
ACT Aspire	19.9	45.1	34.3	0.7	35.0
PARCC	13.3	62.0	24.2	0.5	24.7
Smarter Balanced	16.1	74.5	8.6	0.8	9.4

Note. While the percentages for ACT Aspire and PARCC were calculated from the total score values, due to complications with the computer adaptive testing (CAT), the percentages for Smarter Balanced were calculated from the number of items. Adapted from *Evaluating the content and quality of next generation assessments*, p. 81, by N. Doorey, and M. Polikoff, 2016, Washington, DC: Thomas B. Fordham Institute.

⁸ Although HumRRO conducted a parallel study of the quality of the PARCC and Smarter Balanced high school tests, the researchers did not make detailed summaries of the DOK levels available in their report.

Summary and Conclusions

This report presents the results of an analysis conducted by expert panels of the PISA Reading Literacy and Mathematics Literacy assessments and compares findings to that of other related studies. Reading and mathematics panels conducted item-by-item reviews of each assessment. Although these reviews provided descriptive information about the content of each test, their prime purpose was to examine the extent to which the two PISA assessments reflected deeper learning, as judged by panelists' ratings of item depth of knowledge. Based on Webb's four-point scale (Webb, 2002a) the study defined deeper learning as being represented by ratings of DOK3 and DOK4. Because PISA is highly regarded internationally as a test of problem solving, the study was undertaken in the belief that PISA could serve as a benchmark for assessing deeper learning for new state tests of college and career ready standards. Note, however, as mentioned earlier in this report, that PISA makes no claims about its representation of deeper learning, and DOK plays no role in the construction of the tests.

PISA Reading Literacy Results

Panelists analyzed the full set of 92 items that constitute the 2015 Reading Literacy assessment. The item set reflects a mix of multiple choice, open response, machine-scored, and human-scored items. Item stimuli feature passages of both continuous text and non-continuous texts, such as advertisements, applications, and brochures. Although some items are based on multiple texts or multiple text types, the great majority are based on a single stimulus.

To provide a sense of item content, panelists characterized each item relative to dimensions relevant to the CCSS. Of the continuous text passages, the preponderance were judged to be at grade level in text complexity for the 15-year-old student sample that is the target of the assessment. Nearly 90% of the items addressed the Key Ideas and Details domain, while the remaining addressed Craft and Structure ($n = 7$) or Integration of Knowledge and Ideas ($n = 3$). Panelists judged most of the items free of construct-irrelevant features that could impede students' ability to show their knowledge.

Mean depth of knowledge across all items was 1.75, representing a basic level of skill application. Based on panelists' ratings, nearly 60% of the items were rated as DOK2, requiring modest mental processing; approximately one third were rated at a rote level (DOK1); and only 9% achieved DOK3, where abstract thinking, reasoning and more complex inferences are required. None of the items were rated as DOK4. Thus based on study definitions, less than 10% of the items assessed deeper learning. The percentage increased slightly to 11% when taking into

account the percentage of the total possible score points that could be attributed to deeper learning, since only six items had a score value of 2, and of those, only half were at DOK3.⁹

While all DOK3 items used a human-scored, open response format, relatively few of the items using this format and score type reached this level. Based on these results, it appears that PISA may not be getting full value from its open response items for assessing thinking that is more complex. In this vein, panelists commented that although some items may have elicited DOK3 responses, their associated rubrics did not require a response of this level for full credit.

PISA Mathematics Literacy Results

Seventy items comprised PISA's 2015 Mathematics Literacy assessment. As with the reading assessment, the items reflected a mix of multiple choice and open response items. Despite this, less than half of the latter item format required human judgment for scoring. Functions, Statistics, and Geometry together accounted for more than three fourths of the items, with Numbers and Algebra each receiving relatively less attention, and Modeling virtually none. Most items, according to panelists' ratings, did incorporate mathematical practices, and again like the reading assessments, were generally free of construct-irrelevant obstacles.

Across all items, panelists' ratings revealed a mean depth of knowledge of 1.80, suggesting a relatively basic level of mathematics application. Just over half of the items were judged to be DOK2, requiring some mental processing; about one third were judged to reflect routine procedures or rote concepts (DOK1); and, the remaining 10 items (14.3%) were judged to be at DOK3, requiring strategic thinking and application of mathematical reasoning. As with reading, none of the mathematics items achieved DOK4. Thus based on study definitions, only 14.3% of the items addressed deeper learning. As with reading, taking into account the number of score points associated with given items made no appreciable difference in the allocation to deeper learning since only one of the six items accorded two rather than one possible score point was rated at DOK3.

Similar to reading, it appears that PISA may not be getting full value for its open response, human scored items. Mathematics panelists also suggested that while the scenarios established as the stimulus for some units were very rich, the item prompts and scoring rubrics did not necessarily take full advantage of the scenario in eliciting and crediting deeper learning.

⁹ As previously noted, the IRT scaling procedures used for PISA give all items equal weight, regardless of the number of score points associated with an item.

How PISA’s Attention to Deeper Learning Compares to Expectations for the Common Core State Standards

PISA, of course, was not developed to be consistent with the CCSS and its expectations for depth of knowledge. Moreover, because it is intended for an international student population that varies widely in educational opportunity and achievement, it may not be surprising that the DOK levels found in PISA are generally lower than were those found for the CCSS, particularly in regards to reading. That is, PISA items must be sensitive to the students whose ability ranges from the lowest to the highest end.

Although available studies show substantial variation in expectations for deeper learning, PISA’s DOK levels in reading appear lower than what is expected of the CCSS in English language arts. However, we note again that the latter also includes standards for language and writing, which naturally lend themselves towards higher levels of DOK. PISA and CCSS expectations for deeper learning are closer in mathematics. In this case, the PISA distribution is similar or greater than what was found in three of the expert analyses of middle school standards, and two of the studies of high school standards.

Similarly, in comparison to expert panel analyses of the DOK for new CCSS-aligned tests (i.e., ACT Aspire, PARCC, and Smarter Balanced), PISA generally showed less attention to higher levels of deeper learning. Although the differences were again more notable in ELA than in mathematics, it is important to keep in mind important content and format differences between the tests. This includes the focus of PISA solely on reading literacy as well as the inclusion of performance tasks, which are uniquely suited to assessing deeper learning, in the PARCC and Smarter Balanced assessments, but not in PISA.

Attention to deeper learning in PISA did not vary much whether percentages were based on the number of items or total score points. In part, this was because PISA contains relatively few items with a score value larger than one, and because all items are weighted equally in their scaling procedures. However, the analysis of the relationship between item type, score value, and DOK mirrors findings from earlier studies showing that open response items, particularly in mathematics, are more likely to tap higher levels of DOK than multiple choice ones (Herman, La Torre Matrundola, & Wang, 2015; Yuan & Le, 2012).

Conclusions

We began this study with a hypothesis that because it is so highly regarded internationally as a measure of knowledge application and practical problem solving, that PISA’s depth of knowledge and attention to deeper learning might serve as an appropriate benchmark for the new assessments aligned to the CCSS and other college and career ready standards in the United

States. Our results suggest otherwise, and instead indicate new complexities in the identification of an appropriate benchmark.

For historical and comparison purposes we chose to use Norman Webb's depth of knowledge framework (see Webb et al., 2005) to evaluate the extent of deeper learning in assessment. From the perspective of Webb's framework, the adequacy of an assessment's DOK should be judged relative to the standards it is designed to address. Although they are not fully synonymous, there is general agreement that the CCSS is a reasonable instantiation of deeper learning, at least in regards to its academic goals (see National Research Council, 2012). Despite this, the data reviewed for this report show tremendous variation in how different expert panels characterize the deeper learning expectations for the CCSS. Even when individual panels reach consensus, findings can vary significantly across panels. Furthermore, reports often vary in the details they provide about the methodology—such as the procedures used in the study, who and how many experts were involved, and the level of agreement—making it difficult to judge the relative rigor and credibility of the final ratings. Determining how well an assessment meets the deeper learning expectations of the CCSS, or other college and career ready standards, requires a firmer foundation of these concepts as well as a rigorous, well-designed, and validated process for credibly setting these expectations.

Moreover, when establishing reasonable deeper learning targets for assessment, it is important to take into account the reality that standards represent goals for all students. As such, to provide good measurement, assessments need to include items that are sensitive to the full range of achievement, including that of students who have not yet achieved the goals. Thus, it is not unreasonable to see, as was generally, that studies of the CCSS ELA assessments showed lower levels of deeper learning than did studies of the ELA standards themselves, despite their variation. Furthermore, it should be kept in mind that Norman Webb's (2002a) metric, is based on the assumption that an assessment's DOK is aligned with standards if at least 50% of the items are at or above the specified levels.

State accountability assessments serve to both communicate what is important for students to know and to provide an accurate and reliable measure of student accomplishment. In order to promote and measure deeper learning goals, these two concerns must be delicately balanced and accommodated during assessment development and validation. Historically, measurement concerns have been served by attention to item difficulty, psychometric modeling, and other indicators without regard to DOK, as is the case with PISA. Assessment development and validation of the future will need to consider both if deeper learning goals are to be achieved.

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**Appendix A:
Panelist Recruitment**

Panel Recruitment Letter

Joan Herman, Director
National Center for Research on Evaluation,
Standards, and Student Testing (CRESST)
herman@cse.ucla.edu
P 310-206-3701

February 19, 2015

Dear [Name]:

The National Center for Research on Evaluation, Standards, and Student Testing (CRESST) invites you to participate in an expert panel to analyze the 2015 Programme for International Student Assessment's (PISA) of [reading or mathematics]. PISA, as you probably know, is highly regarded as a test of real world applications and problem solving and is prominent in cross-national comparisons of student performance. Generously funded by the William and Flora Hewlett Foundation, our study concentrates on analyzing how well PISA addresses deeper learning goals. Results will be used to help set a benchmark for the representation of deeper learning in tests aligned to new college and career ready standards (see attached study description).

We are looking for panelists who are knowledgeable about new college and career ready standards, committed to advancing students' critical thinking and problem solving, and experienced in teaching and/or curriculum development for secondary school and/or college freshman [reading or mathematics]. We also prefer individuals who have experience in assessment development and/or review. We expect that our study will require approximately four days of your time, with two of those days on-site in Washington, DC to conduct the PISA review. The on-site meeting will take place in the offices of the National Center for Educational Statistics (NCES).

If you agree and are chosen to participate, you will be asked to sign and have notarized a non-disclosure agreement, review advance materials at home, participate in a two-hour webinar, and attend and complete the rating process at NCES. Travel and accommodations as well as an honorarium of \$3200 will be provided to all participants.

We hope that you are interested in lending your expertise to this exciting effort. If so, please fill out the attached questionnaire and indicate your availability for possible webinar and NCES meeting times. We will need to select panelists based on their availability for one of these dates.

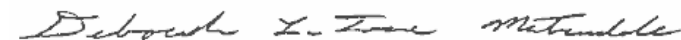
If you are not able to participate, we would appreciate it if you would refer your other colleagues—expert high school teachers or curriculum specialists in [reading or mathematics], particularly those knowledgeable about special populations. Please let us know.

Thank you for your consideration. We hope we can look forward to your participation.

Best,



Joan Herman
Principal Investigator



Deborah La Torre Matrundola
Project Coordinator

Reading Literacy Study Information Form

Thank you for your interest in helping us review and score the cognitive complexity of the 2015 PISA test items in reading. Please fill out this form and return it to Deborah La Torre Matrundola at latorre@cse.ucla.edu by March 13, 2015.

Rater Information

Last Name:	_____	First Name:	_____
Street Address:	_____	Apt/Unit #:	_____
City:	_____	State:	Zip: _____
Home Phone:	() _____	Cell Phone:	() _____
Email Address:	_____		
Organization:	_____		
Position:	_____		

Background Information

Teaching Experience (e.g. years, grades, and ELA subjects taught):

Common Core (CCSS) Curriculum and/or Assessment Development/Review Experience (e.g. participation in creating/reviewing curriculum or assessment aligned with the CCSS):

Experience in Assessment Development and/or Scoring (e.g., participation in development of state or district reading test, scoring of extended constructed response tasks):

Common Core State Standards

Please rate yourself concerning each of the following:

	Beginner	Intermediate	Advanced	Expert
1. Knowledge of the CCSS in ELA:				
2. Experience with the CCSS in ELA:				

General Availability for Study

Webinars (PDT)				Scoring Sessions (9am–5pm EDT)*			
Weekdays (4–6pm):	_____ Yes	_____ No	June 10–11:	_____ Yes	_____ No		
Weekdays (5–7pm):	_____ Yes	_____ No	June 11–12:	_____ Yes	_____ No		
Saturdays (am):	_____ Yes	_____ No	June 18–19:	_____ Yes	_____ No		
Saturdays (pm):	_____ Yes	_____ No					

*Please take into account travel to/from Washington, D.C. when listing your availability for the scoring sessions.

Mathematics Literacy Study Information Form

Thank you for your interest in helping us review and score the cognitive complexity of the 2015 PISA test items in reading. Please fill out this form and return it to Deborah La Torre Matrundola at latorre@cse.ucla.edu by March 13, 2015.

Rater Information

Last Name:	_____	First Name:	_____
Street Address:	_____	Apt/Unit #:	_____
City:	_____	State:	Zip: _____
Home Phone:	() _____	Cell Phone:	() _____
Email Address:	_____		
Organization:	_____		
Position:	_____		

Background Information

Teaching Experience (e.g. years, grades, and math subjects taught):

Common Core (CCSS) Curriculum and/or Assessment Development/Review Experience (e.g. participation in creating/reviewing curriculum or assessment aligned with the CCSS):

Experience in Assessment Development and/or Scoring (e.g., participation in development of state or district reading test, scoring of extended constructed response tasks):

Common Core State Standards

Please rate yourself concerning each of the following:

	Beginner	Intermediate	Advanced	Expert
1. Knowledge of the CCSS in math:				
2. Experience with the CCSS in math:				

General Availability for Study

Webinars (PDT)				Scoring Sessions (9am–5pm EDT)*			
Weekdays (4–6pm):	_____ Yes	_____ No	June 10–11:	_____ Yes	_____ No		
Weekdays (5–7pm):	_____ Yes	_____ No	June 11–12:	_____ Yes	_____ No		
Saturdays (am):	_____ Yes	_____ No	June 18–19:	_____ Yes	_____ No		
Saturdays (pm):	_____ Yes	_____ No					

*Please take into account travel to/from Washington, D.C. when listing your availability for the scoring sessions.

**Appendix B:
Panelist Biographies**

Reading Literacy Panelists

Katherine Allebach Franz, M.A.Ed., is a high school teacher in Minneapolis Public Schools. She has over 15 years of experience teaching courses in language arts (e.g., English, Honors English, IB MYP [International Baccalaureate Middle Years Programme] English, and Reading), humanities, theater, and AVID. Allebach Franz has also served as a literacy coach, conducted trainings on data interpretation as a reading specialist, has written curricula and common assessments for her district, and has participated in efforts to vertically align the CCSS and AP standards.

Katrina Boone, M.A.T., is an America Achieves fellow who teaches for the Shelby County Public Schools in Kentucky. She has over five years of experience teaching language arts at the high school level including courses in Reading and Writing, English, and AP English. Boone has created and scored common assessments at the school and district levels and has helped create CCSS aligned curricula for her school. In addition, she has participated in CCSS alignment studies of curricula and assessment for both Student Achievement Partners and for Collaborative for Student Success.

Mark Conley, Ph.D., is a professor at the University of Memphis in Tennessee. He conducts research on teacher education policy and practice, adolescent literacy, assessment and human and artificial intelligence tutoring, all within interdisciplinary contexts. Prior to moving to Tennessee, he was an associate professor at Michigan State University. Dr. Conley often collaborates with school districts, including the Memphis City School District, to develop programs to assist students as they become literate. Among his extensive experience, he has served as co-chair of the standards committee for the English Language Arts National Board for Professional Teaching Standards; he participated in a CCSS and cognitive complexity alignment study of the ACT and Cambridge tests; and he has 15 years of experience working with the Michigan Department of Education on reading and writing test development.

Linda Friedrich, Ph.D., has served as the director of research and evaluation at the National Writing Project (NWP) since 2002. In this capacity, she has overseen the use, ongoing development, and scoring of writing samples for NWP's CCSS-aligned writing assessment system (Analytic Writing Continuum) and, as a member of their management team, she supports the organization in strategically using research results and tools. Her research interests include teacher leadership and professional development, writing assessment, teacher research, and the diffusion of knowledge and practice. She is coauthor of *How Teachers Become Leaders: Learning from Practice and Research* (Liebman & Friedrich, 2010). Prior to joining NWP, she

served as director of research at the Coalition of Essential Schools. Dr. Friedrich has also worked on the CCSS and cognitive complexity alignment study of the ACT and Cambridge tests.

P. David Pearson, Ph.D., is a professor and former dean in the Graduate School of Education at the University of California, Berkeley. His research interests focus on language and literacy and on human development. Dr. Pearson's current projects include an interdisciplinary study on the use of reading, writing, and language to foster knowledge and inquiry in science as well as a collaborative research partnership between Berkeley, Stanford, and the San Francisco Unified District. Prior to joining the faculty at Berkeley, he was the John A. Hannah Distinguished Professor of Education at Michigan State and Co-Director of the Center for the Improvement of Early Reading Achievement (CIERA). He has also written and co-edited numerous books and articles, including the *Handbook of Reading Research*.

Martha Thurlow, Ph.D., is director of the National Center on Educational Outcomes at the University of Minnesota. In this position, she addresses the implications of contemporary U.S. policy and practice for students with disabilities and English language learners, including national and statewide assessment policies and practices, standards-setting efforts, and graduation requirements. This includes serving on both the technical and students with disabilities advisory committees for Smarter Balanced. Dr. Thurlow has conducted research for the past 35 years in a variety of areas, including assessment and decision making, learning disabilities, early childhood education, dropout prevention, effective classroom instruction, and integration of students with disabilities in general education settings. Dr. Thurlow has published extensively on all of these topics, authoring numerous books and book chapters, and publishing more than 200 articles and reports. In 2003, she completed her 8-year term as co-editor of *Exceptional Children*, the research journal of the Council for Exceptional Children, and is currently associate editor for numerous journals.

Sheila Valencia, Ph.D., is a professor of language, literacy, and culture at the University of Washington, Seattle. In this capacity, she teaches and conducts research in the areas of literacy assessment, instruction, policy, and teacher development. She also has more than 28 years of experience teaching ELA methods at the university level. Dr. Valencia has served on the Common Core Standards Advisory Panel on Literacy, National Assessment of Educational Progress (NAEP) subcommittees, and the International Reading Association and National Council of Teachers of English (IRA/NCTE) standards and assessment committees. Prior to joining the faculty at the University of Washington, she was an assistant professor at the University of Illinois, Urbana-Champaign and an acting assistant professor at the University of Colorado Boulder. She also has over five years of experience as a district reading coordinator in Colorado. Dr. Valencia has authored numerous books, chapters, and articles, and has served on

the editorial boards of *Educational Researcher*, *Educational Assessment*, *Reading Research Quarterly*, *Journal of Literacy Research*, and *The Reading Teacher*.

Karen Wixson, Ph.D., is a former professor and dean in the schools of education at the University of North Carolina, Greensboro and at the University of Michigan. As a professor, she taught reading methods classes to both pre-service and in-service teachers, and she served as director of the Center for the Improvement of Early Reading Achievement (CIERA) at the University of Michigan. Dr. Wixson has extensive experience consulting with NAEP including serving on their framework, achievement-level descriptors, and reading standing committees as well as leading their Validity Studies Panel concerning alignment of their assessments with the ELA CCSS. In addition, she previously worked on the development of the Progress in International Reading Literacy Study (PIRLS) assessment and was a member of the extended work team for the ELA CCSS. Dr. Wixson has also served on the editorial boards for *Educational Assessment*, *Journal of Literacy Research*, and *Reading Research Quarterly*.

Mathematics Literacy Panelists

Christopher Affie, M.A., is an America Achieves fellow who is currently head of the mathematics department at The Gilbert School, a college prep school in Connecticut. He has more than 15 years of teaching experience at secondary schools in Connecticut. Courses he has taught include Pre-Algebra, Algebra 1 and 2, Geometry, Pre-Calculus, Calculus, and AP Statistics. As department head, he has focused on designing and implementing the school's CCSS-aligned mathematics curriculum. Affie has also created district-level common assessments in mathematics, and has completed training on the use of the Educators Evaluating the Quality of Instructional Products (EQuIP) and Instructional Materials Evaluation Tool (IMET) rubrics from Achieve and Student Achievement Partners, respectively.

Patrick Callahan, Ph.D., is co-director of the California Mathematics Project (CMP). He spent 6 years teaching mathematics at the University of Texas at Austin, after which he spent 10 years working at the University of California Office of the President. The focus of his professional and research activities has been on the professional development of K-16 pre-service and in-service teachers in mathematics instruction. Dr. Callahan has served as a member of a National Center on Education and the Economy (NCEE) panel on college and career ready standards. He has also served as a member of the Smarter Balanced Item Quality Review Expert Panel in mathematics and has worked as a content expert for Illustrative Mathematics.

Phil Daro, B.A., is director of mathematics for the Strategic Education Research Partnership (SERP). He previously directed teacher professional development programs for the University of California, including CMP and the American Mathematics Project (AMP). In this

capacity, he helped states to develop mathematics standards as well as accountability and testing systems. Daro is one of the key authors of the mathematics CCSS. He has served on numerous other mathematics committees such as the NAEP Validity Committee, the RAND Mathematics Education Research Panel, the College Board Mathematics Framework Committee, the ACHIEVE Technical (Assessment) Advisory and Mathematics Work Groups, and the Mathematical Sciences Education Board of the National Research Council.

Wallace Etterbeek, Ph.D., is a professor emeritus of mathematics at California State University, Sacramento. In addition to teaching mathematics at the university level, he taught advanced mathematics courses at the high school level including AP Calculus and Level 4 of the IB program. Dr. Etterbeek has extensive experience as a reader and table leader for the AP Calculus and Statistics exams. He has served as a statistician and workgroup member for the Mathematics Diagnostic Testing Project (MDTP), with a focus on the outlining of pathways for courses and development of CCSS-aligned tests for Integrated Mathematics I, II, and III. In addition, he participated in a CCSS and cognitive complexity alignment study of the ACT and Cambridge tests.

David Foster, B.A., is the executive director of the Silicon Valley Mathematics Initiative. In this capacity, he has spent over 15 years developing and scoring the Mathematics Assessment Collaborative and Mathematics Assessment Resource Service (MAC/MARS) performance assessment exam. Foster has 20 years of experience teaching mathematics and computer science courses at the secondary school level. He is an author of the following mathematics curricula: Interactive Mathematics, Glencoe, Agile Mind Middle School Program, and Pearson's CCSS-aligned System of Courses for the high school level. He has also consulted with PARCC and has developed exemplar items for Smarter Balanced.

Curtis Lewis, Ph.D., is an America Achieves fellow who is principal of both the elementary and secondary school programs at the Henry Ford Academy: School for Creative Studies in Detroit. He holds a Ph.D. in curriculum, teaching, and education policy from Michigan State University. Dr. Lewis has over 10 years of experience teaching at the elementary, secondary, and post-secondary levels. Mathematics courses he has taught include Basic Math, Algebra, Geometry, and Trigonometry. Dr. Lewis has also taught courses and professional development on CCSS mathematics to both pre-service and in-service teachers. He has also assisted in the creation of district-level common assessments in mathematics as well as the scoring of student responses on constructed response items.

Barbara Schallau, M.A., is the Mathematics Subject Area Coordinator for East Side High School District (ESHSD) in Silicon Valley, California. In this capacity, she heads the

development and alignment of the district’s mathematics curriculum and provides in-service trainings to faculty. Schallau also has over 25 years of experience teaching mathematics with ESHSD, and has recently started teaching adult education for the district as well. Courses she has taught include Pre-Algebra, Algebra 1 and 2, Geometry, the Integrated Math Program (IMP) Years 1–4, and CCSS Math 1. In addition, Schallau has assisted in the development of CCSS-aligned curricula and common interim assessments for use at the elementary and middle school levels, she has standardized rubrics for the MAC tasks, and she helped create mathematics assessment items for the Santa Clara County Office of Education (SCCOE).

Guillermo Solano-Flores, Ph.D., is a professor of bilingual education and English as a second language at the School of Education of the University of Colorado Boulder. In this capacity, he has taught graduate-level courses on the educational assessment of bilingual populations, sociolinguistics in education, and on language issues in educational research. Dr. Solano-Flores has served as a member of the English language learners (ELL) advisory committee for Smarter Balanced, has authored conceptual frameworks for the consortium concerning the development of mathematics test translations and accessibility resources in mathematics assessments for ELLs, and served on their item quality review panel. He has also done work on the NAEP, PISA, and TIMSS assessments. Dr. Solano Flores also co-created a translation model for the Assessment of Higher Education Learning Outcomes (AHELO) tasks and facilitated international teams in their translation, utilizing his theory of test translation error.

Appendix C:
Review Panel Training and Data Collection

Reading Depth of Knowledge Framework

Level	Descriptors
Level 1	<ul style="list-style-type: none">• Task requires recall or recognition of details from the passage.• Identification of needed information often explicit, obvious, or prompted.• Students do not need to make significant connections to the text; they do not need to draw relationships between words, sentences, and/or paragraphs to address the task/item.
Level 2	<ul style="list-style-type: none">• Requires engagement of some mental processing beyond recall or recognition and requires application of skill or knowledge.• Students need to draw some relationships between words, sentences, and paragraphs and between the task/item and the relevant portions of the passage.
Level 3	<ul style="list-style-type: none">• Requires higher level processing, including synthesis of details and/or examples, of supporting ideas, inferring and/or producing a logical progression of ideas, application of prior knowledge, inference across an entire passage, or the identification of connections among texts.• Students need to make significant connections in text and to infer relationships words, sentences, and paragraphs across the passage(s).
Level 4	<ul style="list-style-type: none">• Requires student to perform complex tasks such as synthesizing and analyzing complex ideas, analyzing the complex connections among texts, developing hypotheses, or finding themes across texts, which are not explicitly related.• Given the complexity, tasks at Level 4 often require an extended period of time.

Mathematics Depth of Knowledge Framework

Level	Descriptors
Level 1	<ul style="list-style-type: none">• Task is primarily rote or procedural, requiring recall, recognition, or direct application of a basic concept, routine computation, algorithm or representation.
Level 2	<ul style="list-style-type: none">• Task requires some mental processing and more than rote application of skill, concept or procedural and/or algorithmic tasks.• Students often make decisions about how to approach the problem.
Level 3	<ul style="list-style-type: none">• Involves developing a solution strategy, and may have more than one possible answer.• Task often requires significant departure from traditional application of concepts and skills.• Solution strategy often involves working with multiple mathematical objects (numbers, expressions, equations, diagrams, graphs) or problem structures.
Level 4	<ul style="list-style-type: none">• Task requires extended reflection, including complex problem solving, abstract reasoning, an investigation, processing of multiple conditions of the problem, and nonroutine manipulations.• Task often requires extended time.

Reading Literacy Sample Web-Based Coding Form

Unit R219: XX

a) Please indicate the level of text complexity for the unit.

- Below grade level
- At grade level
- Above grade level

b) Please enter your ratings for each item.

Item #	Item DOK				CCSS Domain				Construct-irrelevant obstacles	
	Level 1	Level 2	Level 3	Level 4	Key ideas & details	Craft & structure	Integration of knowledge & ideas	Range of reading & Level of text complexity	No	Yes
R219Q01A	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
R219Q01B	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
R219Q01C	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
R219Q01D	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
R219Q01E	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
R219Q02	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

c) Notes concerning construct-irrelevant obstacles:

Mathematics Literacy Sample Web-Based Coding Form

Unit M155: XX

Item #	CCSS Domain	Mathematical practice	Item DOK				Construct-irrelevant obstacles	
			Level 1	Level 2	Level 3	Level 4	No	Yes
R155Q01	<input type="text"/>	<input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
R155Q02	<input type="text"/>	<input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
R155Q03	<input type="text"/>	<input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
R155Q04	<input type="text"/>	<input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

c) Notes concerning construct-irrelevant obstacles:

Rating Session Notebook: Table of Contents

Section 1: Supplemental materials

- Note to Reviewers of Secure Items
- Instructions for Accessing Units on the Computer
- Item Classifications by Framework Characteristics
- Item Allocation by Cluster

Section 2: Reading

- Reading Units (Clusters)
- Coding Guide and Answer Key

Section 3: Mathematics

- Mathematics Units (Clusters)
- Coding Guide and Answer Key

Reading and Mathematics Literacy Variables

Table C1

Variables With Dummy Codes for the Reading Literacy and Mathematics Literacy Expert Panels

Variables	Reading values	Mathematics values
Text complexity	Below grade level (1) At grade level (2) Above grade level (3)	N/A
DOK	1–4	1–4
CCSS domain	Key ideas and details (1) Craft and structure (2) Integration of knowledge and ideas (3) Range of reading and level of text complexity (4)	HS: Number & quantity (1) HS: Algebra (2) HS: Functions (3) HS: Modeling (4) HS: Geometry (5) HS: Statistics & probability (6) MS: Ratios & proportional relationships (7) MS: The number system (8) MS: Expressions & equations (9) MS: Functions (10) MS: Geometry (11) MS: Statistics & probability (12) ES: Operations & algebraic thinking (13) ES: Number & operations in base ten (14) ES: Number & operations – fractions (15) ES: Measurement & data (16) ES: Geometry (17)
Mathematical practice	N/A	None (0) Make sense of problems and persevere in solving them. (1) Reason abstractly and quantitatively. (2) Construct viable arguments and critique the reasoning of others. (3) Model with mathematics. (4) Use appropriate tools strategically. (5) Attend to precision. (6) Look for and make use of structure. (7) Look for and express regularity in repeated reasoning. (8)
Construct-irrelevant obstacle	No (0) Yes (1), If yes, text box	No (0) Yes (1), If yes, text box

Note. The CCSS mathematics domains were collapsed across all grade spans for ease of analysis. The constructs analyzed for the study are as follows: Algebra (2, 9, 13), Functions (3, 7, 10), Geometry (5, 11, 17), Modeling (4), Numbers (1, 8, 14, 15), and Statistics (6, 12, 16).

Table C2

Variables With Dummy Codes for the PISA Reading Literacy and Mathematics Literacy Frameworks

Variables	Reading values	Mathematics values
Aspect/process	Access and retrieve (1) Integrate and interpret (2) Reflect and evaluate (3)	Formulate (1) Employ (2) Interpret (3)
Item format	N/A (0) Simple multiple choice (1) Complex multiple choice (2) Open response (3)	N/A (0) Simple multiple choice (1) Complex multiple choice (2) Open response (3)
Text format	Continuous (1) Non-continuous (2) Mixed (3) Multiple (4)	N/A
Scoring	N/A (0) Computer scored (1) Human scored (2)	N/A (0) Computer scored (1) Human scored (2)
Points	0–2	0–2

Rating Session Agendas

PANEL (Day 1)	
9:00–9:30 am:	Continental breakfast Welcome, introductions, and confidentiality agreements
9:30–10:00 am:	Review of practice coding of sample items (reliability) and re-training on rating process and rubric (as needed)
10:00–10:30 am:	Introduction to computer-based tests, notebooks (frameworks, coding guides, etc.)
10:30–12:30 pm:	Rating of items individually (Cluster 01) Discussion/consensus making (Cluster 01)
12:30–1:00 pm:	Lunch
1:00–5:00 pm:	Rating of items individually Group discussion/consensus making after each cluster

* Breaks will be taken throughout the day as necessary.

PANEL (Day 2)	
9:00–9:30 am:	Continental breakfast Debrief on Day 1
9:30–noon:	Rating of items individually Discussion/consensus making after each cluster
noon–12:30 pm:	Lunch
12:30–3:30 pm:	Rating of items individually Discussion/consensus making after each cluster
3:30–4:30 pm:	Final consensus making
4:30–5:00 pm:	Debrief and closing remarks

* Breaks will be taken throughout the day as necessary.

Appendix D:
Reading Literacy Analyses

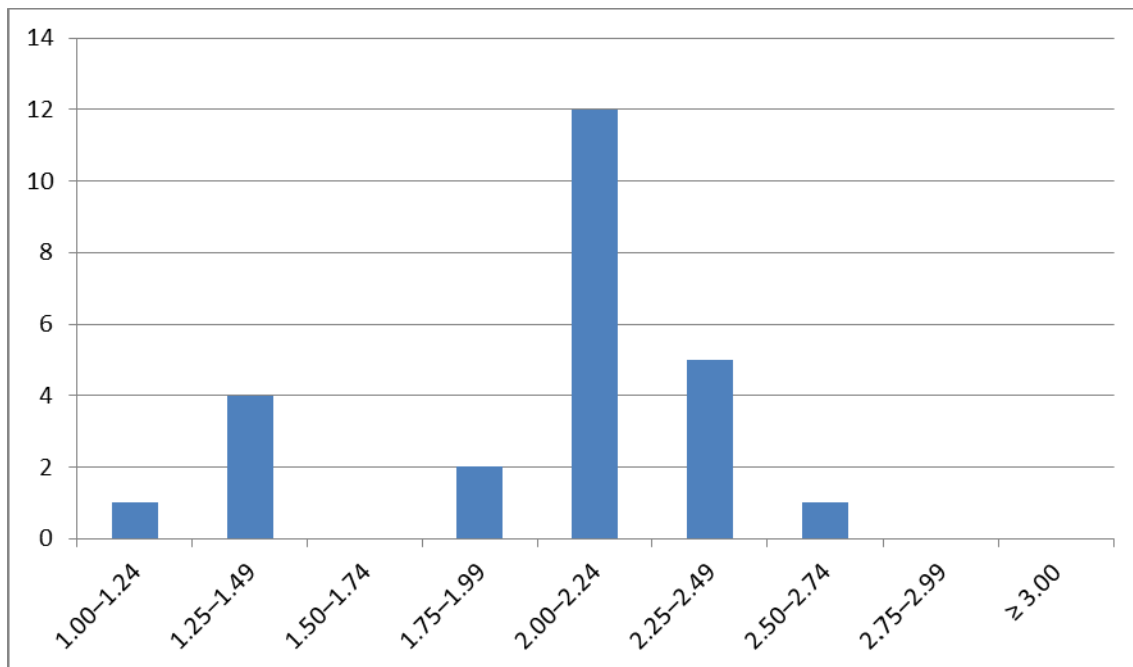


Figure D1. Mean text complexity ratings for the reading literacy stimuli ($n = 25$).

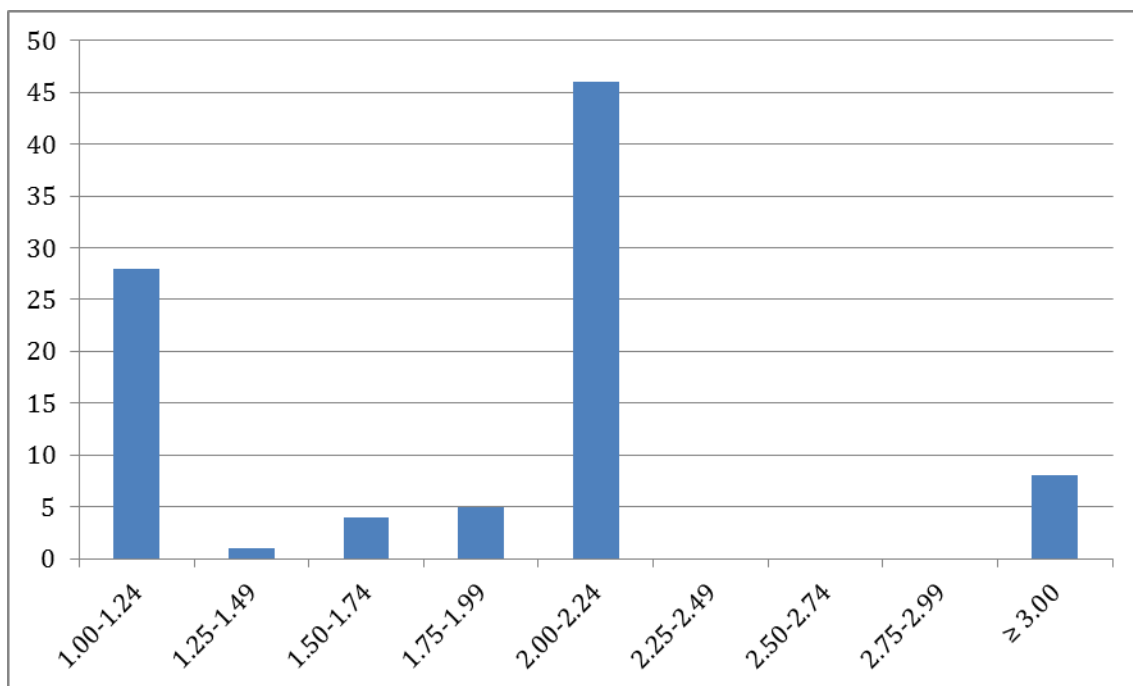


Figure D2. Mean DOK ratings for the reading literacy items ($n = 92$).

Table D1

Overall Summary Statistics for Reading Literacy

Variable	<i>n</i>	Mean (<i>SD</i>)	Median	Mode	Min	Max
Text complexity	25	1.95 (0.38)	2.00	2.00 & 2.13	1.13	2.63
DOK	92	1.75 (0.59)	2.00	2.00	1.00	3.00

Note. When calculating the mean at the rating level, the standard deviations for text complexity ($n = 200$) and DOK ($n = 736$) change to 0.51 and 0.61.

Table D2

Distribution of Reading Literacy Items by Number of Panelists Who Provided the Modal Response

Modal given by	CCSS domain		DOK		Text complexity	
	# Items	%	# Items	%	# Items	%
0 panelists	0	0.0	0	0.0	0	0.0
1 panelists	0	0.0	0	0.0	0	0.0
2 panelists	0	0.0	0	0.0	0	0.0
3 panelists	0	0.0	0	0.0	0	0.0
4 panelists	7	7.6	4	4.3	0	0.0
5 panelists	12	13.0	2	2.2	3	12.0
6 panelists	12	13.0	2	2.2	8	32.0
7 panelists	17	18.5	6	6.5	8	32.0
8 panelists	44	47.8	78	84.8	6	24.0
Total	92	100.0	92	100.0	25	100.0

Note. Percentages represent weighted averages.

Table D3

Panelist Agreement on the Presence of Construct-Irrelevant Obstacles for Reading Literacy Items

# Panelists	# Items	%
0 panelists	68	73.9
1 panelist	18	19.6
2 panelists	4	4.3
3 panelists	0	0.0
4 panelists	1	1.1
5 panelists	0	0.0
6 panelists	1	1.1
Total	92	100.0

Table D4

Panelist Agreement on Modal Responses for CCSS Domain and DOK in Reading Literacy

Modal CCSS domain		DOK modal response					
# Panelists	%	DOK1	DOK2	DOK3	DOK4	# Total	% Total
0 panelists	0.0	0	0	0	0	0	0.0
1 panelists	0.0	0	0	0	0	0	0.0
2 panelists	0.0	0	0	0	0	0	0.0
3 panelists	0.0	0	0	0	0	0	0.0
4 panelists	50.0	1	2	4	0	7	7.6
5 panelists	62.5	1	11	0	0	12	13.0
6 panelists	75.0	3	8	1	0	12	13.0
7 panelists	87.5	2	13	2	0	17	18.5
8 panelists	100.0	24	19	1	0	44	47.8
Total		31	53	8	0	92	100.0

Note. There was a correlation of -0.42 between CCSS domain and DOK rating indicating that there was higher agreement on lower DOK items.

Table D5

Distribution of Reading Literacy Ratings by Individual Panelists

Variable	Panelist 1	Panelist 2	Panelist 3	Panelist 4	Panelist 5	Panelist 6	Panelist 7	Panelist 8	# Total	% Total
CCSS domain (<i>N</i> = 92)										
Key ideas and details	80	82	77	77	77	65	70	63	591	80.3
Craft and structure	11	5	12	10	7	19	10	11	85	11.5
Integration of knowledge and ideas	1	5	3	5	8	8	12	18	60	8.2
Range of reading and level of text complexity	0	0	0	0	0	0	0	0	0	0.0
DOK (<i>N</i> = 92)										
Level 1	32	35	30	35	32	32	28	27	251	34.1
Level 2	51	49	54	49	52	52	56	55	418	56.8
Level 3	9	8	8	8	8	8	8	10	67	9.1
Level 4	0	0	0	0	0	0	0	0	0	0.0
Text complexity (<i>N</i> = 25)										
Below grade level	1	4	4	7	5	4	3	4	32	16.0
At grade level	22	21	18	17	17	20	20	12	147	73.5
Above grade level	2	0	3	1	3	1	2	9	21	10.5

Appendix E:
Mathematics Literacy Analyses

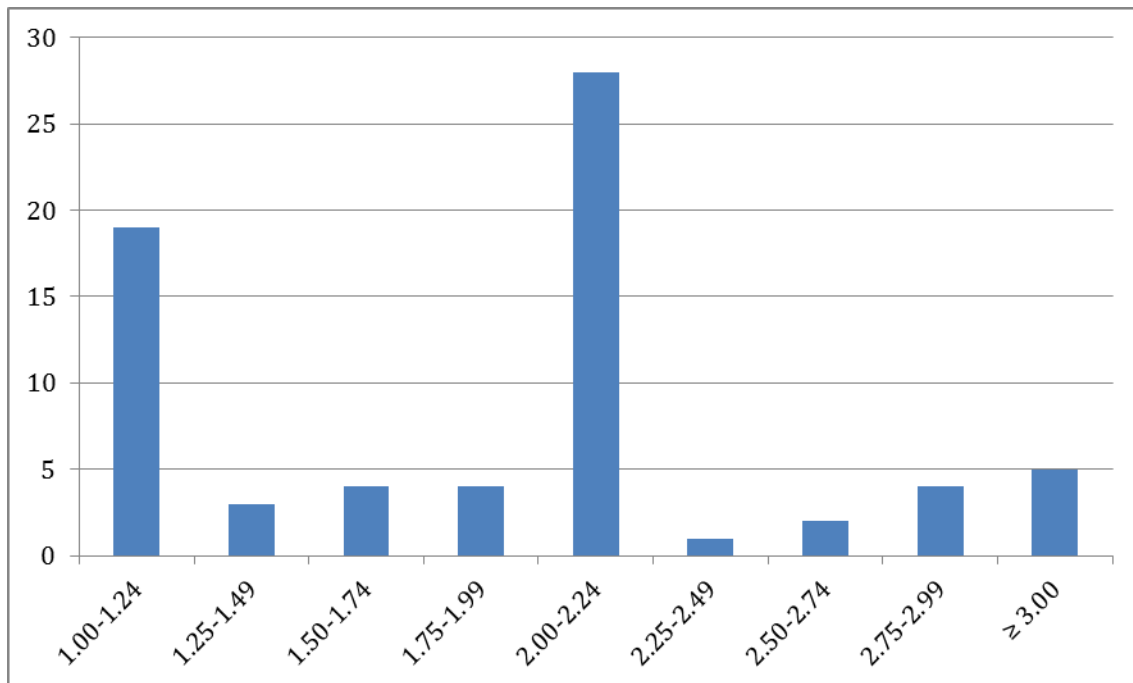


Figure E1. DOK ratings for the mathematics literacy items ($n = 70$).

Table E1

Summary Statistics for Mathematics Literacy

Variable	N	Mean (SD)	Median	Mode	Min	Max
DOK	70	1.80 (0.62)	2.00	2.00	1.00	3.00

Note. When calculating the mean at the rating level, the standard deviation for DOK ($n = 560$) changes to 0.66.

Table E2

Distribution of Mathematics Literacy Items by Number of Raters Who Provided the Modal Response

Modal given by	CCSS domain		DOK		Mathematical practice	
	# Items	%	# Items	%	# Items	%
0 panelists	0	0.0	0	0.0	0	0.0
1 panelists	0	0.0	0	0.0	1	1.4
2 panelists	0	0.0	0	0.0	16	22.9
3 panelists	8	11.4	0	0.0	22	31.4
4 panelists	16	22.9	4	5.7	20	28.6
5 panelists	13	18.6	4	5.7	4	5.7
6 panelists	13	18.6	8	11.4	2	2.9
7 panelists	14	20.0	7	10.0	1	1.4
8 panelists	6	8.6	47	67.1	4	5.7
Total	70	100.0	70	100.0	70	100.0

Note. Mathematical practice was recoded 0–1 for the presence of any practice.

Table E3

Detailed Distribution of CCSS Mathematics Domain Ratings by Individual Rater (N = 559)

Variable	# Total	% Total
Algebra		
Elementary school: Operations and Algebraic Thinking	13	2.3
Middle school: Expressions and Equations	68	12.2
High school: Algebra	7	1.3
Total	88	15.7
Functions		
Middle school: Functions	33	5.9
Middle school: Ratios and Proportional Relationships	98	17.5
High school: Functions	22	3.9
Total	153	27.4
Geometry		
Elementary school: Geometry	6	1.1
Middle school: Geometry	87	15.6
High school: Geometry	19	3.4
Total	112	20.0
Modeling		
High school: Modeling	14	2.5
Total	14	2.5
Numbers		
Elementary school: Numbers and Operations – Fractions	3	0.5
Elementary school: Numbers and Operations in Base Ten	23	4.1
Middle school: The Number System	42	7.5
High school: Number and Quantity	1	0.2
Total	69	12.3
Statistics		
Elementary school: Measurement and Data	12	2.1
Middle school: Statistics and Probability	92	16.5
High school: Statistics and Probability	19	3.4
Total	123	22.0

Note. One panelist failed to rate the primary domain for one mathematics item.

Table E4

Mathematics Literacy Panelist Agreement on the Presence of Construct-Irrelevant Obstacles

# Panelists	# Items	%
0 panelists	54	77.1
1 panelist	9	12.9
2 panelists	6	8.6
3 panelists	1	1.4
Total	70	100.0

Table E5

Mathematics Literacy Panelist Agreement on Responses for CCSS Domain and DOK

CCSS domain	# DOK1	# DOK2	# DOK3	#DOK4	# Total	% higher DOK
Algebra	35	42	11	0	88	12.5
Functions	47	82	24	0	153	15.7
Geometry	7	89	16	0	112	14.3
Modeling	1	8	5	0	14	35.7
Numbers	38	22	9	0	69	13.0
Statistics	61	48	14	0	123	11.4
Total	189	291	79	0	559	14.1

Table E6

Mathematics Literacy Panelist Agreement on Modal Responses for CCSS Domain and DOK

Modal CCSS domain		DOK modal response					
# Panelists	%	DOK1	DOK2	DOK3	DOK4	# Total	% Total
0 panelists	0.0	0	0	0	0	0	0.0
1 panelists	0.0	0	0	0	0	0	0.0
2 panelists	0.0	0	0	0	0	0	0.0
3 panelists	37.5	2	4	2	0	8	11.4
4 panelists	50.0	5	9	2	0	16	22.9
5 panelists	62.5	5	6	2	0	13	18.6
6 panelists	75.0	6	6	1	0	13	18.6
7 panelists	87.5	5	8	1	0	14	20.0
8 panelists	100.0	1	3	2	0	6	8.6
Total		24	36	10	0	70	100.0

Note. There was a correlation of -0.02 between CCSS domain and DOK rating indicating that there was no relationship between the ratings of these two variables.

Table E7

Mathematics Literacy Panelist Agreement on Modal Responses for the Presence of a CCSS Mathematical Practice and DOK

Modal for presence of mathematical practice	DOK modal response					
	DOK1	DOK2	DOK3	DOK4	# Total	% Total
No practice	7	0	0	0	7	10.0
Any practice	17	36	10	0	63	90.0
Total	24	36	10	0	70	10.0

Note. In the event that panelists were evenly split (4:4) concerning the DOK of an individual item, Panelist 1's rating was coded as the modal response.

Table E8

Mathematical Literacy Panelist Agreement on Modal Responses for the Presence of Specific CCSS Mathematical Practices and DOK

Mathematical practice	DOK modal response				# Total	% Total
	DOK1	DOK2	DOK3	DOK4		
No practice	104	59	5	0	168	30.1
Practice 1	31	80	19	0	130	23.3
Practice 2	14	46	15	0	75	13.4
Practice 3	9	30	4	0	43	7.7
Practice 4	4	21	17	0	42	7.5
Practice 5	5	8	2	0	15	2.7
Practice 6	13	13	1	0	27	4.8
Practice 7	6	26	13	0	45	8.1
Practice 8	3	8	3	0	14	2.5
Total	189	291	79	0	559	100.0

Note. In the event that panelists were evenly split (4:4) concerning the DOK of an individual item, Panelist 1's rating was coded as the modal response.

Table E9

Distribution of Mathematics Literacy Items by Number of Raters Who Provided the Majority CCSS Domain Response

Majority given by	Algebra		Functions		Geometry		Modeling		Numbers		Statistics	
	# Items	%	# Items	%	# Items	%	# Items	%	# Items	%	# Items	%
0 panelists	33	47.1	19	27.1	50	71.4	58	82.9	41	58.6	36	51.4
1 panelists	14	20.0	15	21.4	2	2.9	11	15.7	12	17.1	9	12.9
2 panelists	10	14.3	11	15.7	3	4.3	0	0.0	7	10.0	2	2.9
3 panelists	8	11.4	5	7.1	0	0.0	1	1.4	4	5.7	5	7.1
4 panelists	1	1.4	7	10.0	1	1.4	0	0.0	2	2.9	7	10.0
5 panelists	0	0.0	6	8.6	1	1.4	0	0.0	2	2.9	4	5.7
6 panelists	2	2.9	6	8.6	1	1.4	0	0.0	1	1.4	3	4.3
7 panelists	2	2.9	1	1.4	7	10.0	0	0.0	1	1.4	3	4.3
8 panelists	0	0.0	0	0.0	5	7.1	0	0.0	0	0.0	1	1.4
Total	70	100.0	70	100.0	70	100.0	70	100.0	70	100.0	70	100.0

Table E10

Distribution of Mathematics Literacy Items by Number of Raters Who Provided the Majority CCSS Mathematical Practice

Majority given by	No practice	Practice 1	Practice 2	Practice 3	Practice 4	Practice 5	Practice 6	Practice 7	Practice 8
0 panelists	4	16	21	36	42	56	49	41	61
1 panelists	26	14	26	27	22	13	15	17	4
2 panelists	15	18	20	6	3	1	6	9	5
3 panelists	10	11	3	0	0	0	0	2	0
4 panelists	8	9	0	1	1	0	0	1	0
5 panelists	1	1	0	0	2	0	0	0	0
6 panelists	1	1	0	0	0	0	0	0	0
7 panelists	1	0	0	0	0	0	0	0	0
8 panelists	4	0	0	0	0	0	0	0	0
Total	70	70	70	70	70	70	70	70	70

Table E11

Distribution of Mathematics Literacy Ratings by Individual Rater

Variable	Panelist 1	Panelist 2	Panelist 3	Panelist 4	Panelist 5	Panelist 6	Panelist 7	Panelist 8	# Total	% Total
CCSS domain ($N = 70$)										
Algebra	5	14	21	11	12	7	5	13	88	15.7
Functions	28	10	11	22	12	19	31	20	153	27.3
Geometry	14	20	11	13	16	17	7	14	112	20.0
Modeling	4	0	8	0	0	1	0	1	14	2.5
Numbers	7	5	10	3	8	9	19	8	69	12.3
Statistics	12	21	9	20	22	17	8	14	123	22.0
DOK ($N = 70$)										
Level 1	24	27	24	28	19	25	21	21	189	33.8
Level 2	39	33	33	31	43	36	39	38	292	52.1
Level 3	7	10	13	11	8	9	10	11	79	14.1
Level 4	0	0	0	0	0	0	0	0	0	0.0
Mathematical practice ($N = 70$)										
No practice	6	28	7	18	8	65	6	30	168	30.0
Any practice	64	42	63	51	62	5	64	40	391	70.0

Note. Panelist 4 failed to rate the domain and mathematical practice for one item.

Table E12

Detailed Distribution of Mathematical Practice Ratings by Individual Rater (N = 70)

Variable	Panelist 1	Panelist 2	Panelist 3	Panelist 4	Panelist 5	Panelist 6	Panelist 7	Panelist 8	# Total	% Total
No practice	6	28	7	18	8	65	6	30	168	30.1
Practice 1	5	21	18	12	20	2	31	21	130	23.3
Practice 2	25	13	8	15	6	0	6	2	75	13.4
Practice 3	17	2	2	1	8	0	9	4	43	7.7
Practice 4	16	0	8	2	7	2	2	5	42	7.5
Practice 5	1	1	4	1	0	0	6	2	15	2.7
Practice 6	0	3	13	0	7	0	4	0	27	4.8
Practice 7	0	2	6	18	12	1	3	3	45	8.1
Practice 8	0	0	4	2	2	0	3	3	14	2.5
Total	70	70	70	69	70	70	70	70	559	100.0

Note. Panelist 4 failed to rate the mathematical practice for one item.