Project report

NAPLAN Online 2014 Development Study: Cognitive interviews research activity 3: Technically Enhanced Items (Numeracy)

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UNIVERSITY OF CANBERRA

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Executive summary

Background

NAPLAN Online 2014 Development Study: Cognitive interviews research activity 3: Technically Enhanced Items (Numeracy)

This report acknowledges ACARA's intent to establish a rigorous world-class curriculum and assessment program. To this end, this report describes the findings of a research project that examined design considerations of technically-enhanced test items that impact students' mathematics engagement with these items in a meaningful way.

Cognitive interviews were used to capture a rich data source of students' mathematics engagement across the technically-enhanced test items by analysing students' cognitive and behavioural engagement on these items. We also determined the specific aspects of item design that contributed to students' errors and lack of understanding in the items. The analysis was undertaken using Mayer's (2002) *Taxonomy for computer-based assessment of problem solving*, specifically, the cognitive processes elements of this framework.

The test items were categorised according to eight technical function(s):

- Key in Answer in the Box(es) provided
- Pull-down Menu
- Click to Choose
- Click and Drag
- Click to Place
- Use Drawing Tools (draw circle, line, parabola, etc)
- Use Measurement tools (cm-ruler, inch-ruler, protractor)
- Mixture of any two Types 1-7.

A breakdown of the number of items according to their technical functions per grade level can be found on page 10 of the full report.

The findings are especially worthwhile in considering how students interact and engage with technically-enhanced items. The understanding of how to use and manipulate the technical tools and the kinaesthetic demands of the technical tools were, at times, more influential in task success than the actual mathematics complexity. Tasks with embedded animations and that require the "analyse-reasoning" cognitive processing skills were found to adequately assess numeracy knowledge and skills not easily assessed via traditional paper-and-pencil mode. A list of suggestions for the technical aspect of the test items is provided on page 40 of the report.

Priority Areas

In order to address the scope and intent of the research design, two priority areas were identified. These priorities formed the basis of methodological design and data analysis.

Priority 1: Investigate the cognitive and behavioural engagement as students interact with technically enhanced Numeracy items proposed for NAPLAN online.

Priority 2: Monitor and assess the knowledge, thinking skills and strategies students possess and utilise when solving these technologically enhanced items.

Research Questions

There were five research questions posed for the project.

Priority 1

1.1. Are there design considerations that inhibit or enable students to interact with, and process, these items in a meaningful way?

1.2. What design elements most impact on student access and performance, especially in relation to students' numeracy knowledge and capacity?

1.3. Which items are especially useful to determining students' numeracy understandings across curriculum content areas?

Priority 2

2.1 Which taxonomy features align to the respective technology-enhanced items?

2.2 Which items more adequately assess numeracy knowledge and skills not easily assessed by the traditional item types?

Key Findings and Recommendations

Priority 1

KF1.1: Numeracy and Design demands were found to influence Year 3 and Year 5 students' capacity to engage with items in a meaningful way. The Design aspect influenced students' engagement in Year 7 and Year 9.

R1.1: It is necessary to construct mathematics test items from a "holistic design" perspective which considers the entire representation of the test item (Lowrie, Diezmann, & Logan, 2011), in particular the design aspect related to the technical demands to solve the particular item. The recommendations for each of the identified individual items are provided in detail on pages 13 -22 of the full report.

KF1.2: In general, the students found it difficult to utilise the "Use Drawing Tools" (Type 6) technical function. The majority of the students found using this tool challenging and spent time on items associated with this tool. The Year 5 students found measurement tools challenging to manoeuvre.

R1.2: When changing the test mode from traditional pencil-and-paper mode to digital mode, we should also be cognizant that some items which have worked on pencil-and-paper need not necessarily work well with a mouse on the screen. For example, Measurement Incorporated Item 18230 (this item requires students to draw lines on the screen to partition an irregular shape). More discussion on this item is provided on page 30.

In this study, there was no time limit given for each test item. Students were given time to explore how to use the technical tools for each item. NAPLAN is, however, a timed test. In addition to students' knowledge and skills in numeracy, factors such as test-taking speed and, possible test-taking practices and strategies can influence the test performance and outcome. In addition, presenting NAPLAN in a digital form requires different cognitive demands (more mental and visual processing) and strategizing (decoding information across multiple and different representations). Such demands are challenging. Hence we recommend that instructions on the use of the technical tools, possibly in the form of practice questions, be provided to the students before they commence taking the actual test.

We also recommend that a set of minimum technical requirements for accessing the online tests (e.g., compatible browsers, recommended internet connection speed, recommended screen display, provision of keyboard and mouse, clearing of browser cache before each test administration, etc) be provided to schools so as to ensure the smooth administration of the online tests during the heavy testing periods.

KF1.3: A total of nine items (18%) were found to be useful to determine students' numeracy understandings across curriculum—a majority in Years 3 and 5.

Priority 2

KF2.1: All the items were categorised according to the cognitive processes from the *Taxonomy for computer-based assessment of problem solving* (Mayer, 2002) framework. The majority of the items (51%) were classified as “apply” (the application of executing or implementing a procedure in a problem situation), which is the third construct in a six construct hierarchy. Only 16% of the items were classified as “create” (assemble parts of a problem situation together to find the solution), the highest construct.

R2.1: We recommend more cognitively challenging items involving animation and the “create” construct be included in computer-based test as these cognitive processing skills could not be easily assessed via traditional paper-and-pencil mode. Items involving remembering mathematical definitions and those assessing fluency of computational skills could be easily assessed via the paper-and-pencil mode.

KF2.2: Two items were identified to assess numeracy knowledge not easily assessed by traditional item types. They were, Pacific Metrics Item 5 (Year 5) and Pacific Metrics 12 (Year 9). Pacific Metrics Item 5 assesses students’ spatial reasoning skills in a dynamic environment, while Pacific Metrics Item 12 assesses students’ ability to comprehend changing information in an animation and use their numeracy knowledge to problem solve.

R2.2: We recommend that items such as Pacific Metrics Item 5 and Pacific Metrics Item 12 be included as TEI assessment items. Not only are such items engaging for students as they solve the items during the test, the delivery of such type of assessment items also provide novel opportunities to assess and gather information/data about students’ understanding of mathematics concepts and skills. We provided a suggestion of possible TEI items on pages 36-37 of the full report.

We noted that some of test items included textbook exercise-type tasks involving mathematical definitions (e.g., Pacific Metrics Items 13, 15, both Year 7). Since it is important that the design and selection of test items match the purpose of the assessment (Griffin, 2014), we wonder if items involving application of definitions of mathematical objects (e.g., Pacific Metrics Item 15 Year 9) are appropriate for assessing and determining students’ numeracy knowledge and skills in a national test. After all, the ability to recite definitions does not equate to being able to apply these definitions in problem situations.

Background

Terms of reference

This project investigated the cognitive and behavioural engagement of students with NAPLAN Numeracy items delivered within the new tailored (multi-stage) test design, with a particular focus on technically enhanced numeracy items.

This study:

1. Investigated the cognitive and behavioural engagement as students interact with technically enhanced Numeracy items proposed for NAPLAN online.
2. Monitored and assessed the knowledge, thinking skills and strategies students possess and utilise when solving these technologically-enhanced items.

The technically-enhanced test items were designed by two companies, Pacific Metrics and Measurement Incorporated.

Research design

To understand the ways in which students engaged with technically-enhanced items, a total of 42 cognitive interviews were conducted in Year 3, 5, 7 and 9. Our methodological approach involved both quantitative and qualitative analysis of test items. The quantitative analysis examined the extent to which the proposed technically-enhanced items enabled or hindered students' mathematics engagement on those items. The qualitative analysis looked into students' feedback on the test items. One-to-one hour-long interviews enabled us to map the behavioural engagement of the students in an online environment.

Participants

The four schools participating in the research study are all situated in the ACT region and are from both public and private administrations (refer to Table 1).

Table 1. Participating schools, number of students and data collection schedule

Date	School	No. of students N = 42			
		Year 3	Year 5	Year 7	Year 9
11-12/9/2014	**School A**	6	5	—	—
17/9/2014	**School B**	—	—	4	8
21/10/2014	**School C**	5	5	—	—
28/10/2014	**School D**	—	—	5	4

Profile of students in the study

Participating schools were requested to provide students of varying mathematical capability, that is, low-ability (below 50% in mathematics), average-ability (50-69% in mathematics), and high-ability (top 30% in mathematics). During the interviews, we collected additional information from the students about their mathematical achievements. All Year 3 students who took part in the study said that they like doing mathematics. Most of the Year 3 students mentioned that they either did okay or well in the NAPLAN numeracy assessment. Most of them work out mathematical problems on the online learning resource, *Mathletics*, either in school or at home. Some students' parents give them additional mathematics tasks to work on at home.

All but three of the ten Year 5 students who participated in the study said that they like mathematics. Like the Year 3 students, they said that they either did okay or well in the NAPLAN numeracy assessment. Most of them have *Mathletics*, either as a classroom activity or for homework. One student said that he did not find *Mathletics* fun. None of them did any other mathematics tasks at home other than those given by their teachers for homework.

Six of the seven Year 7 students who took part in the study said that they enjoyed doing mathematics. Four students said that they did well in the NAPLAN numeracy assessment and three students said that their recent NAPLAN numeracy scores were in the top bands. All of them have *Mathletics*, either as a classroom activity or for homework. None of them did any other mathematics tasks at home other those given for homework.

All Year 9 students said that they enjoyed doing mathematics; one student said she did not like algebra. Out of the twelve Year 9 students who participated in the study, one student did not sit for the recent NAPLAN numeracy assessment; seven students said that their scores were in the top bands for the NAPLAN numeracy assessment, and the rest said that they did okay for this national assessment. Among the seven students who said that their NAPLAN numeracy scores were in the top bands, two students have a parent each who helps them in their homework and monitors their schoolwork progress. Eight students said that they work on Mathletics either in school or at home as homework. Four students said that they did not work out mathematics problems on the computer at home.

Data collection instruments

Students were individually interviewed and their responses were video-recorded to allow retrospective analysis. The videos provided evidence as to the level of engagement the students had with the technical tools in the test items, both in terms understanding the mathematics tasks as well as the ease of use of the technical tools to answer the tasks.

An accompanying open-ended questionnaire/observational grid based on the test items was also designed to capture as much information as possible during the one-hour interview. Prior to the design of the instrument, we analysed each test item with regard to its technical tool design. There were two versions of the open-ended questionnaire/observational grid. The first version included all 14 test items for Year 3 and all 12 items for Year 5. During the data collection at the first school, School A, it was observed that insufficient instructions on how to use the technical tools in the test items and some students from School A (first school of data collection) spending time on manipulating certain technical tools (e.g. drawing tool) resulted in students not being able to complete the entire set of 14 items with the allocated 1-hour interview hour. The open-ended questionnaire/observational grid was thus revised to two sets – Set A and Set B. Both sets consisted of a proportional number of items from Pacific Metrics and Measurement Incorporated. Items where the technical tools were observed to be challenging to the students were included in both Sets A and B.

The interviews were conducted by four experienced interviewers who had been working with children across primary and secondary schools. Although one hour was allocated to the interviews, often the latter would take a couple of more minutes. We chose to give students as much time as possible to understand the challenge that they encountered and to gather as much information about their views on the technically-enhanced items. Following one set of interviews, members of our team discussed about the salient findings which enabled us to identify patterns of student behaviour when solving the technically-enhanced items

Framework for categorising test items

The technically enhanced items were categorised using Mayer's (2002) *Taxonomy for computer-based assessment of problem solving*. Specifically, the cognitive processes aspect of the framework was utilised in order to better understand the alignment of the assessment items with their objectives and identify items that would best suit this technical enhancement.

Cognitive processes of Mayer's framework for analysing the design of tasks

Six types of cognitive processes	
Remember	Recognizing and/or recalling information from long term memory.
Understand	The meaning and sense making associated with interpreting, classifying, inferring, and comparing
Apply	The application of executing or implementing a procedure in a problem situation.
Analyse	Involves differentiating, organizing or attributing essential information and working with the relation among these parts to solve the problem.
Evaluate	The verification of the soundness of an approach used to solve a problem.
Create	Assembling parts of a problem situation together to find the solution.

Ethical considerations

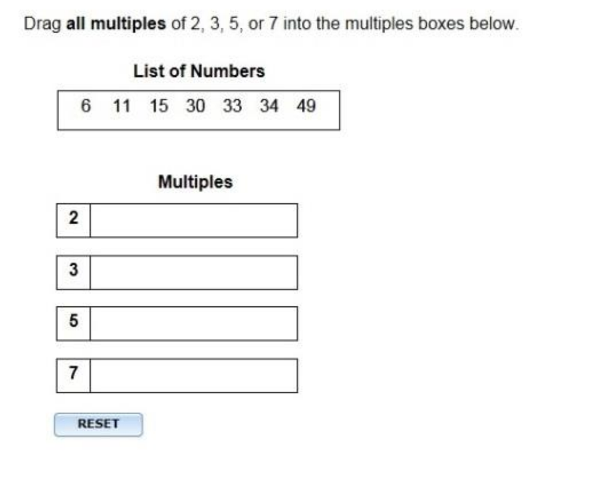
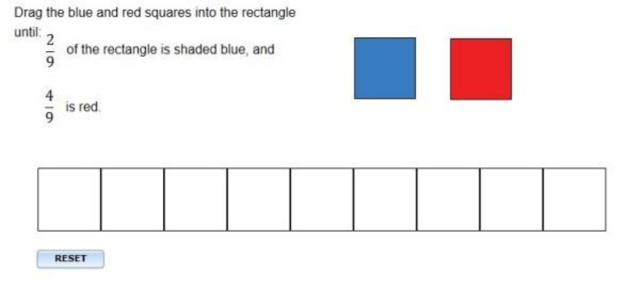
Initially, principals of the selected schools were invited to take part in the research study. Once permission was sought from the principals, the respective schools identified students who were of varying mathematical capability, that is, low-ability (below 50% in mathematics), average-ability (50-69% in mathematics), and high-ability (top 30% in mathematics). These students were asked to participate in an interview involving completion of NAPLAN items in a digital format and to explain their responses. The research took place at the school, and was administered by UC researchers with postgraduate higher degrees in mathematics education and current Working with Vulnerable People checks. Interviews took no longer than 1¼ hours. They were video recorded with the lens directed toward the test instrument and no identifying images of the children were captured.

Participation in this study was voluntary and students were free to withdraw at any time. Informed consent was collected from all parents/caregiver of the participants. There were no out-of-the-ordinary risks associated with this research and there was no discomfort to the students. In all reporting of the research and any publications, the identity of the students and the school will be anonymous. The project has ethical clearance from the University of Canberra (no. HREC 14-159).

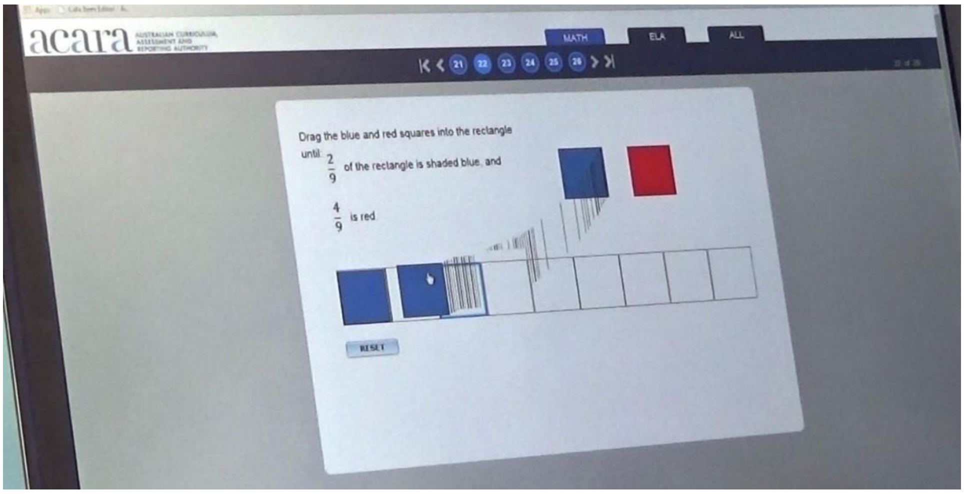
The Test Items

Appendices A, B, C and D show the details of the Year 3, Year 5, Year 7 and Year 9 items respectively.

We would like to bring to your attention that the following two test items – Pacific Metrics Items 8 and 22 – were moved from the suggested Year level 5 to Year 3 as the content of these two items had already been taught at the Year 3 level. In addition, as there were no specific instructions on how to use a number of the technical tools, some Year 5 students in the first school of data collection, School A, were taking more time to understand how to manipulate the technical tools in the Year 5 items. Hence more duplicate items had to be placed in both Set A and Set B of the open-ended questionnaire/observational grid for Year 5, as compared to that for Year 3.

Pacific Metrics Item 8	Pacific Metrics Item 22
	

We found that the Year 3 students in general were able to handle these two items successfully. For Item 8, the students understood and were able to explain what "multiples" mean. They were able to answer this task in general, missing out listing a number or two in some rectangles. We wonder whether there were probably too many numbers (i.e., List of Numbers) in the task and this may have caused the students missing out placing the numbers in the appropriate boxes. We discuss this further in the "Addressing the Research Questions" section. For Item 22, all but one Year 3 student answered the item correctly. Hence, this item is suitable for assessing Year 3 students. We noted that there were traces of black vertical lines that follow the squares when they are dragged into the rectangle. A screenshot is shown below:



Categorisation of the Test Items

The technically-enhanced test items were designed by two companies, *Pacific Metrics* and *Measurement Incorporated*.

The test items were categorised according to the technical function(s) as follows:

- Type 1: Key in Answer in the Box(es) provided
- Type 2: Pull-down Menu
- Type 3: Click to Choose
- Type 4: Click and Drag
- Type 5: Click to Place
- Type 6: Use Drawing Tool (draw circle, line of best fit, parabola, etc)
- Type 7: Use Measurement tools (cm-ruler, inch-ruler, protractor)
- Type 8: Mixture of any two Types 1-7.

Table 2 shows the breakdown of the items according to their technical functions per grade level.

Table 2. Breakdown of the items according to their technical functions by year level.

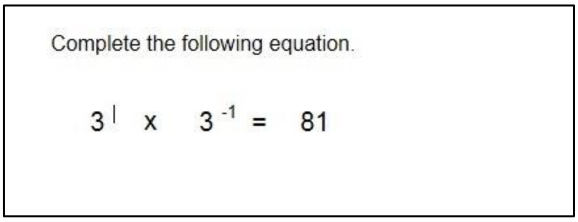
Technical tool categorisation	Number of items			
	Year 3 (n=13)	Year 5 (n=12)	Year 7 (n=12)	Year 9 (n=12)
Type 1: Key in answer box	MI 18153 MI 18171	—	MI 18192	MI 18227
Type 2: Pull-down menu	—	—	PM 13 PM 14	PM 15, PM 16, PM 18, MI 18232
Type 3: Click to choose	PM 5	—	—	—
Type 4: Click and drag	PM 1 PM 3 PM 8 PM 22	PM 4 PM 9 PM 10 MI 18196	PM 7 PM 17 MI 18183 MI 18181a MI 18181b	PM 12
Type 5: Click to place	MI 18188	PM 6 MI 18175 MI 18190 MI 18174a MI 18174b	—	MI 18229
Type 6: Use Drawing Tools	PM 2 MI 18167	—	PM 24 MI 18191 MI 18187 MI 18186	PM 20, PM 21
Type 7: Use Measurement Tools	—	—	—	—
Type 8: Mixture of any two Types 1-7	MI 18173 (Type 7+1) MI 18152 MI 18606 (Type 6+5)	PM 23 (Type 5+2) MI 18176 (Type 7+1) MI 18189 (Type 4+2)	—	MI 18230 (Type 6+1) MI 18233 (Type 4+2) PM 19 (Type 6+5)

Note: PM refers to Pacific Metrics, and MI refers to Measurement Incorporated.

Technical Issues during Data Collection period

Issue 1:
We observed that the Measurement Incorporated test items could not be completed loaded in the Microsoft Internet Explorer Ver 11.0. Hence, the web browsers used during the data collection were Chrome (Windows-based laptops) and Safari (Mac laptops).

Issue 2:
We observed that the Pacific Metric test item, Item 25, could not work on Chrome at times, that is, the answer-cell was not working, hence students were unable to key in their answer.



Issue 3:
We observed that the Measurement Incorporated items were taking some time to load after each item from the main menu of items was clicked upon. As a result, time was spent waiting for the items to load before the student could read and answer the item.

Issue 4:
Table 3 noted the issues with accessing the test items during the data collection period.

Table 3. Participating schools and the technical issues encountered during Cognitive Interviews.

Date	School	Issue	Other Notes
12/9/2014	**School A**	The unavailability of the Measurement Incorporated test items (for 1 student)	The laptop used was the researcher's office laptop (Windows-based). The student was then asked to work on Pacific Metric items.
17/9/2014	**School B**	Unavailability of the Pacific Metrics test items during the first half of the data collection session (for 3 of 4 students taking the interviews). Some Measurement Incorporated items involving the Type 2 (Pull-down menu) could not load completely.	The laptops used were from the school (Mac). Students were asked to work on other Measurement Incorporated items. Students were asked to skip those Type 2 (Pull-down menu) items.
21/10/2014	**School D**	The unavailability of the Measurement Incorporated test items for approximately 15 minutes (for 1 of 2 students taking the interviews).	The laptop used was the researcher's office laptop (Windows). The Student was then asked to work on one Pacific Metric item before going back to work on the Measurement Incorporated test items.

Addressing the Research Questions

The following sections address the five research questions in the two priority areas.

Priority 1

Are there design considerations that inhibit or enable these students to engage with these items in a meaningful way?

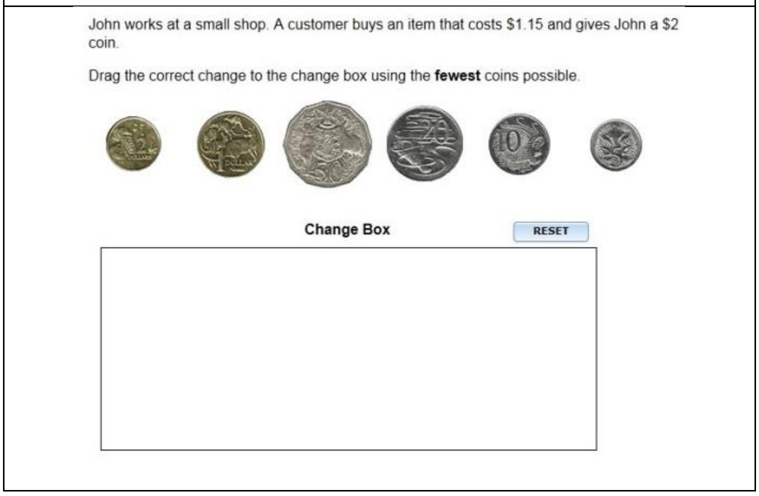
Students' cognitive processing was analysed in relation to elements that either enabled or inhibited meaningful engagement with the items. For the Year 3 and 5 students, there were both numeracy aspects and design aspects and for the Year 7 and 9 students, it was predominantly the design aspects that influenced engagement.

YEAR 3

We found the numeracy and design demands contributed to student being able to engage with the respective items in a meaningful way.

NUMERACY ASPECT

Pacific Metrics Item 1



Not surprisingly, the numeracy (content) demands of this task were influential in whether or not students were able to correctly solve the task. The students in the sample were generally able to manage the literacy demands (e.g., "fewest coins possible") and consequently their knowledge on which operation to apply determined success. Students who could not successfully solve this item made computation errors in their subtraction ($2 – $1.15).

We give a suggestion to rephrase this item as the first sentence, "John works at a small shop" is extraneous information which does really not play any role in calculation of the answer. We suggest that the item could be rephrased more succinctly, as follows:

John buys an item that costs $1.15 and pays for it with a $2 coin.
How much change did John get/receive?

Using the **fewest** coins possible, drag the change John got/received to the Change Box.

DESIGN ASPECT

From a design perspective, two items were found to influence students' engagement with the task – Measurement Incorporated Item 18171, and Pacific Metrics Item 8.

Measurement Incorporated Item 18171 – InLine text Boxes/pattern

A pattern is formed by subtracting the same number each time.

Enter the next three terms of the pattern in the table.

Term	Number
1	65
2	59
3	53
4	
5	
6	

Reset

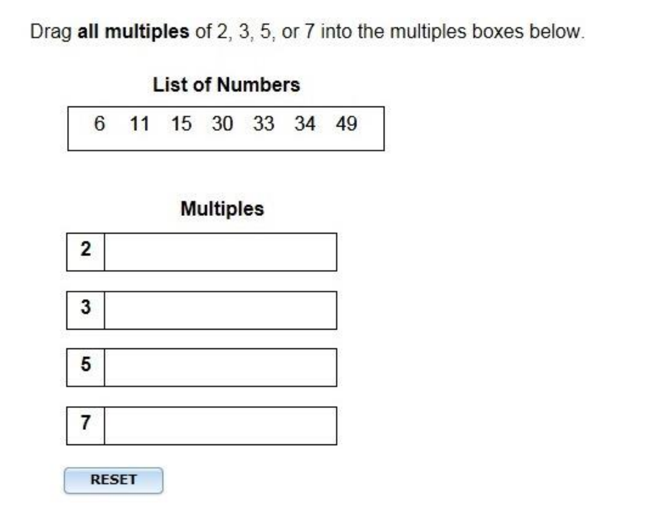
The design of Measurement Incorporated Item 18171 was quite influential in whether students were able to solve this item successfully. Students who were unsuccessful in solving this item did not understand the meaning of the word, "Term" in the table. Although how the pattern works is already indicated in the sentence, "A pattern is formed by subtracting the same number each time", the font size was much smaller than that in the table, resulting in the students focusing on the numbers in the table.

In addition, the pattern was represented in a vertical manner, rather than in the horizontal format. Students in the study indicated that they were more familiar with the horizontal format taught at school. Hence, there may be less confusion for the students if the representation of the item was as follows:

Fill in the blanks to complete the pattern:

65, 59, 53, □ , □ , □

Pacific Metrics Item 8



For the Pacific Metrics Item 8, the students understood and were able to explain their understanding of "multiples". Generally, they were able to answer this task, with a few students missing out listing a number or two in some rectangles. We wonder whether there may have been too many numbers (i.e., List of Numbers) in the task and this caused the students to miss out placing the numbers in the appropriate boxes. We also noted that each number in the List of Numbers remain in that list after that number has been dragged and placed into a Multiples-box. This is so, for example, "6" can be placed in the "Multiples 2-box" as well as in the "Multiples 3-box". This "retention" of the number after it has been dragged away, in addition to the long list of numbers, may have caused students to miss out placing all the relevant numbers into their relevant boxes.

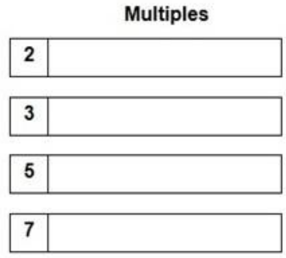
As the objective of the task was to assess students' understanding of the *multiple* concept, we suggest to reduce the List of Numbers from seven to five: 6, 11, 15, 34, 49. We also noted that some students accurately allocated the number "49" to the "Multiples 7-box" via the elimination method, that is, 49 is not a multiple of 2, 3, and 5. They then checked whether 49 is a multiple of 7 by using the counting-on strategy, that is, 7, 7+7 = 14, 14+7 = 21, ...

To reiterate, since the objective of the task was to assess students' understanding of the *multiple* concept, another alternative design that we suggest is shown below. In this alternative design, we suggest that each number from the list "disappears" once it is drag into any box.

Look at the list of numbers below:

4, **9, 11**, **27**, **49**

Drag all multiples of 2, 3, 5, or 7 into the multiples boxes below.

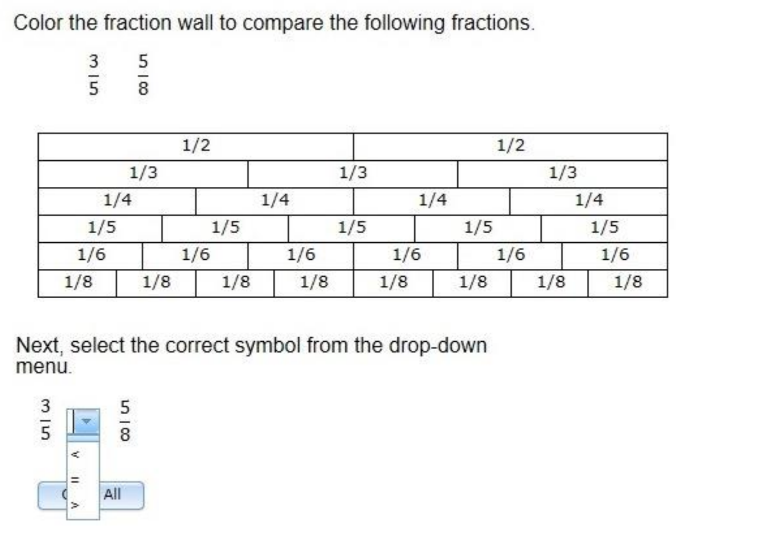


YEAR 5

We found the numeracy and design demands contributed to Year 5 students being able to engage with the respective items in a meaningful way.

NUMERACY ASPECT

Pacific Metrics Item 23

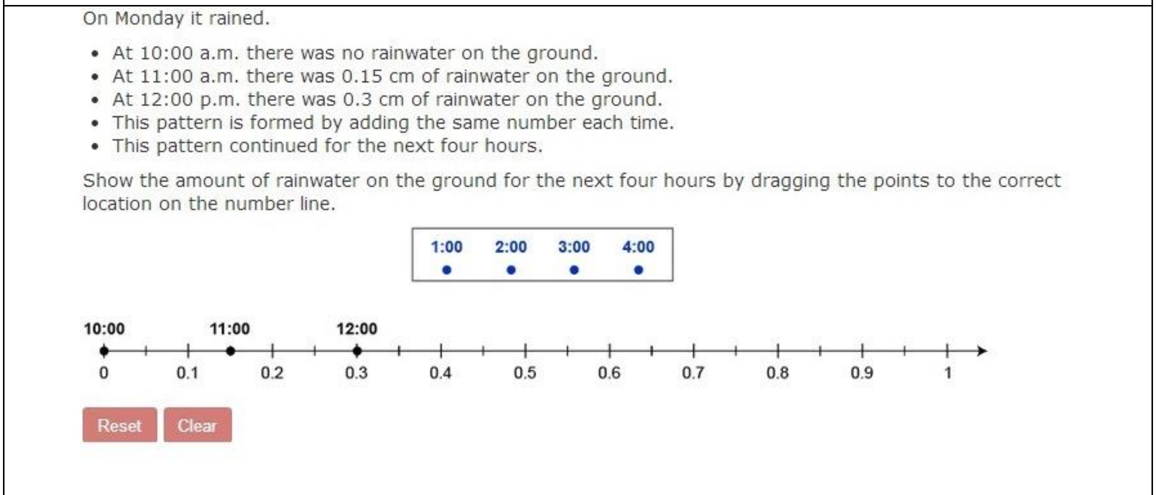


This task involved interpreting and using a fraction wall to determine the relationship between two fractions, $\frac{3}{5}$ and $\frac{5}{8}$. The graphic (fraction wall) helps students to visualize the sizes of the two fractions and thus aids in determining the answer to the task. Students who attempted this item were able to solve this task successfully. We give a suggestion to relabel the fractions in the fraction wall so that there is consistency in how the fractions are presented in both the graphic and the item stem. Specifically, we suggest that the fraction representing half, for example, be presented as "$\frac{1}{2}$" instead of "1/2". Presentation in this way also helps students to see the relationship between the part (i.e., 1) and the whole (i.e., 2) better.

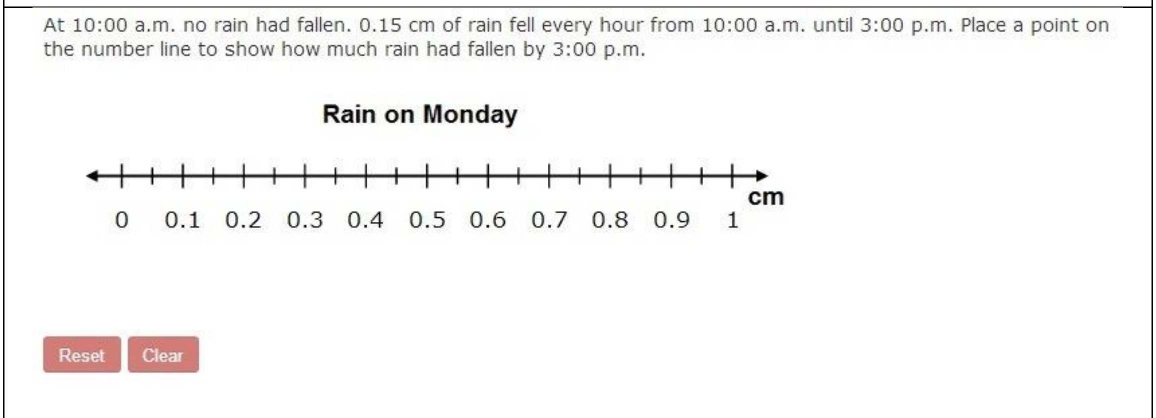
DESIGN ASPECT

In this Design aspect, two items were found to influence students' engagement with the task – Measurement Incorporated Item 18174b, and Measurement Incorporated Item 18190.

Measurement Incorporated Item 18174b – Select Points/Rain by Hours

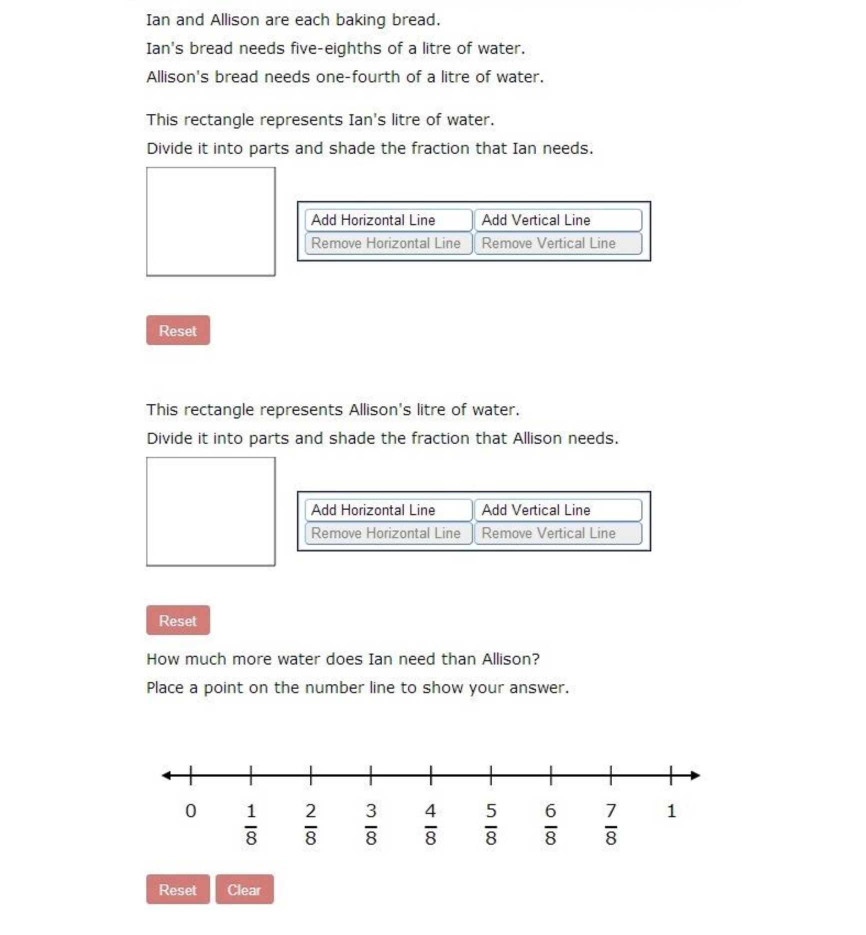


Measurement Incorporated Item 18174a – Select Points/Rain by Hours

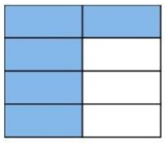
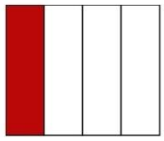


The design of this task was influential in the approach taken by students to answer the item. A parallel item (with a different representation), Measurement Incorporated Item 18174a – Select Point/Rain by Hours, required students to compute the amount of rainfall at a certain given time using the given pattern of rainfall. Unlike the parallel item, for the Measurement Incorporated Item 18174b, majority of the students did not need to engage with the amount of the rainfall at different time intervals provided. Neither do they need to compute the amount of rainfall for the next four hours (It is stated in the item: “This pattern continued for the next four hours”.) Majority of the students observed that there was a pattern of an interval of 1½ spaces in between marked times, and proceeded to place the four points (for 1:00, 2:00, 3:00, 4:00) along the number line with 1½ space-intervals in between them. Questions were raised about the intended assessment objective for this item. This example highlights the challenges involved in designing technically enhanced items in the sense that the multiple forms of information actually allow the students to process information with the support of scaffolds embedded within the item. That is, the task had an unintended consequence of allowing students to use a pattern arrangement to organise information rather than decoding the item in a more sophisticated. Item 18174a, despite its relatively sparse information, required higher levels of processing (from apply to analyse) and more specifically assesses students measurement sense.

Measurement Incorporated Item 18190 – Partition Shapes/Baking Bread



In this item, the problem solver is required create pictorial representations of $\frac{5}{8}$ and $\frac{1}{4}$ to solve the problem. Students who were successful in solving this item created pictorial representations of $\frac{5}{8}$ and $\frac{1}{4}$ that were visually similar that enabled them to use to solve the task. We wonder had the two fractions been represented in the following way, for example,

 and 

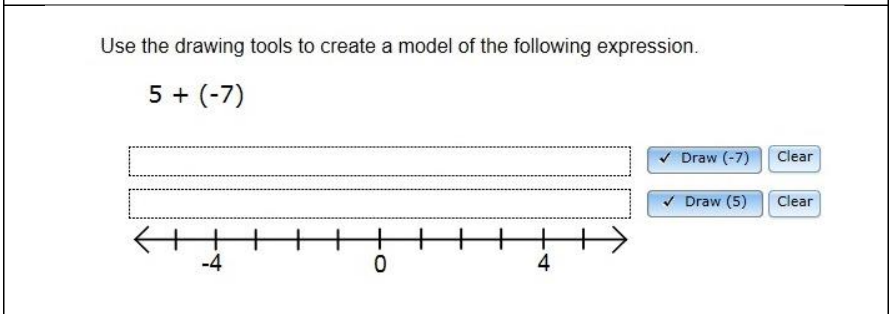
how useful will these two representations be to solve the problem? Hence the main concern for this item is: What is the objective of this item?

YEAR 7

We found the design demands contributed to Year 7 students being able to engage with the respective items in a meaningful way.

DESIGN ASPECT

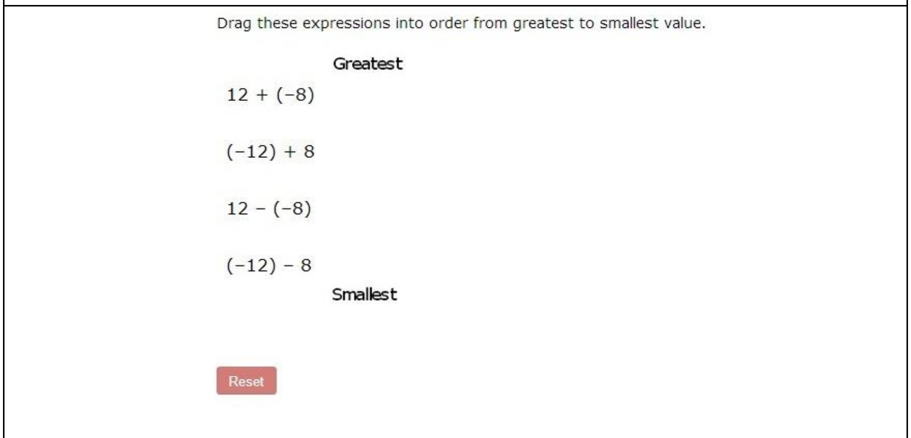
Pacific Metrics Item 24



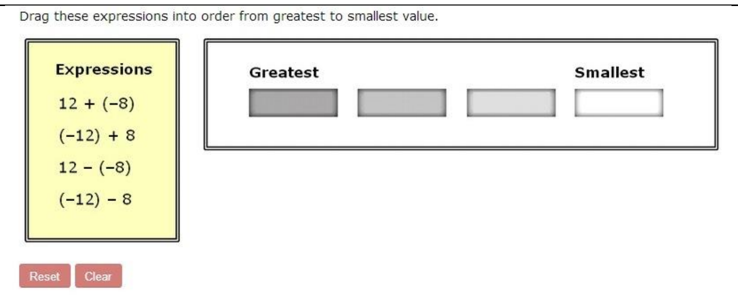
This task involved representation of the expression 5 + (–7). Whilst majority of the students knew how to compute the answer to the expression, they did not know what model they were required to draw for the expression. The model provided in the answer key is not taught in the classrooms. Again, questions were raised about the intended assessment objective for this item.

We would like to bring to your attention the following two items:

Measurement Incorporated Item 18181a – Classification/Order of Expressions



Measurement Incorporated Item 18181b – Classification/Order of Expressions



These two items are exactly the same in terms of content and differ only in the way they are presented. In Item 18181a, students are required to reorder the expressions from greatest to smallest in a vertical format. In item 18181b, students reorder the same set of expressions from left to right (horizontal format). Students were asked to solve both items and their opinions regarding the items were sought. All students said that they preferred Item 18181b for two reasons: (1) The layout is clearer, and (2) It is easier to click and drag each expression into the given boxes along a horizontal format.

The following shows students' verbatim comments:

Students' verbatim comments:

(About Item 18181a) *The technology is hard to manoeuvre.*

(About Item 18181a) *It is difficult to change the order* (of the expressions).

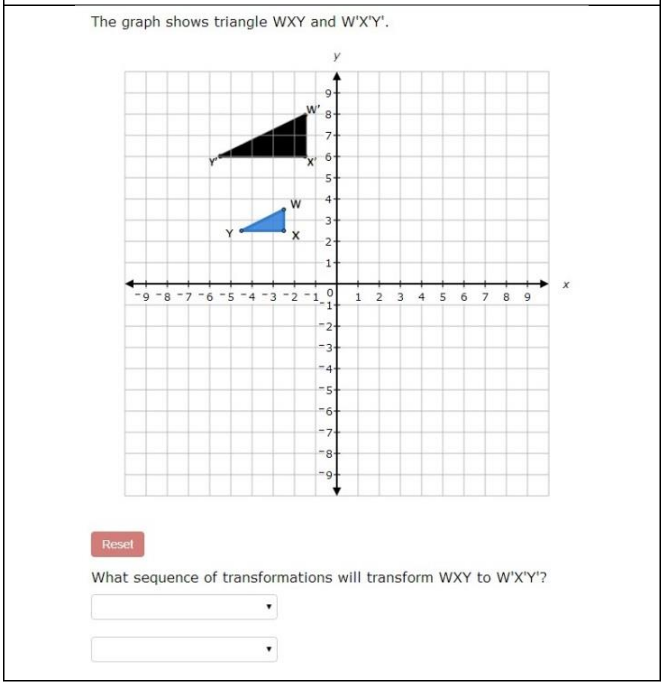
(About Item 18181b) *Clearer and easy layout.*

(About Item 18181b) *This layout was a lot better* (student was comparing to Item 18181a).

YEAR 9

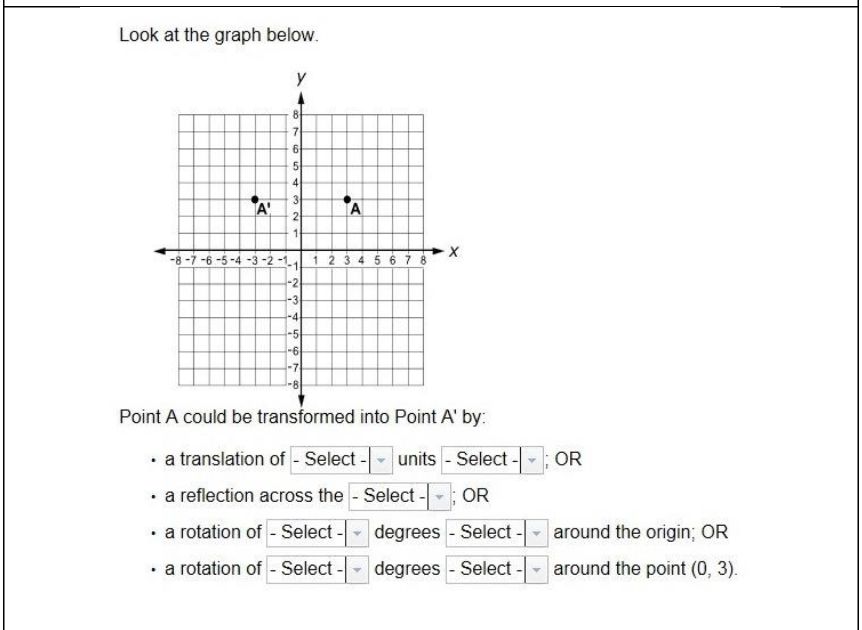
We found the design demands contributed to student being able to engage with the respective items in a meaningful way.

Measurement Incorporated Item 18232 – Object transform/Similar Triangle



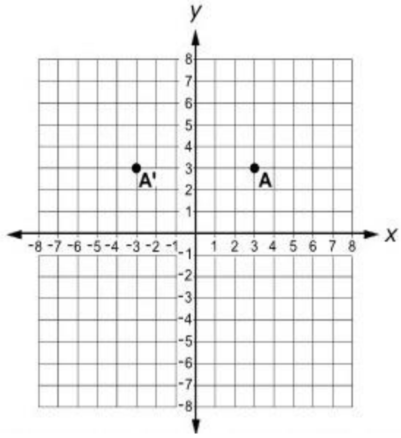
In this item, for the second sequence of transformations, there is no correct answer from the list of 6 options available. The answer of “Translation y + 4” provided in the answer key is incorrect. The majority of the students found it challenging to keep scrolling up and down in order to look at the diagram and the options from the Pull-down Menus.

Pacific Metrics Item 16



For this item, the wording, "OR" was confusing to the students. They did not know whether they should answer all the four parts to the item or just choose one part to answer. We suggest the item could be rephrased in the following manner:

Look at the graph below. Answer all parts (a) – (d).



Point A could be transformed into Point A' by:

(a) a translation of - Select - units - Select - .
(b) a reflection across the - Select - .
(c) a rotation of - Select - degrees - Select - around the origin.
(d) a rotation of - Select - degrees - Select - around the point (0, 3).

Pacific Metrics Item 18

Solve this equation for *x*. Show at least **three** steps.

3(2*x* - 9) = 27

Step	Solution
Given	3(2*x* - 9) = 27
1	- Select Step 1 -
2	
3	
4	

- Select Step 1 -
None
5x - 12 = 27
6x - 27 = 27
6x = 54
6x - 9 = 27
x = 6
2x - 9 = 9
x = 9
6x = 36

RESET

For this item, we wonder whether changing the design of this item to allow students to solve the given equation for x using their own solution steps be more appropriate for assessing their mathematical knowledge and skills. We noted that the instruction stated, "Show at least three steps".

We wonder the reason for this instruction since using the options in the pull-down menu only limits the solution method to only three steps, for example,

Step 1: 6x – 27 = 27
Step 2: 6x = 54
Step 3: x = 9
Step 4: None

We also observed that the current design limits students to solve the equation for x in only one way. There are many ways to solve the equation for x, for example,

<u>Example 1</u> (using 3 steps)
Step 1: 2x – 9 = 9
Step 2: 2x = 18 (this is not an option in the pull-down menu)
Step 3: x = 9,

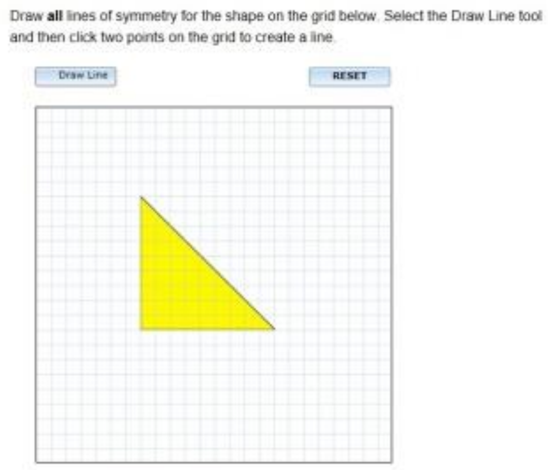
<u>Example 2</u> (using 4 steps)
Step 1: 2x – 9 = 9
Step 2: 2x – 9 + 9 = 9 + 9 (this is not an option in the pull-down menu)
Step 3: 2x = 18 (this is not an option in the pull-down menu)
Step 4: x = 9

What design elements most impact on student access and performance, especially in relation to students' numeracy knowledge and capacity?

YEAR 3

The following two technical tools were found to most impact students' access and performance: Type 6 (Use Drawing Tool), Type 4 (Click and Drag).

Pacific Metrics Item 2



The Drawing Tool (Line) in the task was highly influential in determining the performance in the item. All students in the study found it challenging to draw a line using the Drawing Tool (Line). The following shows students' verbatim comments about their experiences using the Drawing Tool.

Students' verbatim comments:

Difficult to use. The line does not go in the spot you want it to go.

A bit hard to draw line.

It is not clear how to draw the line because it does not tell us how to do it.

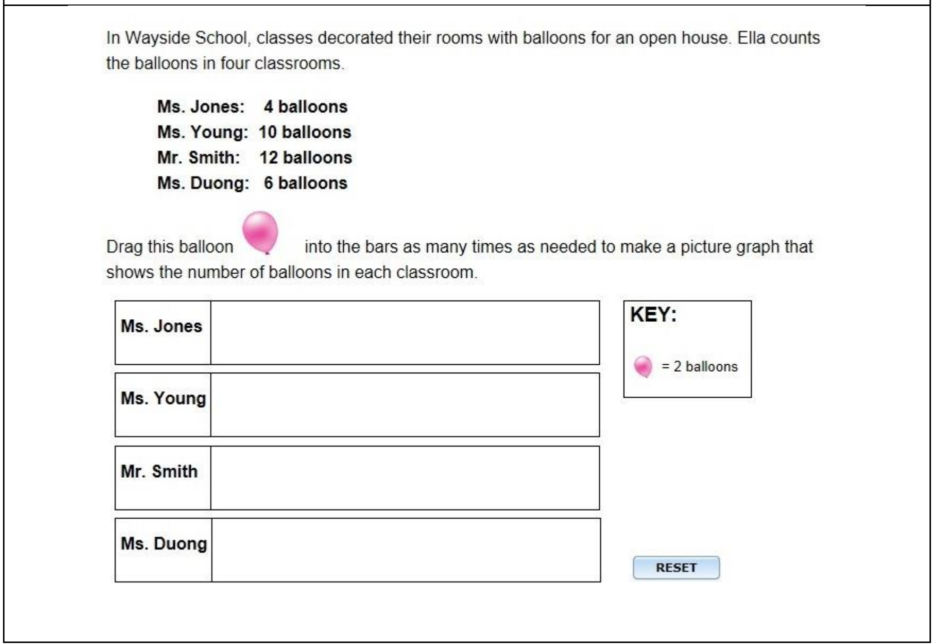
A bit fiddly. Hard to connect the lines.
(Note: This student attempted to draw lines to trace the shape of the triangle.)

We also note that a CLEAR button is not available for this item. Thus, for students who drew more than one line of symmetry, they were not able to clear away only one line as the RESET button clears away all answers.

A student's verbatim comments:

Tricky! Line does not delete easily!

Pacific Metrics Item 3



In this task, many students either did not notice the Key to the picture graph, or when they did notice the Key they did not understand what it meant. The length of each rectangle is only long enough to fit in 8 balloons. Hence, students who did not notice or understand the Key to the picture graph, attempted to, for example, place 10 balloons in the Ms. Young-box. Since each box could only fit in 8 balloons, this caused some confusion for these students when they were not able to drag all 10 balloons into the Ms. Young-box. In some instances, when the student tried to, for example, add in the 9th balloon into a box, the first balloon (already placed in the box) moved into the edge of the box and disappeared out of sight, thus giving the student the impression that he/she could continue adding as many balloons as he/she liked since the previously placed balloons were just "moving into the box".

Student's verbatim comments:

Ms. Young has 10 balloons and I can't fit in 10 balloons.

Maybe you can make the balloons smaller so that you can fit them (balloons) into it (box).

This question is hard because need more space to put the balloons.

We need to be able to see all the balloons.

We suggest that the length of the boxes be lengthened. In this way, we will be able to identify students who did not understand or ignored the Key to the picture graph. In such an instance, students will drag the exact same number of balloons into the boxes as given in the task.

We would also like to note that care be taken when using colours in test items. A student did not want to fill in any balloons into Mr. Smith's box.

> A student's verbatim comments:
>
> *Mr. Smith is a boy. He wouldn't like pink (a pink balloon).*

We observed that a number of students did not notice the balloon in the Key. We would also like to suggest that the font size of the Key be increased, and that the balloon in the Key be the same size as the one that the student is required to drag into the box.

> A student's verbatim comments:
>
> *If you have it (the Key) bolder, you can see it more clearly.*

We would like to bring to your attention the following task which is similar to the Pacific Metrics Item 3 discussed above in that it also assesses the Pictograph concept.

Measurement Incorporated Item 18188 – Pictographs/Tyres

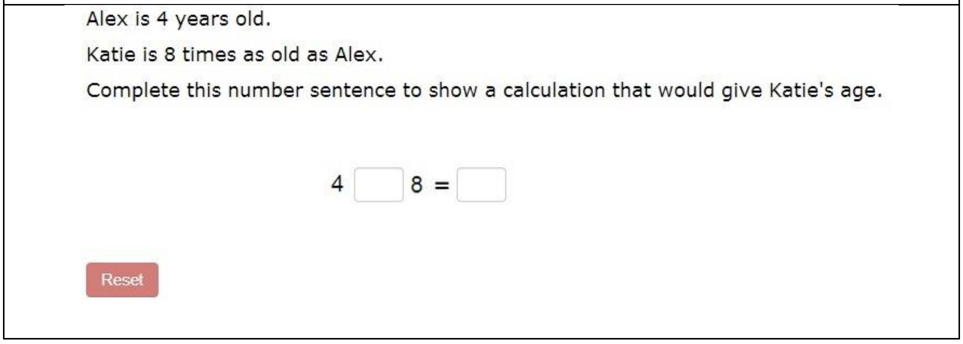
This table shows how many tyres were sold by a shop in the first six months of the year.

Month	Tyres Sold
January	16
February	14
March	8
April	10
May	14
June	8

Complete the pictograph to represent the data from the table.

Students in general preferred this design as they needed only to click the mouse to create the object, which they found easier than dragging the object into the box. We would like to note that this task, unlike the Pacific Metrics item 3 does not have the issue of insufficient length of box. However, as the Key indicated that "O = 4 Tyres", thus half of "O" represented 2 tyres. Visually "O" looks like 1 tyre. This visual representation caused some confusion with some students who indicated that it was troublesome to click twice in order to be able to create one tyre. We observed that this visual representation affected some students' performance to solve the task successfully.

Measurement Incorporated Item 18153 – InLine Boxes/Alex and Katie



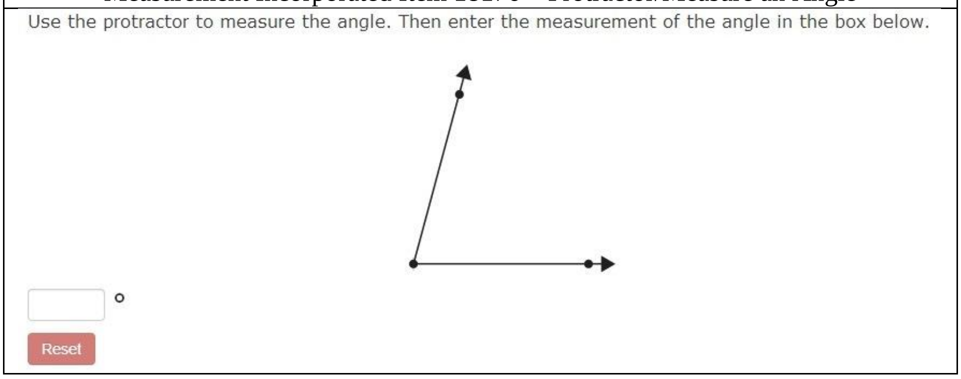
For this item, many students could not find the multiplication symbol on the computer keyboard to key in their answer. Hence the design of the item inhibited students from solving the task successfully. A handful of students wondered if they could use the letter “x” on the keyboard to represent the multiplication symbol. We also note that students who erroneously thought that the operation should be a “÷” could not find the division symbol on the computer keyboard. We suggest that the symbols for the four operations (+, −, × and ÷) could be provided for students to Click and drag (Type 4) into the relevant box in the number sentence.

YEAR 5

The following technical tool was found to most impact students’ access and performance:

Type 6 (Use Drawing Tool).

Measurement Incorporated Item 18176 – Protractor/Measure an Angle



For this task, although majority of the students answered this item correctly, they found it challenging to use this measurement tool (protractor) tool, in particular, to align the protractor to the given angle on the screen. A hand-full of students also commented that they were more used to using the hands-on protractor. The following shows students’ verbatim comments about their experiences using the protractor.

Students' verbatim comments:

To put it (protractor) in the right position – not very easy.

The protractor's numbers bigger.

Everything bigger (referring to lines and numbers on protractor).

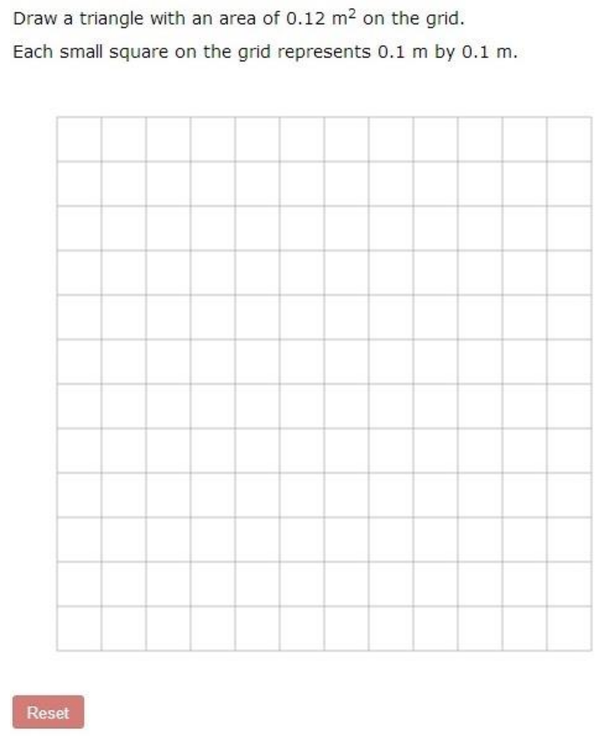
Label the tools (Student could not find the protractor tool).

YEAR 7

The following technical tool was found to most impact students' access and performance:

Type 6: Use Drawing Tool (Line)

Measurement Incorporated Item 18187 – Vertex Based Triangles/Triangle Area



For this item, the technical setup impacted students' interaction with the Drawing tool (line) and problem-solving process. As there was no indication of the availability of the Drawing Tool, a handful of students asked how they could draw the triangle. In addition, the Reset button clears away whatever has been drawn. There was no Clear button option to select and clear away any parts of the triangle which the student would like to change. A student also commented that it felt different drawing lines on the screen as compared to the usual drawing of lines using pencil-and-paper. Specifically, he noticed that he needed to just click three times to place three dots and the lines of the triangle would be automatically generated. He suggested that the tool be modified to clicking and dragging the line in the same manner as how a line would be drawn on pencil-and-paper.

The following shows students' verbatim comments:

> Students' verbatim comments:
>
> *But when we have to reset, it resets everything. We need a Clear button that allows you to clear only one line.*
>
> *Would have been nice to have instructions how to draw it.*
>
> *We have to scroll down and we can't see the words (instruction) when we do the working.*
>
> *Need to scroll. Better all in one screen.*

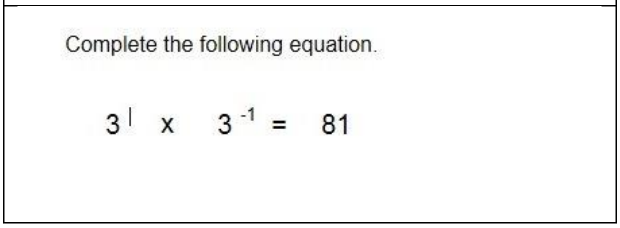
YEAR 9

The following technical tools were found to most impact students' access and performance:

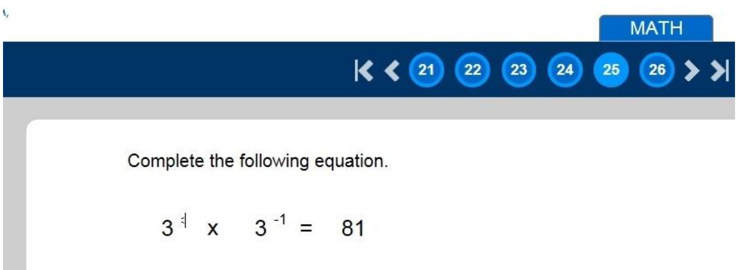
(a) Type 1: Key in Answer in the Box(es)

(b) Type 6 (Use Drawing Tool)

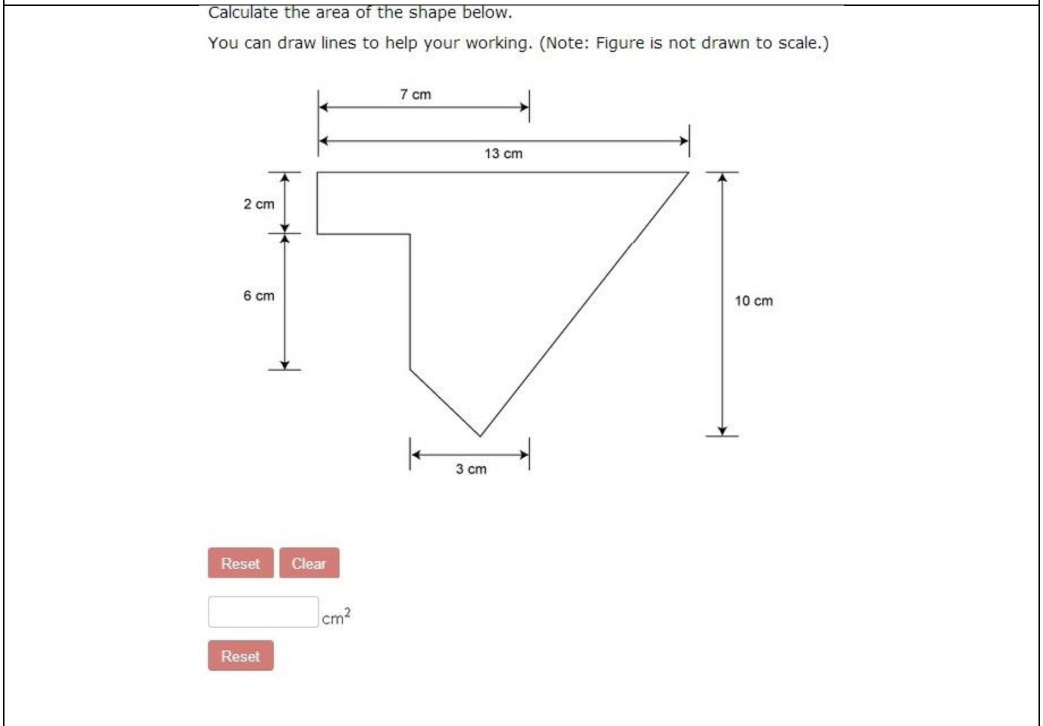
Pacific Metrics Item 25



The technical setup of this item is of concern. Unlike other items of Type 1 (Key in answer in the box(es)), there is only a short vertical line to indicate the position to key in the answer. Some students did not notice this short vertical line and asked what they needed to do. We observed that it is not possible to key in a 2-digit answer. If a 2-digit answer is keyed in and the back-space is used to delete the answer, the "new" answer cannot be keyed in. A screen shot of this technical issue is shown below. In this screen shot, "12" (2-digit number) is keyed in as the initial answer, and backspace was used to delete that answer.



Measurement Incorporated Item 18230 – Straight Lines and In Line Text Box/Area



Unlike other items that require the Drawing Tool, there was no indication of a Drawing Tool (line) in the form of a button for this item. In addition, all students, except one, found drawing lines to partition the shape challenging. The Drawing Tool (line) hindered the problem-solving process of the students. They preferred to solve this item on pencil-and paper. The student who was able to use this drawing tool successfully plays with many computer apps at home.

When changing the test mode from traditional pencil-and-paper mode to digital mode, we should also be cognizant that some items which have worked on pencil-and-paper need not necessarily work well on the screen and using a mouse.

Students' verbatim comments about this item are shown below:

Student's verbatim comments:

Easier to use actual ruler and pencil.

Make the diagram a little bigger to make it easier to draw (the lines).

Need to scroll down to find the answer box. Better to put next to diagram.

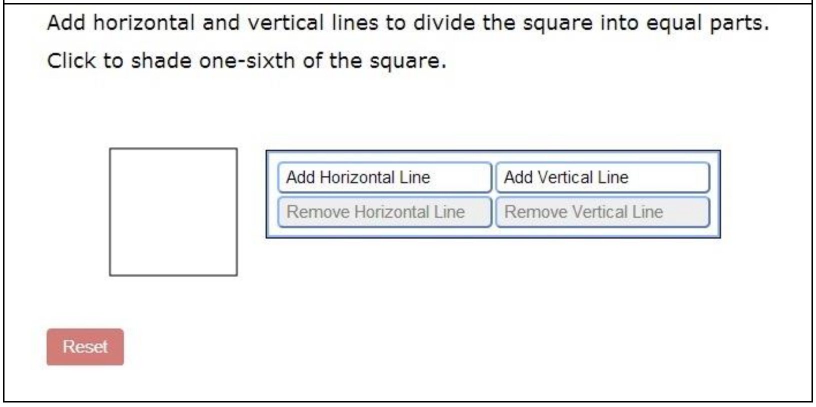
Appendix E provides details of students' responses (across grade levels) towards the technical tools in items that involve creating graphs (picture graph, column graph/bar graph, histogram) and items that involve the use of the Type 6 Drawing Tool (involving creating lines).

Which items are especially useful to determining students' numeracy understandings across curriculum content areas?

YEAR 3

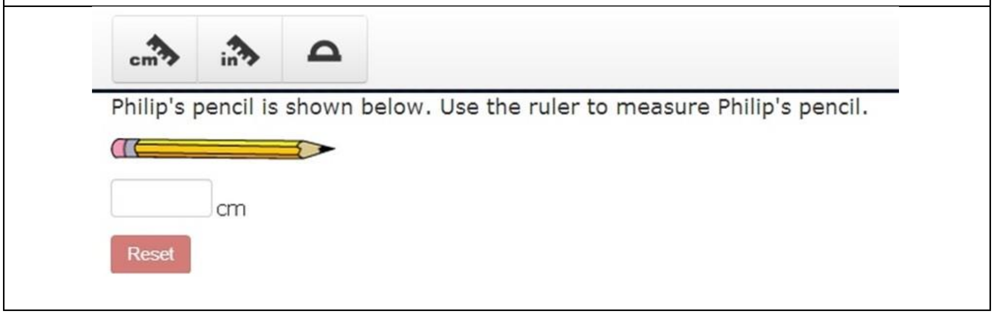
Four items were found to be useful to determine students' numeracy understandings across curriculum content areas.

Measurement Incorporated Item 18167 – Partition Object/One-sixth



This task requires students to draw their own partitions in the square to create a fraction, one-sixth. As the students in the study pointed out, this task is different from those they have seen at school as school tasks usually have the partitions already drawn and just require students to shade in the fraction. Getting students to draw their own partitions in the diagram to represent unit fractions in particular, one-sixth, is definitely useful to assess students' understanding of the unit fraction concept.

Measurement Incorporated Item 18173 – InLine TextBox/Meaure The Pencil



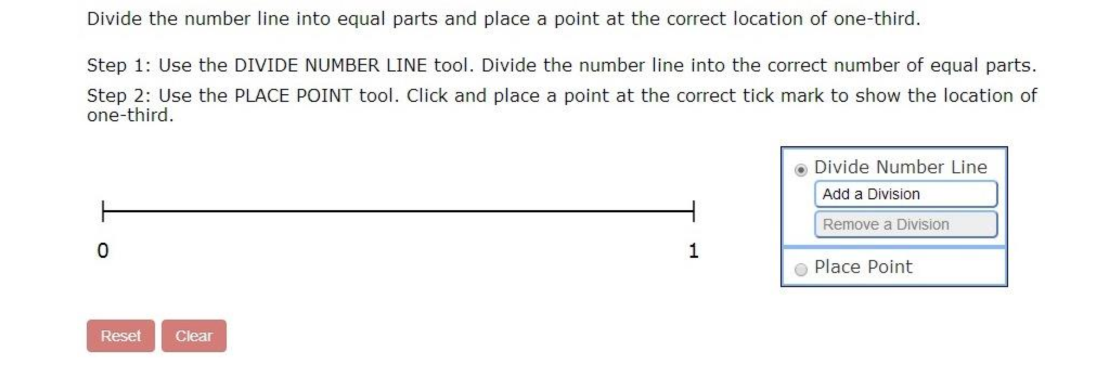
This task requires students to choose the appropriate measuring tool among the three available online rulers (cm-ruler, inch-ruler or protractor) to measure the given diagram of a pencil. Students who do not place the 0-cm mark on the cm-ruler at the appropriate position along the pencil will not be able to obtain the correct answer. Hence, this task is definitely useful to determine students' fluency in measuring a given object.

Whilst this item is excellent to assess students' numeracy understanding, we observed that some students did not see the measurement tools menu, resulting in being unable to answer the question. Some students also found the size of the pencil and the technical tool (cm-ruler) challenging. We present their feedback below.

> Student's verbatim comments:
>
> *Do the pencil bigger.*
>
> *Make the lines on the ruler larger to be able to read it clearly.*
>
> *It is difficult to find the ruler. It would be easier to put the ruler close to the pencil.*
>
> *Place the pencil at the centre of the screen. (*The student found it challenging to align the ruler to the pencil which is positioned at the corner of the screen.)

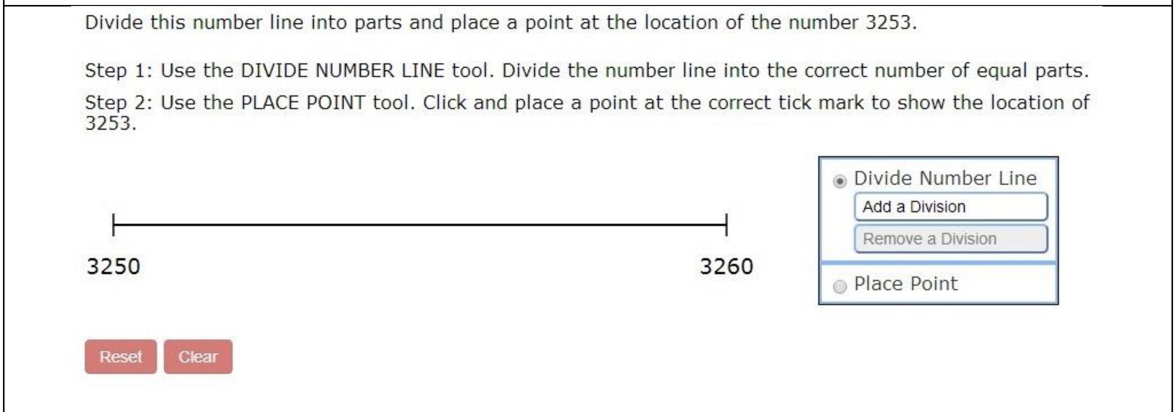
The following two tasks required students to create their own partitions on the number line in order to place a point of the given positions, one-third and 3253 respectively.

Measurement Incorporated Item 18606 – Partition Number/One-Third



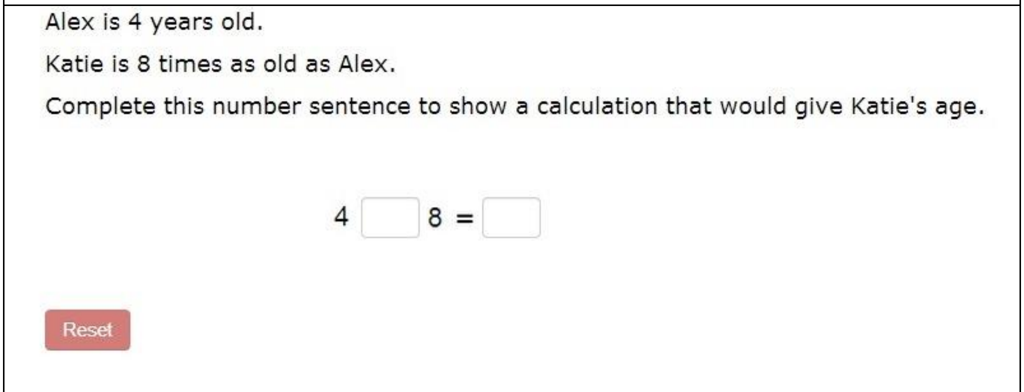
And

Measurement Incorporated Item 18153 – Partition Number Line and Place Point/4-digit number



As the students in the study pointed out, these tasks are different from those they have seen at school, as school tasks usually have the partitions on the number line already marked and just require students to indicate the number on the number line. Getting students to draw their partitions on the number line first before identifying the position of any given number, are definitely useful to determine students' understanding of numbers on the number line. The majority of the students who attempted Item 18606 were not able to partition the number line accurately and indicate the exact position of one-third. None of the students who attempted item 18152 were able to partition the number line and mark the position of 3253 accurately. Questions were raised concerning whether the four digit number (3250, 3253, 3260) was too large a number and whether it is suitable for assessing Year 3 students' knowledge and understanding of the number line.

Measurement Incorporated Item 18153 – InLine Boxes/Alex and Katie

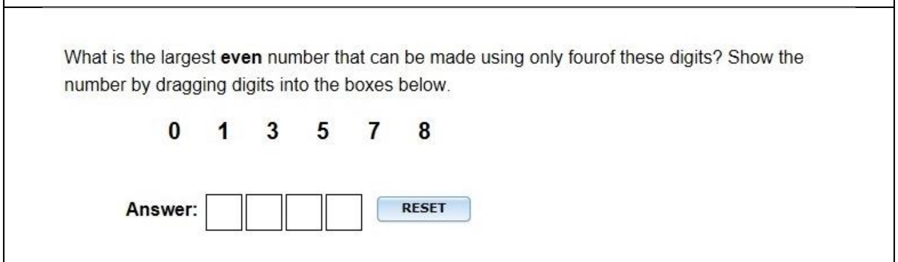


This task requires students to decide the operation of the number sentence and then compute/calculate the answer to the chosen operation. As the students aptly pointed out, the operation of numbers are normally given in classroom tasks and students are required only to calculate the answer. Hence, this task is definitely useful to assess students' ability to understand and analyse the problem situation, communicate an appropriate reasoning for choosing a particular operation (+, –, x, divide) and then display their computation fluency. The only drawback of this item, as mentioned earlier, is that the multiplication and division symbols are not available on the keyboard. We have also provided a suggestion to overcome this technical issue earlier.

YEAR 5

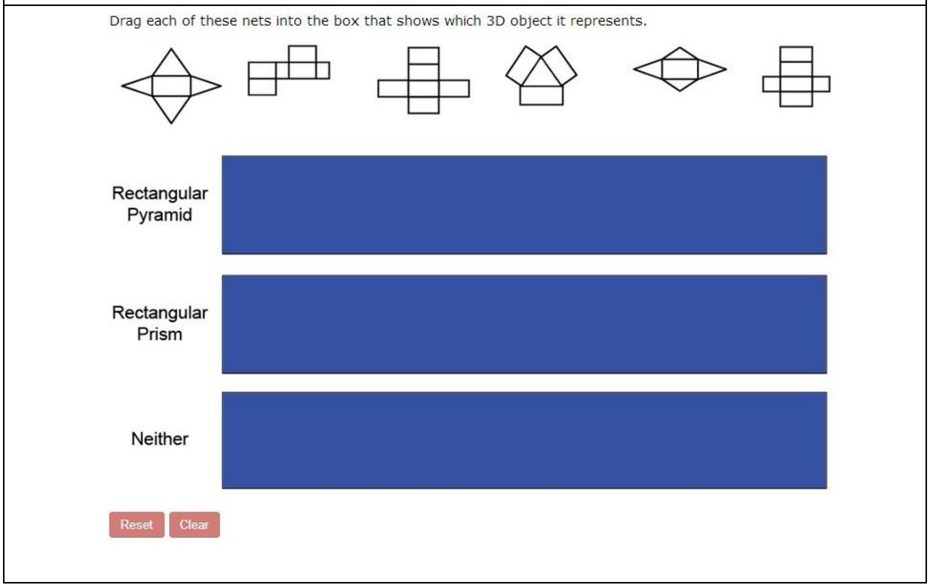
Two items were found to be useful to determine students' numeracy understandings across curriculum content areas.

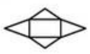
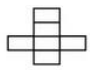
Pacific Metrics Item 4



This task requires students to draw upon their mathematical knowledge on even and odd numbers. In this task, there are two even numbers – 0 and 8. This task is a good task to assess students' ability to apply their mathematical knowledge on even and odd numbers, as well as reasoning of answer to the item, including whether to include both even numbers (0 and 8) in the answer, and if so, where to place these two even numbers. We found that majority of the students knew that 0 and 8 were even numbers. Successful problem solvers were able to reason which of these two even numbers should be placed as the last digit.

Measurement Incorporated Item 18196 – Classification/Nets



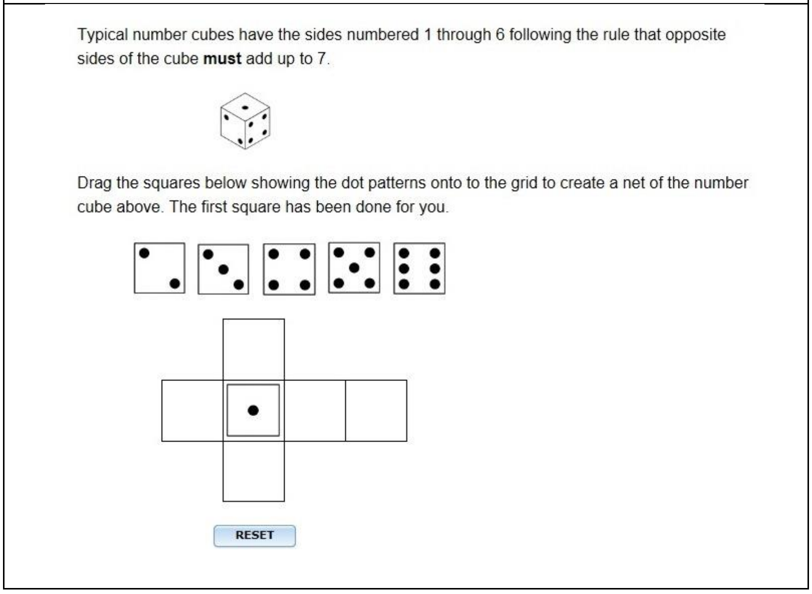
This task requires students to determine and select the correct nets to the three given 3D objects. This is a good spatial task to assess students' ability to visualize and fold the nets mentally. This item is good as there is also a "Neither" option which prompts students to think about possible nets that do not fit into the "Rectangular Pyramid" and "Rectangular Prism" category. Majority of the students were not able to answer this item successfully. The reason being that many students placed the  net under the "Rectangular Pyramid" category, and the  net under the "Rectangular Prism" category. These two nets should fall under the "Neither" category.

Whilst this item is excellent to assess students' spatial visualization ability, we recommend that the size of the diagrams of the nets should be increased so as to reduce any unnecessary cognitive load to see the diagrams clearly before and during visualisation.

YEAR 7

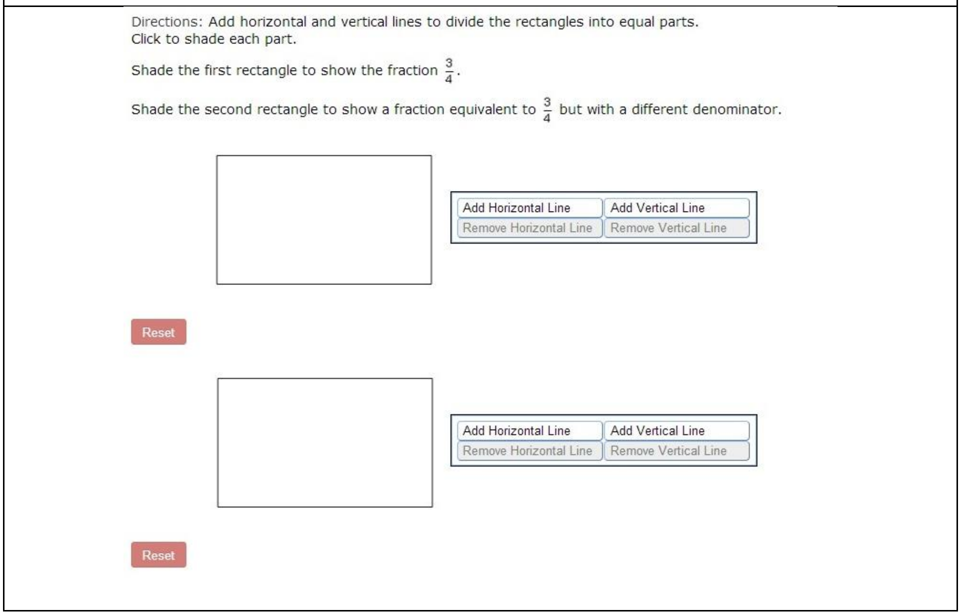
Two items were found to be useful to determine students' numeracy understandings across curriculum content areas.

Pacific Metrics Item 7



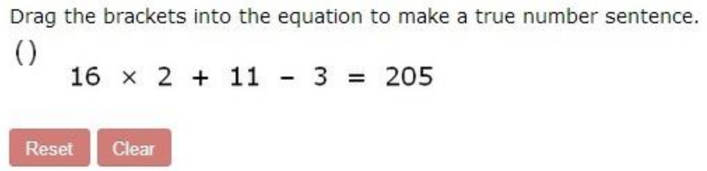
This multiple-solution task assesses students' spatial knowledge on closing the nets of a cube to obtain the cube. Problem solving is a key element in this task – in addition to spatial skills, students are required to use the given rule that opposite of a cube must add up to 7 to create a net of a cube. Specifically, students' numeracy skills (number bonds for 7, i.e., 1+6, 2+5, 3+4) are also being assessed in this item.

Measurement Incorporated Item 18191 – Partition Shape/Equivalent Fractions

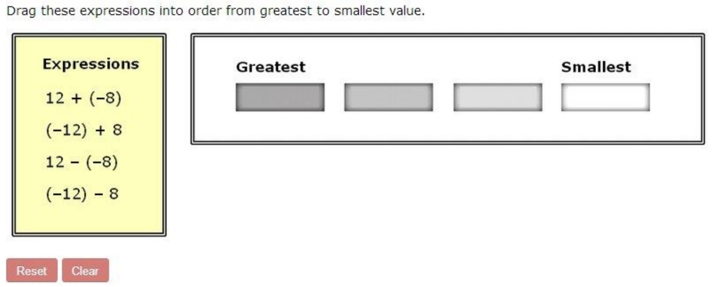


This task requires students to create a fraction $\frac{3}{4}$ visually in two different ways. This item assesses students understanding of equivalence fractions. Usually, students' understanding of equivalence of fractions is via symbolic forms, for example, $\frac{3}{4} = \frac{?}{8}$. The design of the task assess students' understanding of equivalence of fractions via a diagrammatic form where the parts and the whole are represented visually.

Measurement Incorporated Item 18183 – Classification/Order of Operations



Measurement Incorporated Item 18181b – Classification/Order of Expressions



Both items (shown above) are good tasks to assess students' numeracy knowledge. In Item 18183, students are required to place the brackets in the appropriate positions in order to make the number sentence true. The usual way to assess Order of Expressions tasks is to ask the students to solve and compute the answer to a given expression directly. Item 18183 challenges students at a higher level than just to compute an answer. Similarly, in Item 18181b, students are required not only to compute the answers to given expressions, they are challenged at a higher level to arrange the given expressions in descending order after completing the computations.

YEAR 9

Pacific Metrics Item 12 was found to be useful to determine students' numeracy understandings across curriculum content areas. This item was an animation showing the Sieve of Eratosthenes. This item is discussed in detail under Priority 2.

Priority 2

Which taxonomy features align to the respective technology-enhanced items?

In order to address this research question, we examined the extent to which the respective items aligned to the cognitive processes described in Mayer’s (2002) taxonomy. This analysis was undertaken to determine the breadth of the processing required to solve the technically enhanced items. As a general rule, we anticipated that the more cognitively challenging processes, such analyse and create, would be more likely to occur in the higher grades.

The summary of the analysis (presented in Table 4) outlines the placement of items across the six constructs of the hierarchy. A majority of the items across the four year levels were classified within the apply construct. This construct requires the execution or implementation of a procedure in a problem situation. From our perspective, it was pleasing to see that few items required the less sophisticated reasoning constructs (i.e, remembering and understanding). Since these items should evoke different reasoning challenges than those available in a pencil-and-paper form, it should be the case that students should be required to apply cognitive processing to solve the majority of these technically enhanced items. Nevertheless, we would encourage item designers to develop more items that provided opportunities for student to appropriately use multiple forms of information to create a solution. Noteworthy, no Year 9 items elicited such requirements.

Table 4. Items according to Year level for Mayer's hierarchical cognitive processes framework

	Remember	Understand	Apply	Analyse	Evaluate	Create
Year 3	—	MI 18153	PM 1, PM 5 PM 3, MI 18188 PM 2, PM 8, PM 22, MI 18173	MI 18171	—	MI 18167, MI 18152, MI 18606
Year 5	—	—	MI 18196 PM 4, PM 10, PM 23, MI 18175, MI 18174b, MI 18176	PM 9, MI 18174a	—	PM 6, MI 18190 MI 18189
Year 7	PM 13, PM 24, MI 18186, MI 18192	PM 14, PM 17,	PM 7, MI 18181a, MI 18181b	MI 18183	—	MI 18191 MI 18187
Year 9	PM 15	PM 12	PM 18, PM 19, PM 20, PM 21, MI 18227, MI 18229, MI 18233	MI 18230, PM 16, MI 18232	—	—

Note: PM refers to Pacific Metrics, and MI refers to Measurement Incorporated.

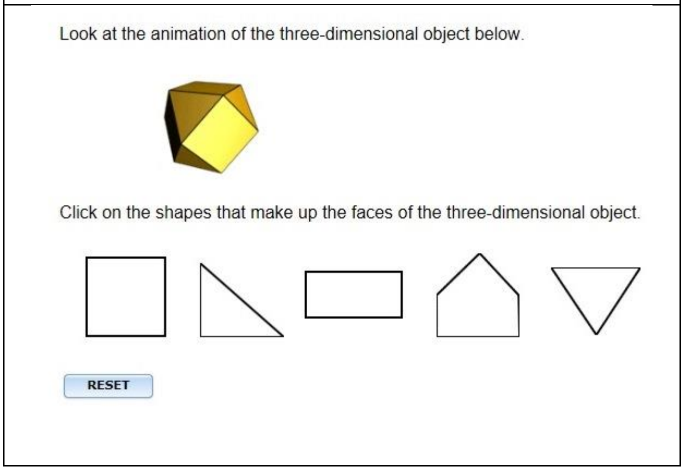
Which items more adequately assess numeracy knowledge and skills not easily assessed by traditional item types?

Despite the technical enhancement of the selected items, it was identified that only two items could adequately assess students' numeracy *knowledge* in a way that could not be developed for more traditional item types: Pacific Metrics Item 5 (Year 5 item) and Pacific Metrics Item 12 (Year 9 item). Additionally, a number of items were identified that provided opportunities for students to demonstrate numeracy *skills* that are not afforded with traditional item types. These items were classified under the "create" cognitive processing in Table 4. Firstly, we discuss the two items that assessed students' numeracy knowledge in distinctive ways and secondly, we provide an overview of the items that assessed numeracy skills.

Numeracy Knowledge

Pacific Metrics Item 5. This item involved visualisation and graphic decoding. There was evidence that the students employed visual processing to solve this task. The students commented that they liked the animation of the turning 3-D object and found it helpful to answer the task. We observed the students gesturing (typically with their hands) as they explained why they chose the respective shapes from the five options given.

Pacific Metrics Item 5



The animation provided an avenue to assess students' spatial skill which could not be easily assessed via normal pencil-and-paper. In addition, the square-shape was placed in a position where one of its vertices is parallel to the edge of the screen, and one of the options included a square where its side is parallel to the edge of the computer screen. As literature in mathematics education have often pointed out (see Clements et al., 1999; Ho, 2003), prototypes of shapes with a fixed position are often given only as examples in the mathematics class, students who are not exposed to shapes when they are rotated or placed in a different position different from the prototypical ones they have seen. In this item, students who identify the square in the animation as a "diamond" will not choose the first option (a square where its side is parallel to the edge of the computer screen) as their answer. In addition, this item also involves students understanding of triangles – right-angled and equilateral.

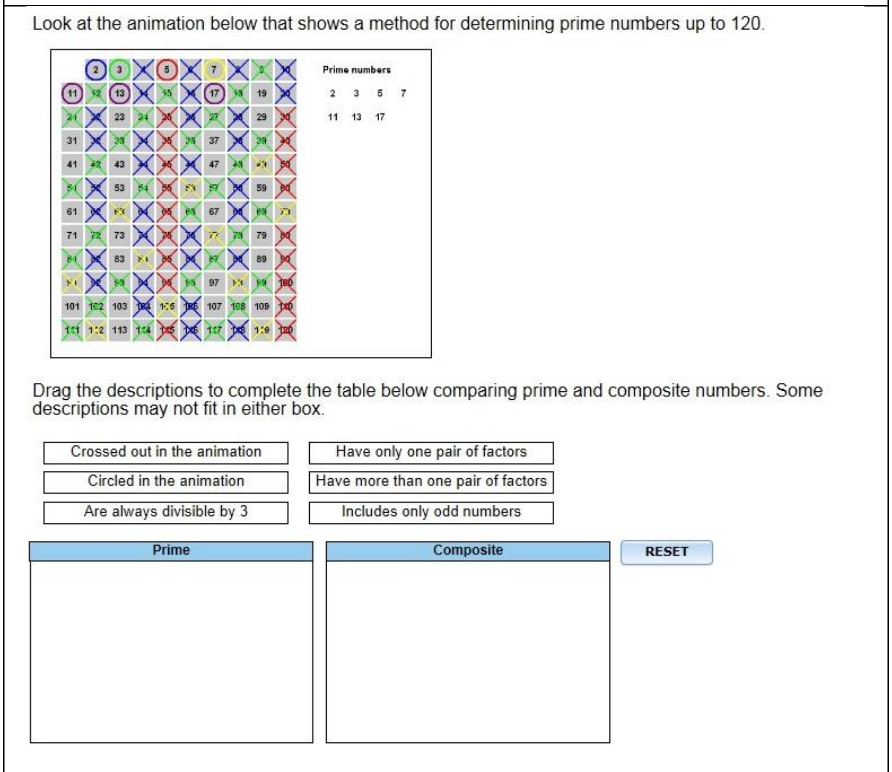
Hence, this item is especially useful in determining students' knowledge and understanding of geometric shapes.

> A student's verbatim comments:
>
> *Good. Spinning, can see all sides.*
>
> *I like it spinning around.*
>
> *You can see like all around. It is moving not very fast and not very slow.*
>
> *Because it is spinning, it is easy to see all the angles.*

We noted that one of the students suggested that the size of the shapes in the list of the options should be the same as those in the 3D animation object. This student was not sure at the first whether there was any answer to the task as the sizes of the shapes in the list of option did not match those in the 3D animation object. We would like to include this suggestion as one of the recommendations for the technical tools in the report. We also note that this is the only Year 3 that could assess numerical knowledge and skills not easily assessed via pencil-and-paper.

Pacific Metrics Item 12. The following Year 9 item was also identified as providing assessment opportunities not afforded by traditional item types.

Pacific Metrics Item 12



This item involved application of mathematical knowledge about prime and composite numbers to interpreting the given animation (a dynamic graphic). This animation shows the Sieve of Eratosthenes – an algorithm for obtaining all prime numbers up to 120. Traditional pencil-and-paper assessment will not be able to assess students' numeracy knowledge and understanding as efficiently and seamlessly compared to using technology (i.e., show the algorithm via animation). The item is also a good assessment task as there were descriptions (from the six given ones) which did not fit into any of the "Prime" and "Composite" numbers category.

We observe that the different colours used in the animation aided students to understand the sequence of eliminating multiples of 2, 3, 4, etc in the Sieve of Eratosthenes. We would like to suggest that the size of the animation be made bigger for easier viewing of the animation as well as to slow down the speed of the animation for better grasping and understanding of the animation. We also include the following suggestion which was made by a number of students: Allow the animation to run once, then stop. Include a Restart button so as to enable the student to replay the animation. Also include a Pause button so that student can stop the animation as and when he/she prefers. Students' verbatim comments about this item are shown below:

A student's verbatim comments:

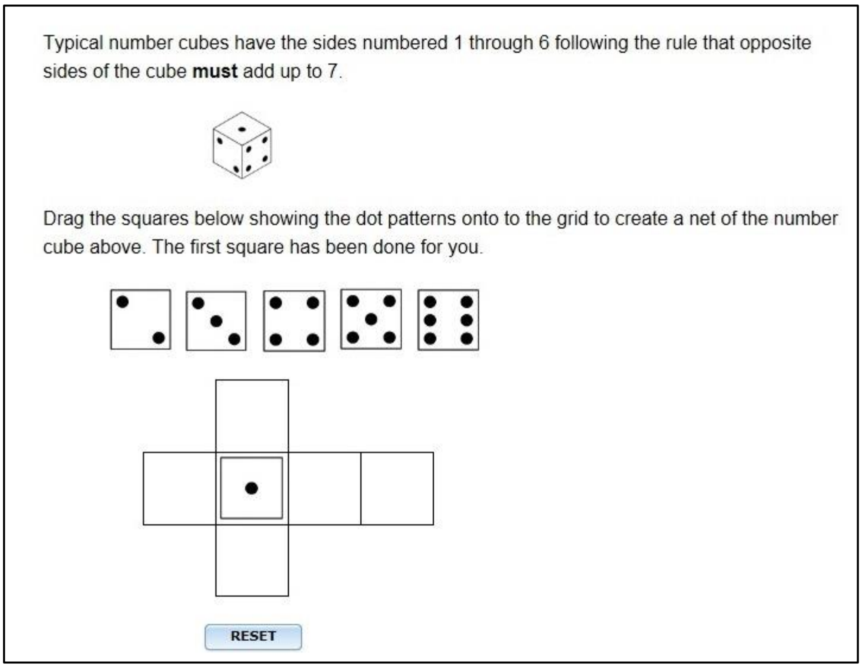
Animation is too small.

Font size too small. Larger animation.

Have a button to pause the animation.

Have a Restart button.

We would like to give a suggestion of a technically-enhanced item for your consideration. This suggestion originates from the Pacific Metrics Item 7 (shown below):

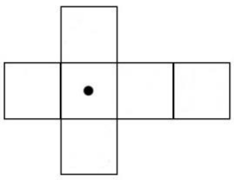


The suggestion is as follows:

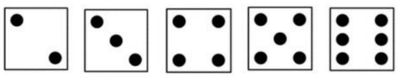
Suggestion:

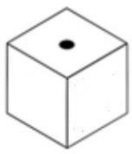
A typical six-sided cube has sides numbered 1 through 6 following the rule **that opposite sides of the cube must add up to 7**.

A net of such a cube with five missing faces is shown below.



Using this net and the rule given above, complete the missing faces of the cube by dragging the following squares onto the cube.





(cube can be rotated in all directions for students to place the squares)

Presenting NAPLAN in a digital form requires different cognitive demands (more mental and visual processing) and strategizing (decoding information across multiple and different representations). Such demands are challenging, yet they provide a novel avenue for the delivery of assessment to assess students in ways not easily assessed via a traditional pencil-and-paper test. In the suggestion above, the item assesses students in two aspects - spatial reasoning skills (folding the net into the given cube with two faces already indicated and also where to place each square in a cube) in a 3-dimensional space, and numeracy skills (number bonds for 7, i.e., 1+6, 2+5, 3+4). This example also allows for multiple solutions.

Numeracy Skills

To date, numeracy assessment has focused on students' understanding and application of mathematical knowledge. Many numeracy skills have been unable to be assessed due to logistical constraints associated with assessing large volumes of students at the same time (e.g., uniformity of equipment etc.). Some of these technically enhanced items provided opportunities for students to demonstrate numeracy skills and understandings that are not afforded by traditional items, that is, the ability to assemble all the pieces of information together to create their own models or mathematical situations. As identified in Table 4, eight items were classified as “create” along Mayer’s cognitive processing hierarchy. These items were unlike standard items where prototypical models, graphs or diagrams are provided and the students need to interpret the given information. Items such as MI 18152 and MI 18606 (Year 3) gave students the opportunity to create the number line partitions themselves, which shows a different numeracy skill and understanding than those afforded by traditional item types. For example, the two items could be assessing whether students understand how a number line works (how many partitions are needed between 3250 and 3260 or 0 and 1 for the situation described?) and if they can place the information on the number line they create.

Items such as MI 18189 and PM 6 (Year 5) provided opportunities for students to create their own graphs from the given data. Some scaffolding is provided, but the main data needs to be inputted by either clicking and dragging the columns up or clicking on the gridlines at a specific point until the correct information from the table is reflected in the graph. These items could be assessing students’ understanding of the connection between the two axes of the graph and whether they can transfer information from a table to a graph. Many traditional graph item types will ask students to decode or decipher the information in a graph, so a different skill and understanding is being assessed by these technically enhanced items.

One of the more interesting items identified within the “create” classification was MI 18187. This Year 7 item required students to draw their own triangle on a grid with a specific area. Some of the students struggled with this item, not necessarily due to the technical aspect of creating the triangle (although this was a concern), but with applying their understanding in a way to create a triangle with an area of $0.12m^2$. This is a slightly different skill to being able to calculate the area of a given triangle.

The items discussed above provide opportunities to assess students in ways that traditional item types cannot. However, it is imperative that a balanced assessment be given that incorporates both traditional and technically enhanced types of items so that a thorough understanding of students’ knowledge and skills can be gained. For example, having one graph item where the students are required to decode the information given and another item where they construct their own graph. This would provide a better understanding about what the students knows about data.

Key Findings and Recommendations

Priority 1

KF1.1: Numeracy and Design demands were found to influence Year 3 and Year 5 students' capacity to engage with items in a meaningful way. The Design aspect influenced students' engagement in Year 7 and Year 9.

R1.1: It is necessary to construct mathematics test items from a "holistic design" perspective which considers the entire representation of the test item (Lowrie, Diezmann, & Logan, 2011), in particular the design aspect related to the technical demands to solve the particular item. The recommendations for each of the identified individual items are provided in detail on pages 13 -22 of the full report.

KF1.2: In general, the students found it difficult to utilise the "Use Drawing Tools" (Type 6) technical function. The majority of the students found using this tool challenging and spent time on items associated with this tool. The Year 5 students found measurement tools challenging to manoeuvre.

R1.2: When changing the test mode from traditional pencil-and-paper mode to digital mode, we should also be cognizant that some items which have worked on pencil-and-paper need not necessarily work well with a mouse on the screen. For example, Measurement Incorporated Item 18230 (this item requires students to draw lines on the screen to partition an irregular shape). More discussion on this item is provided on page 30.

In this study, there was no time limit given for each test item. Students were given time to explore how to use the technical tools for each item. NAPLAN is, however, a timed test. In addition to students' knowledge and skills in numeracy, factors such as test-taking speed and, possible test-taking practices and strategies can influence the test performance and outcome. In addition, presenting NAPLAN in a digital form requires different cognitive demands (more mental and visual processing) and strategizing (decoding information across multiple and different representations). Such demands are challenging. Hence we recommend that instructions on the use of the technical tools, possibly in the form of practice questions, be provided to the students before they commence taking the actual test.

We also recommend that a set of minimum technical requirements for accessing the online tests (e.g., compatible browsers, recommended internet connection speed, recommended screen display, provision of keyboard and mouse, clearing of browser cache before each test administration, etc) be provided to schools so as to ensure the smooth administration of the online tests during the heavy testing periods.

KF1.3: A total of nine items (18%) were found to be useful to determine students' numeracy understandings across curriculum—a majority in Years 3 and 5.

Priority 2

KF2.1: All the items were categorised according to the cognitive processes from the Taxonomy for computer-based assessment of problem solving (Mayer, 2002) framework. The majority of the items (51%) were classified as Apply (the application of executing or implementing a procedure in a problem situation), which is the third construct in a six construct hierarchy. Only 16% of the items were classified as Create (assemble parts of a problem situation together to find the solution), the highest construct.

R2.1: We recommend more cognitively challenging items involving animation and the “create” construct be included in computer-based test as these cognitive processing skills could not be easily assessed via traditional paper-and-pencil mode. Items involving remembering mathematical definitions and those assessing fluency of computational skills could be easily assessed via the paper-and-pencil mode.

KF2.2: Two items were identified to assess numeracy knowledge not easily assessed by traditional item types. They were, Pacific Metrics Item 5 (Year 5) and Pacific Metrics 12 (Year 9). Pacific Metrics Item 5 assesses students’ spatial reasoning skills in a dynamic environment, while Pacific Metrics Item 12 assesses students’ ability to comprehend changing information in an animation and use their numeracy knowledge to problem solve.

R2.2: We recommend that items such as Pacific Metrics Item 5 and Pacific Metrics Item 12 be included as TEI assessment items. Not only are such items engaging for students as they solve the items during the test, the delivery of such type of assessment items also provide novel opportunities to assess and gather information/data about students’ understanding of mathematics concepts and skills. We provided a suggestion of possible TEI items on pages 36-37 of the full report.

We noted that some of test items included textbook exercise-type tasks involving mathematical definitions (e.g., Pacific Metrics Items 13, 15, both Year 7). Since it is important that the design and selection of test items match the purpose of the assessment (Griffin, 2014), we wonder if items involving application of definitions of mathematical objects (e.g., Pacific Metrics Item 15 Year 9) be more appropriate for assessing and determining students’ numeracy knowledge and skills in a national test. After all, the ability to recite definitions does not equate to being able to apply these definitions in problem situations.

Recommendations (Detailed technical aspects)

In this section, we provide the following suggestions related to the technical aspects of the technically-enhanced test items.

- Provide schools with a set of minimum technical requirements for accessing the online tests (e.g., compatible browsers, recommended internet connection speed, recommended screen display, provision of keyboard and mouse, clearing of browser cache before each test administration, etc) so as to ensure the smooth administration of the online tests during the heavy testing period.

- Provide a short tutorial at the beginning of the test to show students how to access and use the tools available;
- Fill the entire screen with the item instead of concentrating it at the centre of the screen or at a corner of the screen;
- Increase the font size of the wordings;
- Increase the size of the diagrams;
- Increase the size of the Measurement tools (ruler and protractor) so as to increase the ease of reading the markings on these tools;
- Consistency in the labelling of the RESET button (Note: the button in Pacific Metrics Item 23 – Year 5- was labelled as "Clear All". This "Clear All" button has the same function as the RESET button and did not function the same way as the "CLEAR" button in other items);
- Whenever possible, an item should be designed so that it can be viewed on its entirety on the screen, without requiring the scroll-up-down tool. (For example, for Measurement Incorporated Item 18233, many Year 9 students found it challenging to keep scrolling up and down to read the given data in order to create the histogram);
- If the length of an item exceeds viewing its entirety on the screen and requiring the use of the scroll-up-down tool, a note should be provided to alert the student. (For example, a handful of Year 5 students missed answering the third part of the Measurement Incorporated Item 18190 as they did not know they had to scroll-down to view more of the item);
- Care should be taken when using colours in online objects.

Implications

The scope and type of test items need to agree with the purpose of the assessment (Griffin, 2014). When changing the test mode from traditional pencil-and-paper mode to digital mode, different cognitive demands (more mental and visual processing) and strategizing (decoding information across multiple and different representations) are required in a digital environment. Such demands are challenging. Hence, it is important to construct mathematics test items from a "holistic design" perspective which considers the entire representation of the test item (Lowrie, Diezmann, & Logan, 2011).

The following three implications arose from the study:

1) A proportional number of each category of technical function(s) could be included in the test according to the objective of the assessment and grade level of assessment.
2) Certain test items which have worked on pencil-and-paper need not necessarily work well with a mouse on the screen. Hence, in timed-assessments, provision of appropriate amount of time given to test items should be made considered and made.
3) Consideration of appropriate allocation of marks should be made for items that test mathematical concepts and skills in a digital mode.

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