

**Challenge and enjoyment:
Getting the right balance in
primary mathematics
classrooms**

Janette Bobis



The chocolate box task.... Working by yourself



Does this scoring change your thinking?

Does it change the task?

How many **number facts** can you write ?

Record:

1 point for each fact; and
5 points if it is a multiplicative fact.

Variation:




Write as many **mathematics** facts as you can.

Other ?




What Year Level could do this task?

Exit Ticket

How Challenging




| | | |
|---|---|--|
|  Very easy 1 |  In the middle 2 |  Very challenging 3 |
|---|---|--|

Judgement of Learning (JOL)

| | | |
|---|---|---|
|  Not very well 1 |  In the middle 2 |  Very well 3 |
|---|---|---|

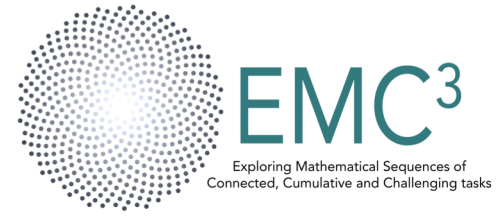
I marked this box because

Level of Enjoyment

| | | |
|--|--|--|
|  No enjoyment 1 |  In the middle 2 |  Very enjoyable 3 |
|--|--|--|

Challenge
Learning
Enjoyment

Exploring Mathematical sequences of Connected, Cumulative, Challenging tasks



Peter Sullivan



Janette Bobis



Ann Downton



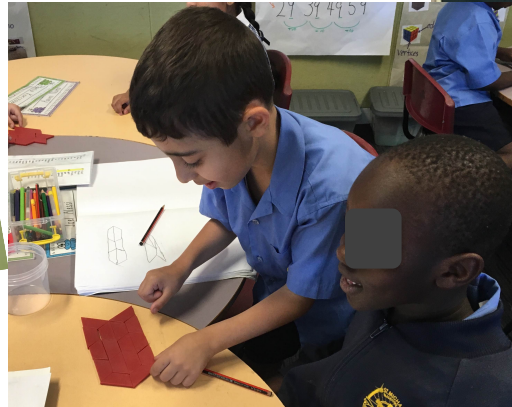
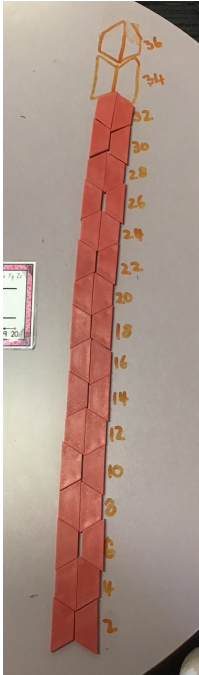
Sharyn Livy



James Russo



Designing and implementing sequences of challenging mathematical tasks with the greatest potential to engage students **cognitively, socially and emotionally**



What is a 'Challenging' Task?

Challenging tasks are **demanding and thought-provoking** mathematical problems that aim to include **all** students in the lesson through characteristics such as being simply-posed, possessing a low-floor and high ceiling, and including enabling and extending prompts (Sullivan & Mornane, 2014).

- Is a problem that involves **struggle**.
- Is **engaging** (valued, interesting, enjoyable for students & teacher!)
- Usually has more than one answer and/or solution pathway
- Takes time
- Focuses on important aspects of mathematics & fosters connections

Tasks matter. But some matter more for student learning !

It is through tasks, that students' attentions are directed to important mathematical ideas and cognitive processes can be activated.

(Stein, Grover & Henningsen, 1996)

Student learning is greatest in classrooms where the tasks consistently encourage high-level student thinking and reasoning and least in classrooms where the tasks are routinely procedural in nature.

(NCTM, 2014, p. 17)

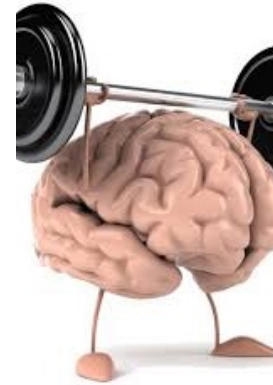
Why is 'struggle' & 'challenge' important?

Struggle involves students expending effort while experiencing some level of confusion while attempting to resolve problems where the solution strategy or answer is not apparent.

Hiebert & Grouws (2007) :

If students struggle in order to make sense of mathematics they are more likely to remember and understand it.

*.... they are also more likely to develop a disposition for **persistence** and an underlying **growth mindset**.*



If you are not
STRUGGLING,
you are not
LEARNING.

Students' willingness to engage with challenging tasks

Sullivan et al. (2014)

Asked students to solve a challenging task.
Surveyed 777 Year 5-6 students about their preferences for solving mathematics tasks.

Preferences for working on challenging tasks

64%



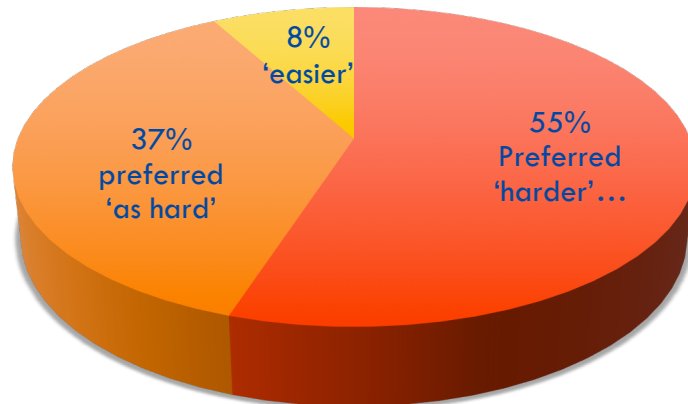
26%



12%



Preferences for challenging tasks



While most students preferred to work by *themselves* on tasks *at least as challenging* as the one they just answered, there was a diversity of views.

Students' and teachers' preferences for challenge in the mathematics classroom

Sullivan et al. (2014) showed that 92% of Year 5/6 students preferred to work on tasks just as challenging or more challenging as the one they just solved.



Chapman (2018) & Cheeseman et al. (2013) found many teachers were hesitant to integrate challenging tasks into their classrooms, suggesting that this hesitancy is often because teachers are not comfortable with student struggle.

Teachers (Prep-2) comfortable with student struggle....

(Russo, Bobis, Downton, Hughes, Livy, McCormick, Sullivan, 2020)

<https://doi.org/10.1016/j.tate.2019.102983>

Report higher
enjoyment teaching
mathematics

High **teacher**
enjoyment = High
student enjoyment
(Frenzel et al. 2016)
Enjoyment can be 'contagious'

Teach more mathematics
Low enjoyment = 2 hr/wk
Hi enjoyment = 7.5 hr/wk

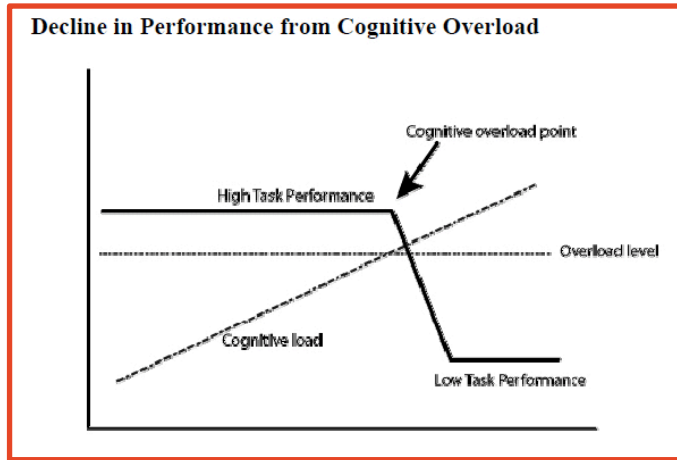


More experienced
Linked to:

- Familiarity with content
- Pedagogical expertise

Challenge is good, BUT

Not ALL students **like/enjoy** challenging tasks and not all challenging tasks are **engaging**. Task difficulty has been found to have the **opposite** effect – eliciting avoidance, anxiety and dislike in students.



Enjoyment can be a mediator between motivation and learning (Puca & Schmalt, 1999)

motivation



Enjoyment



learning



The role of emotions in learning mathematics

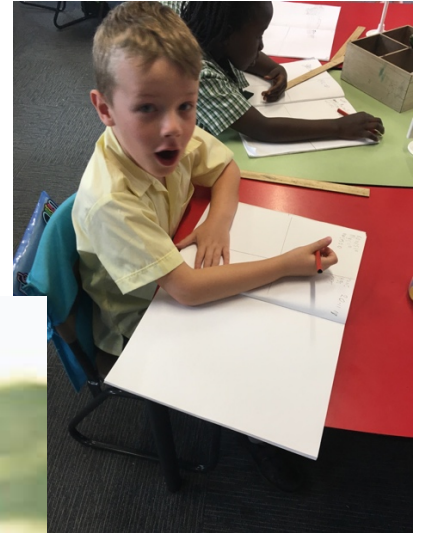
Emotions play an important role in students' learning of mathematics.

They contribute to the development of a learner's **overall disposition** towards mathematics which can impact their short & long-term **achievement** and **motivation**.

(Hannula, 2019)



What emotions?



Developing student enjoyment for challenging mathematical tasks

Hannula (2019) suggests

The way students perceive problems, the enjoyment they derive from working on them and their feelings associated with autonomously solving difficult problems might be related to how they are introduced to problem solving in the first few years of school.



Enjoying and learning from challenging tasks: Questions??

1. Can/how do early years students differentiate between enjoying and learning, easy or difficult tasks?

2. Is liking/enjoying a task linked to how much mathematics a student might learn from that task?

3. What are the characteristics of tasks that students “enjoy” doing?

4. What pedagogical moves can a teacher make to support student learning & enjoyment while engaged in challenging tasks?

Importance of enjoyment in learning: How it works

Links between student motivation and engagement and their learning (Bobis et al. 2011)

Neuroscientists have shown that **certain types of tasks** are more likely to trigger prefrontal brain activity than other types of problems (Daly, et al. 2019)

Left Prefrontal Cortex



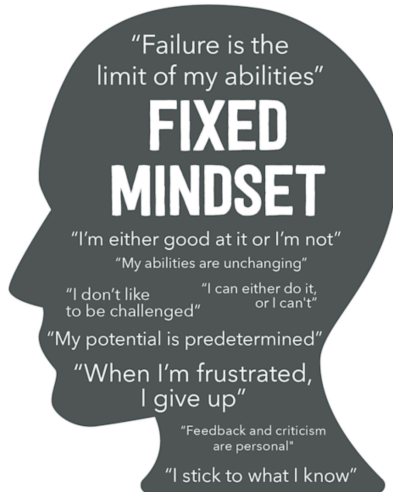
Neuroscience

Dopamine is a neurotransmitter in the brain – sending signals between nerve cells of the brain. One pathway dopamine moves through plays a major role in regulating **motivation** and **reward-responses** (Koelsch, 2014).

Dopamine (or the ‘happy hormone’) helps regulate movement, **attention**, **learning**, and **emotional** responses. It also enables us to see **rewards (goals)** and to **take action** to move toward them.

Designing problems with greater potential to engage students

Problems designed based on the principals of **Mathematical Mindset (MM)** (Boaler, 2015; Dweck, 2013).

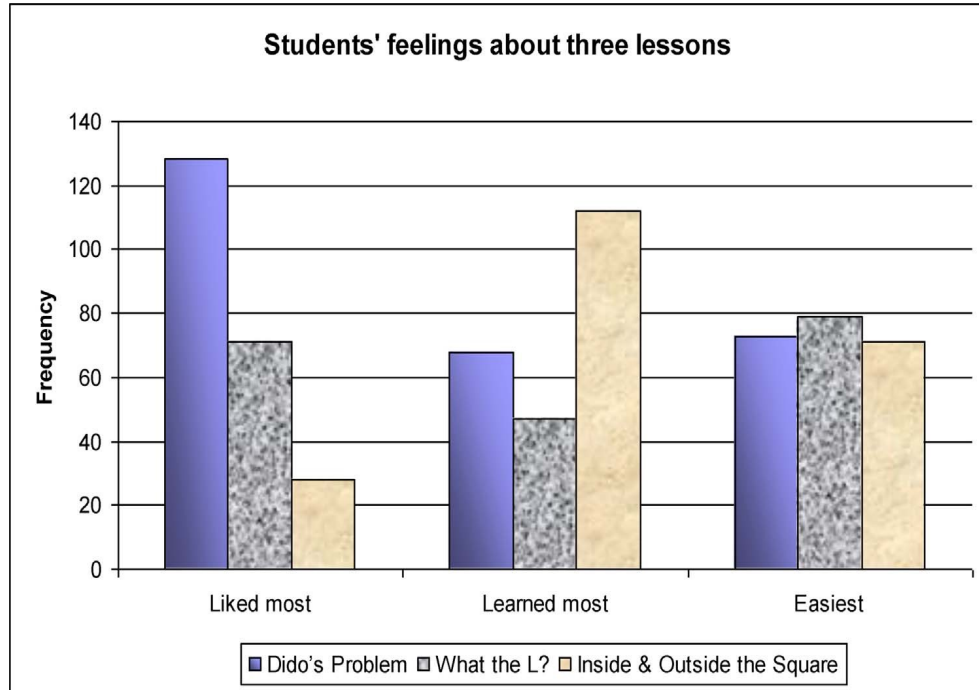


Design principals based on MM

(Boaler, 2015)

- Open up the task so that there are multiple methods, pathways, and representations.
- Ask the problem before teaching the method.
- Include inquiry opportunities.
- Add a visual component and ask students how they 'see' the mathematics.
- Extend the task to make it low floor and high ceiling.
- Ask students to convince and reason; be skeptical.

Students' distinguishing between learning, liking and easy



Clarke & Roche (2018)

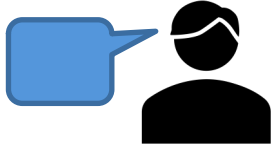
Intervention study aimed to increase student persistence on **challenging contextual** tasks.

Twelve Yr 5-8 teachers taught a series of lessons involving the same set of challenging tasks.

Surveyed 224, **11-15 year olds** to determine the extent to which they could distinguish between tasks:

1. They *learned* the most from;
2. Considered *easiest*; and
3. They *liked* the most.

Students' distinguishing between learning, liking and easy



Student 'Top' Reasons for Choices

Reason for students 'liking' lessons

- Fun/interesting/creative
- Opportunity to eat the 'mintie'
- It was practical
- Challenged my thinking

What are my two numbers?



I am thinking of two numbers on the number chart.

One number is 15 more than the other.




One of the numbers has a 3 in it.

What might be my two numbers?




Give as many answers as you can.

Exit Ticket & Drawing 'what I liked/did not like'

How Challenging




| | | |
|--|--|---|
|  <p>Very easy 1</p> |  <p>In the middle 2</p> |  <p>Very challenging 3</p> |
|--|--|---|

Judgement of Learning (JOL)

| | | |
|--|--|--|
|  <p>Not very well 1</p> |  <p>In the middle 2</p> |  <p>Very well 3</p> |
|--|--|--|

I marked this box because




Level of Enjoyment

| | | |
|---|---|---|
|  <p>No enjoyment 1</p> |  <p>In the middle 2</p> |  <p>Very enjoyable 3</p> |
|---|---|---|

| | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
| 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 |
| 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
| 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 |
| 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
| 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 |
| 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120 |






1. "Mark the box that best describes (or shows) how challenging (or difficult) you thought this task was for you"

| | | |
|---|---|--|
|  Very easy 1 |  In the middle 2 |  Very challenging 3 |
|---|---|--|

*I marked this box because when I started doing the task, it was a bit hard but when I started doing the task more, it was even harder.

Step 4. Level of task enjoyment

Mark the box that best describes how much you enjoyed working on the task.

| | | |
|--|--|--|
|  No enjoyment 1 |  2 |  Very enjoyable 3 |
|--|--|--|




I marked this box because when we were solving problems, I learnt something new, I learnt different ways to count.

Year 1 Elena

Peter

| | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
| 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 |
| 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
| 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 |
| 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
| 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 |
| 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120 |




"Mark the box that best describes (or shows) how challenging (or difficult) you thought this task was for you"

| | | |
|---|---|--|
|  Very easy 1 |  In the middle 2 |  Very challenging 3 |
|---|---|--|

*I marked this box because I didn't understand what I had to do at first




Student Name: Peter

Step 3. Judgement of learning
Mark the box that best shows how well you think you understand the mathematics/content in the task.

| | | |
|---|---|---|
|  Not very well 1 |  In the middle 2 |  Very well 3 |
|---|---|---|

*I marked this box because The next time I did it I understood what to do and I could do it

Step 4. Level of task enjoyment
Mark the box that best describes how much you enjoyed working on the task.

| | | |
|--|---|--|
|  No enjoyment 1 |  In the middle 2 |  Very enjoyable 3 |
|--|---|--|

*I marked this box because When I did some I felt in the middle but when I did a lot of them I enjoyed it alot.




Year 1: Peter

| | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
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| 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 |
| 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120 |

Year 1: Oliver

Student's Name: Oliver

At the end of the lesson ask student to:
 "Mark the box that best describes (or shows) how challenging (or difficult) you thought this task was for you"

| | | |
|---|---|--|
|  Very easy 1 |  In the middle 2 |  Very challenging 3 |
|---|---|--|

*I marked this box because when I was thinking it was hard to get to the next number in a new way.

Oliver




| | | | | |
|----|----|----|----|----|
| 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 |
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| 31 | 32 | 33 | 34 | 35 |
| 36 | 37 | 38 | 39 | 40 |
| 41 | 42 | 43 | 44 | 45 |
| 46 | 47 | 48 | 49 | 50 |
| 51 | 52 | 53 | 54 | 55 |

I liked using a number chart because it helped me find 15 more.

EMC: Measure of (i) perceived level of challenge, (ii) judgement of learning (JOL) (iii) perceived level of enjoyment V.5

Student Name: Oliver




2. Judgement of learning
 Mark the box that best shows how well you think you understand the mathematics/content in the task.

| | | |
|---|---|---|
|  Not very well 1 |  In the middle 2 |  Very well 3 |
|---|---|---|

*I marked this box because it was hard to concentrate when I am doing the task

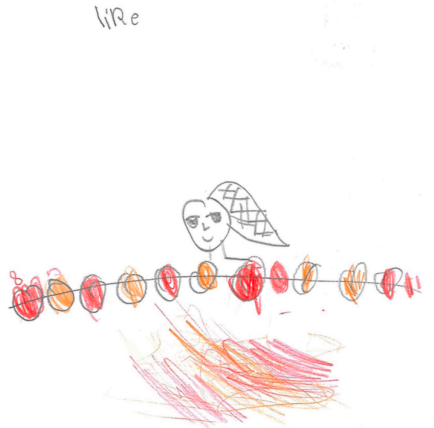
* was sick and not at school Monday-Wed.

3. Level of task enjoyment
 Mark the box that best describes how much you enjoyed working on the task.

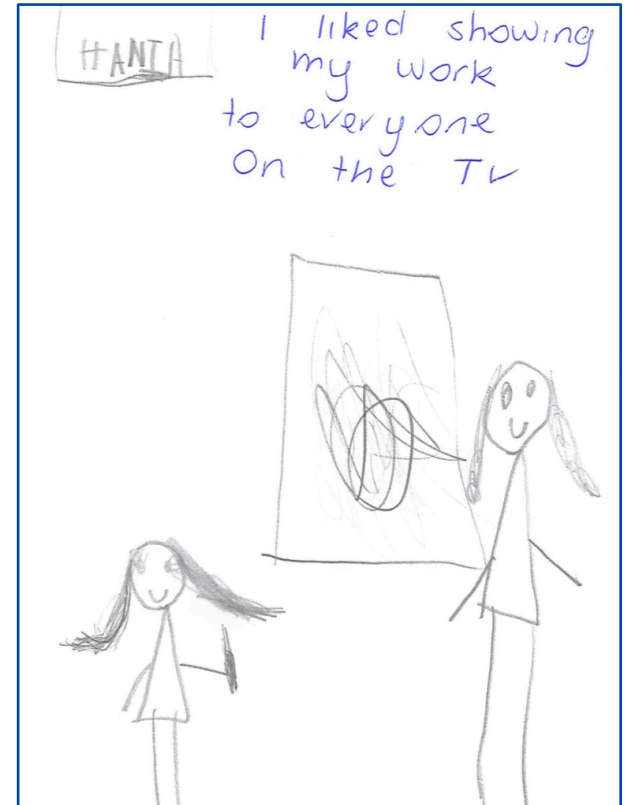
| | | |
|--|---|--|
|  No enjoyment 1 |  In the middle 2 |  Very enjoyable 3 |
|--|---|--|

*I marked this box because I liked it when I found the numbers and found different ways.

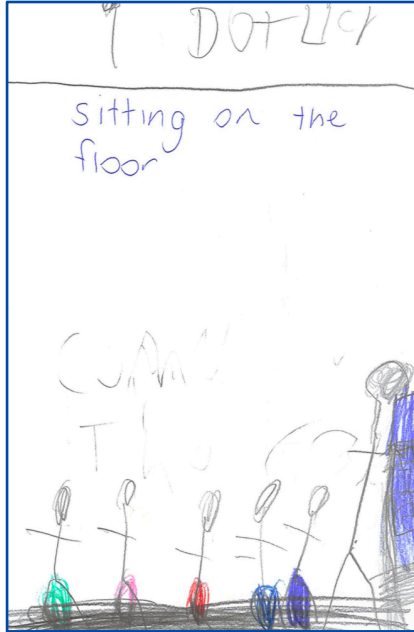
What students liked doing in the lesson



bead string - because
I can stand up and
show everyone



Don't like



Don't like

Place Value

| | | | | | | |
|----|----|----|----|----|----|----|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
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| 36 | 37 | 38 | 39 | 40 | 41 | 42 |
| 43 | 44 | 45 | 46 | 47 | 48 | 49 |
| 50 | 51 | 52 | 53 | 54 | 55 | 56 |

All we needed to do was find another number - 15 more.

Not interesting, too easy!

Sitting down

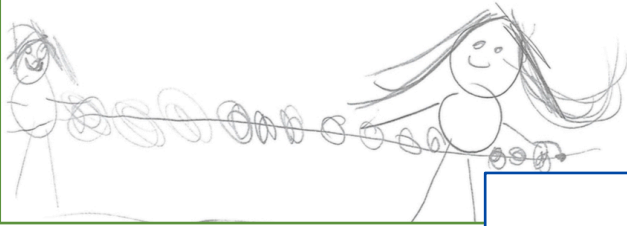
because i did not get to finish my learning.

Sitting on the floor for a long time made me tired and hurt

Want to work by myself and finish

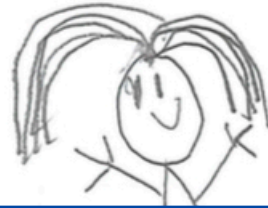
Liked

When I got to go out
the front and do the
numbers on the bead string.



vm jirec

- Answering questions.
- Hearing people's ideas



Bead string

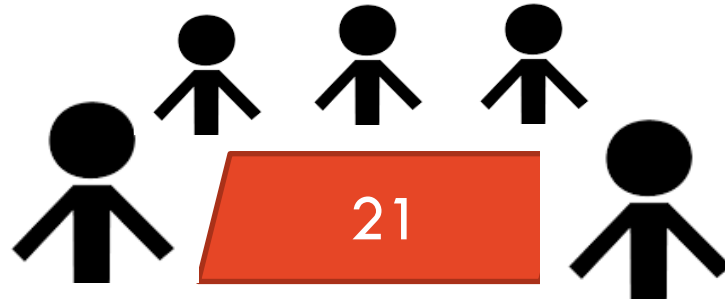


I got to get up and use it for the first
time today. It helped me learn how to count
by tens.

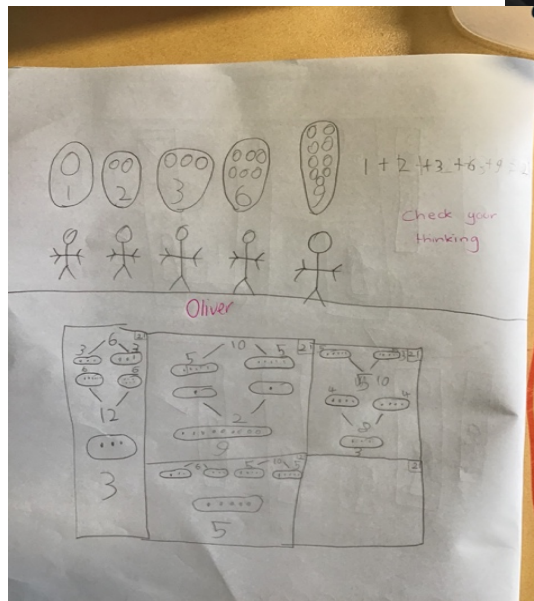
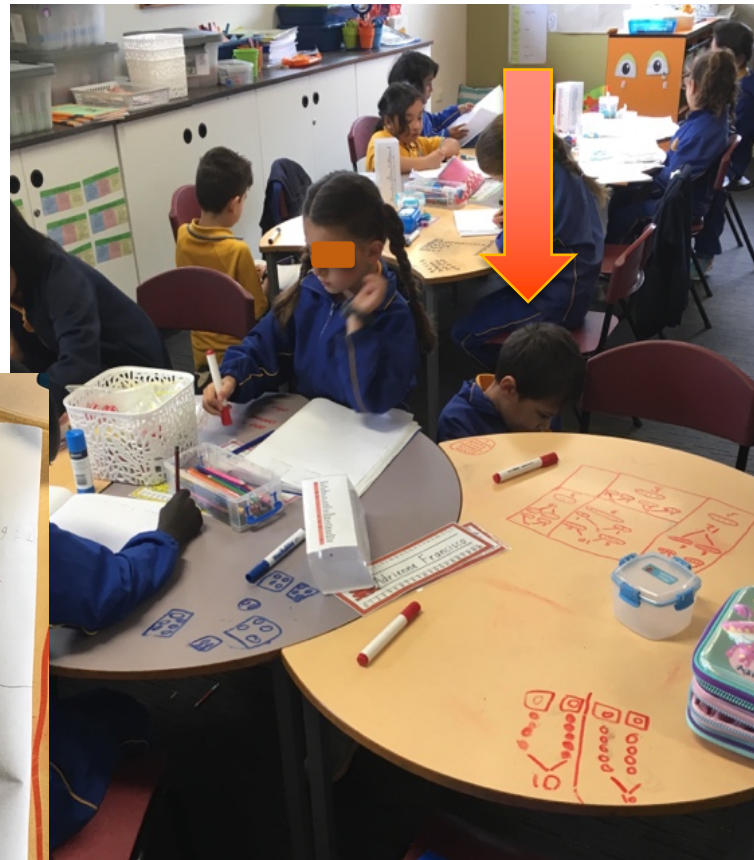
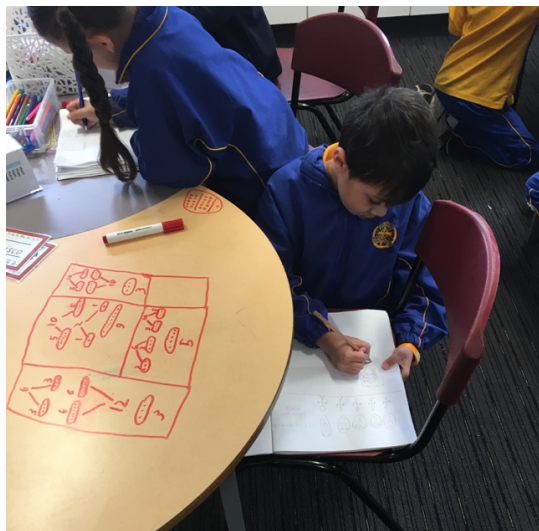
Students with counters

Five students have 21 counters between them.
Two pairs of students have the same number of
counters.

How many counters might each student have?






Oliver

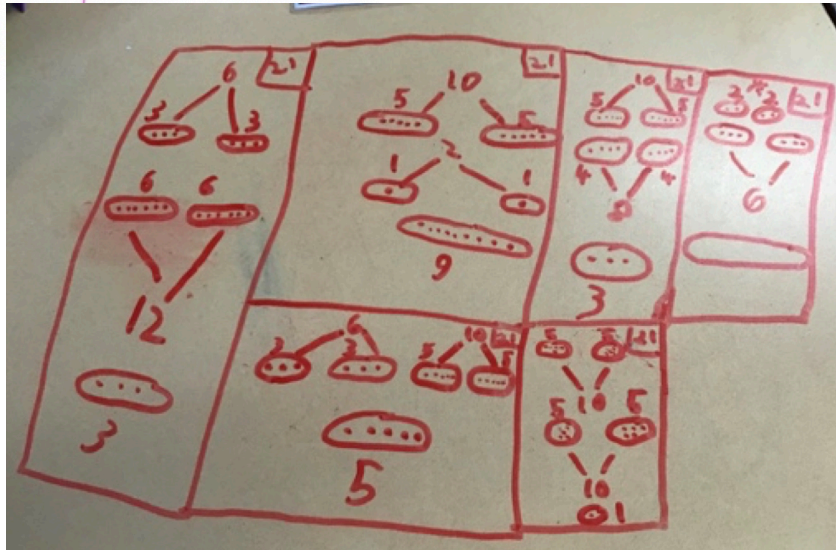


Oliver

1. "Mark the box that best describes (or shows) how challenging (or difficult) you thought this task was for you"

| | | |
|---|---|--|
|  Very easy 1 |  In the middle 2 |  Very challenging 3 |
|---|---|--|

*I marked this box because I knew doubles but it was tricky to find different ways



Student Name: Oliver

2. Judgement of learning

Mark the box that best shows how well you think you understand the mathematics/content in the task.

| | | |
|---|---|---|
|  Not very well 1 |  In the middle 2 |  Very well 3 |
|---|---|---|

*I marked this box because I thought we only had to find one double, but Mrs Moore said I had to find two doubles

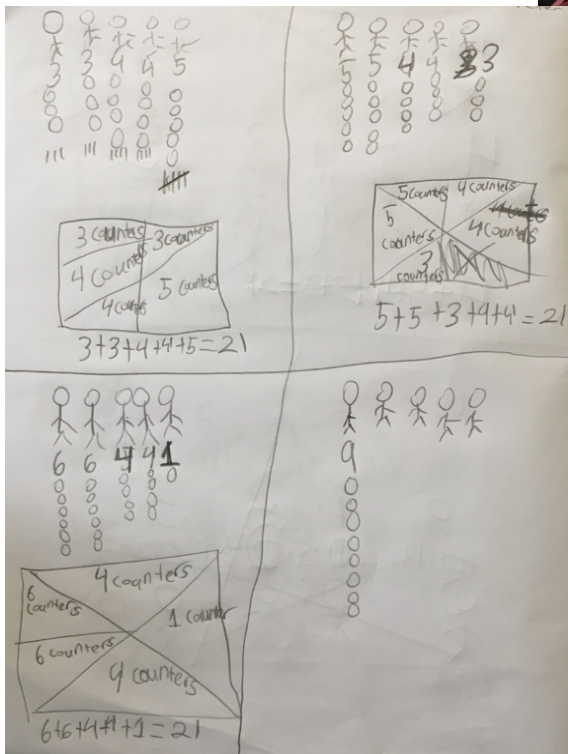
3. Level of task enjoyment

Mark the box that best describes how much you enjoyed working on the task.

| | | |
|--|---|--|
|  No enjoyment 1 |  In the middle 2 |  Very enjoyable 3 |
|--|---|--|

*I marked this box because I liked finding different doubles ~~you~~ I've never made before.




Peter



Student's Name: Peter

At the end of the lesson ask student to:

1. "Mark the box that best describes (or shows) how challenging (or difficult) you thought this task was for you"

| | | |
|---|---|--|
|  Very easy 1 |  In the middle 2 |  Very challenging 3 |
|---|---|--|

*I marked this box because it was challenging to start with yesterday but today I knew what to do.

Peter's interview

Student Name: Peter

2. Judgement of learning

Mark the box that best shows how well you think you understand the mathematics/content in the task.

| | | |
|---|---|---|
|  Not very well 1 |  In the middle 2 |  Very well 3 |
|---|---|---|

*I marked this box because I lots of ideas about what to do

3. Level of task enjoyment

Mark the box that best describes how much you enjoyed working on the task.

| | | |
|--|---|--|
|  No enjoyment 1 |  In the middle 2 |  Very enjoyable 3 |
|--|---|--|

*I marked this box because I got to write numbers to make 21. This was better than yesterday because I did a lot of numbers

| | |
|--------------|--|
| Peter | Today's one was easy, because I knew what to do to get two pairs of two numbers to work out everything... |
| Int. | Did you start the task yesterday? |
| Peter | Yes, and even before yesterday. |
| Int. | Did this help, to come back to the task? |
| Peter | Yeah, when we did a warm-up yesterday, I did good work because of the warm-up. We had to roll dices and we had to find friends of 10.... |
| Int. | What was it about today's task that helped you learn a lot. |
| Peter | Today I had to make 21 and yesterday's task was not better than this one ... this one was better than yesterday's task. |
| Int. | And why was it better? |
| Peter | Because I got to write lots of numbers that I had to learn, and I liked it when I did the task. |

The Sequence of Challenging tasks

More students with counters (1)

Five students have 21 counters between them.

All have different numbers of counters.

How many counters might the students each have?



Structure of number



Variations on Tenzi (1)

Roll 10 dice

- Find combinations that add to 10
- How many different ways can you make 10 from the dice you rolled?

Record your solutions in number sentences.



Structure of number



Characteristics of tasks that students are likely to enjoy, learn from and be challenged by

1. Can be solved in multiple ways, and/or have multiple answers.
2. Ask the problem before teaching ('telling') the method.
3. Include inquiry opportunities.
4. Have a 'visual' component and ask students how they see the mathematics.
5. Are low floor and high ceiling (LFHC).
6. Ask students to convince and reason.
7. **Occur as part of a coherent sequence of challenging tasks**

Teacher actions that support student learning while using challenging tasks

1. Connect the tasks with students' experiences. **Contextualise tasks.**
2. Communicate your **enthusiasm** about the task, encouraging students to persist.
3. Build a classroom climate that **encourages risk taking**. Expect students to succeed.
4. Allow time for, and use strategies to elicit, **student talk** about their thinking.
5. Provide **regular opportunities** for students to explore challenging tasks.
6. Ensure students have adequate **time** to work on the task. Reduce “teacher telling”.
7. Provide **formative feedback** as soon as possible.
8. Move around the class, **observe students** at work, select students who might report, intervene only when necessary to seek clarification of potential misconceptions, to support students who cannot proceed, and to **challenge/extend** those who complete the task.
9. Allow time for **review** so that students see the thinking of other students & **summarise** the learning.
- 10. Savour success!** (* Savouring prolongs the enjoyment!)

Challenge, Struggle & Enjoyment for ALL students

Extending prompts



No
struggle



Productive
struggle



Destructive
struggle

Enabling prompts

Appropriately challenging tasks
are within their **zone of
development** Just **NOT YET** !

Persistence is encouraged by a
growth mindset and positive
emotions !

Productive
'failure'

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