Problem Solving in Primary Mathematics

Dr John West
About me

I have worked as a:

• Mathematics teacher, tutor, mentor and G&T coordinator;
• Lecturer in mathematics education/ pedagogy/assessment/special ed and research methods at ECU and UWA (incl. Singapore/Hong Kong/Vietnam);
• Consultant for CEO, AIS, GATCA (WA);
• Researcher and author;

and

• MAWA Committee member (President elect)
Background

In 2013 a team of ECU researchers were commissioned to report on the status of *STEM Education in WA Schools*. The results revealed:

- declining performance in STEM subjects against our international competitors;
- increasingly negative attitudes towards STEM subjects (internationally; and between Year 4 and Year 8);
- declining participation in academically demanding STEM subjects; and
- concern about the low proportion of Australian students reaching the advanced achievement benchmarks.
Background

Challenges specific to WA include:

• a strong negative impact of social disadvantage, geolocation and gender on achievement, attitudes and participation (i.e., the gap);

• concerns about teacher qualifications and out-of-field teaching; and

• the need to ensure fair and even delivery of support across the state (shown to scale)
The Good News

On the positive side, the research revealed:

- widespread industry support for a diverse range of initiatives to support STEM education; and

- a willingness to work with educators who provide specialist expertise e.g., understanding of curriculum.

Companies just wanted evidence to justify their investment.
International Benchmarking Studies

• The Trends in International Maths and Science Study is conducted every four years to collect data on maths and science achievement in Year 4 and Year 8.
  • TIMSS compares performance of students in approximately 57 countries

• The Programme for International Student Assessment is conducted by the OECD every three years to collect data on reading literacy and mathematical literacy of 15 year-old students.
  • PISA compares the performance of students in approximately 65 countries
Australia’s Year 4 students in both maths and science had the fifth widest gap between high and low achievers in OECD countries.

Former Education Minister Peter Garrett

Over half of all Australian students are in schools where resource shortages are affecting the teaching of reading and maths.

TIMSS-PIRLS 2011

One third (32%) of Australian students are in secondary schools where the principals says a lack of qualified maths teachers hinders learning.

OECD PISA 2012

Fairness in resource allocation is not only important for equity in education, but it is also related to the performance of the school system as a whole.

OECD PISA 2012

High performing countries and economies tend to allocate resources more equitably across socio-economically advantaged and disadvantaged schools.

OECD PISA 2012

By Year 9, the gap between the top achievers and those at the bottom, is equivalent to five years in schooling.

OECD PISA 2009
So what can we do?

Let’s look at the facts:

• Education is under increasing scrutiny
• Teachers are working harder than ever
• Teachers are burning out and leaving the profession
• Students lack confidence in mathematics
• Huge emphasis on summative assessment

The solution...?

• We need to trust our educators more
• We need to help our teachers to work smarter not harder
• Burnout is a bad outcome for everyone
• We need to increase student responsibility and confidence
• We need to increase the emphasis on assessment for learning
Challenging misconceptions

- I've never been good at maths
- I'm on my own!
- Can you help?
- There's only one path to a solution
- Maths is not creative / There's only one correct answer
- Of mathematics teachers...
- Maths is not for everyone
- I've never been good at maths
- I hate mathematics!
- Australia's doing ok
- Smart kids don't need as much help
- I'm not smart enough!
- Maths is too hard; just make it easier!
- Why are we doing this?
International Mathematics Achievement

4th Grade

Singapore 618
Hong Kong SAR 615
Korea 608
Chinese Taipei 597
Japan 593

N. Ireland 570
Russian Federation 564
Norway 549
Ireland 547
England 546
Belgium (Flemish) 546
Kazakhstan 544
Portugal 541
United States 539
Denmark 539
Lithuania 535
Finland 535
Poland 535
Netherlands 530
Hungary 529
Czech Republic 528
Bulgaria 524
Cyprus 523
Germany 522
Slovenia 520
Sweden 519
Serbia 518
Australia 517
Canada 511
Italy 507
Spain 505
Croatia 502
Slovak Republic 498
New Zealand 491
France 488
Turkey 483
Georgia 463
Chile 459
United Arab Emirates 452
Bahrain 451
Qatar 439
Iran 431
Oman 425
Indonesia 397
Jordan 388
Saudi Arabia 383
Morocco 377
South Africa 376
Kuwait 353

23 Point Gap

TIMSS 2015

IEA TIMSS & PIRLS
The Score Card (TIMSS 2015)

• International Ranking (Year 4 Mathematics)
  • 11th place TIMSS 1995
  • 28th place TIMSS 2015

• International Ranking (Year 8 Mathematics)
  • 13th place TIMSS 1999
  • 17th place TIMSS 2015

Thomson, Wernert, O’Grady & Rodrigues (2016)
Sample Year 4 TIMSS items

Tom ate $\frac{1}{2}$ of a cake, and Jane ate $\frac{1}{4}$ of the cake. How much of the cake did they eat altogether?

<table>
<thead>
<tr>
<th>Education system</th>
<th>Percent correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>84</td>
</tr>
<tr>
<td>Northern Ireland-GBR</td>
<td>68</td>
</tr>
<tr>
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<td>Ireland</td>
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<td>Hong Kong-CHN</td>
<td>53</td>
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<tr>
<td>England-GBR</td>
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<tr>
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<td>46</td>
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<td>Germany</td>
<td>41</td>
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<tr>
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<td>Korea, Rep. of</td>
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<td>Denmark</td>
<td>32</td>
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<tr>
<td>Belgium (Flemish)-BEL</td>
<td>30</td>
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<td>Netherlands</td>
<td>28</td>
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<tr>
<td>Japan</td>
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<td>Austria</td>
<td>28</td>
</tr>
<tr>
<td>Malta</td>
<td>24</td>
</tr>
<tr>
<td><strong>International average</strong></td>
<td><strong>23</strong></td>
</tr>
</tbody>
</table>
Sample Year 4 TIMSS items

If the pattern 3, 6, 9, 12 was continued, which of these numbers would be one of the numbers in the pattern?

A. 26  
B. 27  
C. 28  
D. 29

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<td>Australia</td>
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<td>Slovak Republic</td>
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<td>Russian Federation</td>
<td>64</td>
</tr>
<tr>
<td>International average</td>
<td>62</td>
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</tbody>
</table>

International average: 62
Which shows a correct method for finding $\frac{1}{3} - \frac{1}{4}$?

A. $\frac{1 - 1}{4 - 3}$
B. $\frac{1}{4 - 3}$
C. $\frac{3 - 4}{3 \times 4}$
D. $\frac{4 - 3}{3 \times 4}$

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<tr>
<td>Ghana</td>
<td>19</td>
</tr>
</tbody>
</table>
Sample Year 4 TIMSS items

What is the area of this rectangle?

A. $x^2 + 2$
B. $x^2 + 2x$
C. $2x + 2$
D. $4x + 4$

Of course, chance effects explain 25% in this case!
The Score Card (TIMSS 2015)

- While our 2015 scale score is no different from 1995, our international competitors have increased and we have fallen in the rankings
- What is it that they are doing that we aren’t?
- Not the gap between high and low achievers
  - Australia – 275 points
  - Singapore – 280 points
TIMSS Advanced Achievement Benchmarks

• Just 9% of Australian Year 4 students reached the advanced achievement benchmark in mathematics, compared to 50% of students in Singapore

• Just 7% of Australian Year 8 students reached the advanced achievement benchmark, compared to 54% of students in Singapore

Thomson, Wernert, O’Grady & Rodrigues (2016)
Stimulating Reasoning using open-ended tasks

*Australian Primary Mathematics Classroom, 23(1), 32-35*

**Figure 1. Which of these shapes is the odd one out?**
Which one is the ‘odd’ one out? Explain your reasoning.
Stimulating Reasoning using open-ended tasks

*Australian Primary Mathematics Classroom, 23(1), 32-35*

Figure 4. Which of these shapes is the odd one out?
Male

- Oily un-combed hair
- Un-shaved face
- Un-ironed tie
- Shoulder pads
- Birthday present
- Broken suitcase
- Tons of papers
- Spilt coffee
- Stained suit
- Permanent blank expression
- Over-sized glasses
- Coffee stains
Bored tired eyes

Dirty unbrushed hair

Wrinkles from thinking too hard

Unshaved face

Pencils hand in case of math problem

Fat from doing nothing but math

Old math problems

Hole in wrinkled pants—he's too lazy to buy new pair

Plants are too small

Bad body posture

A old stain— he's too lazy to wash his shirt.
Teachers of mathematics:

- have no friends (except other maths teachers);
- are not married or seeing anyone;
- are usually fat;
- are very unstylish;
- have wrinkles from thinking so hard;
- have no social life whatsoever;
- are 30 years old; and
- have a short temper.
Growth Mindset

- Professor Jo Boaler (Stanford/Cambridge)
  - Reframing students’ and teachers’ perceptions of mathematics
  - Developing a growth-oriented mindsets
  - Focusing on developing understanding

- Challenging many myths about the brain and learning maths

- Free resources are available:
  - [www.youcubed.org](http://www.youcubed.org)
# Building a Mathematical Mindset Community

**Teachers and students believe everyone can learn maths at HIGH LEVELS.**
- Students are not tracked or grouped by achievement
- All students are offered high level work
- “I know you can do this” “I believe in you”
- Praise effort and ideas, not the person
- Students vocalize self-belief and confidence

**Communication and connections are valued.**
- Students work in groups sharing ideas and visuals.
- Students relate ideas to previous lessons or topics
- Students connect their ideas to their peers' ideas, visuals, and representations.
- Teachers create opportunities for students to see connections.
- Students relate ideas to events in their lives and the world.

**The maths is visual.**
- Teachers ask students to draw their ideas
- Tasks are posed with a visual component
- Students draw for each other when they explain
- Students gesture to illustrate their thinking

**The maths is OPEN.**
- Students are invited to see maths differently
- Students are encouraged to use and share different ideas, methods, and perspectives
- Creativity is valued and modeled.
- Students' work looks different from each other
- Students use ownership words - “my method”, “my idea”

**The environment is filled with WONDER and CURIOSITY.**
- Students extend their work and investigate
- Teacher invites curiosity when posing tasks
- Students see maths as an unexplored puzzle
- Students freely ask and pose questions
- Students seek important information
- “I’ve never thought of it like that before.”

**The classroom is a risk-taking, MISTAKE VALUING environment**
- Students share ideas even when they are wrong
- Peers seek to understand rather than correct
- Students feel comfortable when they are stuck or wrong
- Teachers and students work together when stuck
- Tasks are low floor/high ceiling
- Students disagree with each other and the teacher

*Developed by Jo Boaler/Youcubed.org and Tulare County Office of Education*
Low-floor, high-ceiling tasks

A **tiered task** is a learning activity that has multiple entry and exit points.

Tiered tasks are suitable for students of a wide range of abilities since they allow students to work at their own level.

Low-floor, high-ceiling tasks are **accessible** to all students yet allow students to demonstrate diverse levels of achievement.
**Recommendations for Task/Lesson Design**

- Open the task to encourage multiple methods, pathways and representations.
- Pose a problem before teaching the method.
- Design a task that allows all learners to contribute to the learning and have room for extension.
- Make opportunities for students to authentically share their thinking with peers.
- Add a visual component.
- Add the requirement to convince and reason, be skeptical.

**Powerful Questions to develop a deep level of understanding**

- How do you see that idea?
- Why does that answer make sense?
- Why does that method work?
- How is that method connected to others?
- How can that idea be represented in different ways?
- Can you prove it?
- Can you prove it visually?
- Can you justify your thinking?
- Can you predict what would happen if...?
- Did you make any interesting mistakes?

*Developed by Jo Boaler/Youcubed.org and Tulare County Office of Education*
I'M A MATH TEACHER
OF COURSE
I HAVE PROBLEMS.
Finding problems

• 45 worked examples and 200 problems with solutions drawn from across the curriculum
• Each chapter focuses on a particular PS strategy
• Transfer of learning
• Purposefully teach PS strategies.
Resources for Collaborative Problem Solving

Dr Paul Swan & David Dunstan
Professor Peter Sullivan

- Lead author, AC:M
- **Extending** and **enabling** prompts ensure tasks are suitable for a range of students
Alex Bellos

- Author of *Alex’s Adventures in Numberland*
- Well-written
- Easy to read
MAWA

- 48 pages
- Affordable ($15)
MAWA

- 48 pages
- Affordable ($10)
### Year 8 Sample Question TIMSS Advanced Achievement Benchmark

**Content Domain: Algebra**

**Cognitive Domain: Applying**

**Description:** Constructs and uses the solution of a linear equation to solve a word problem.

<table>
<thead>
<tr>
<th>Country</th>
<th>Percent Full Credit</th>
</tr>
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<tbody>
<tr>
<td>Korea, Rep. of</td>
<td>69 (1.8)</td>
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<tr>
<td>Chinese Taipei</td>
<td>67 (2.0)</td>
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<td>Singapore</td>
<td>65 (1.8)</td>
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<td>43 (2.2)</td>
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<td>Kazakhstan</td>
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<td>Japan</td>
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<td>11 (1.1)</td>
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<tr>
<td>Australia</td>
<td>11 (1.1)</td>
</tr>
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</table>

The sum of the lengths of the sides of this triangle is 30 cm.

A. Write an equation that would enable you to find the value of $x$.

Equation: $4x + 10 = 30$

B. What is the length of the LONGEST side of the triangle in centimeters?

Answer: $\underline{11}$ cm
Ahmed had the following scores out of 10 on his first 4 mathematics tests: 9, 7, 8, 8. Ahmed has 1 more test with a maximum of 10 points and says he wants to get an overall average of 9. Is it possible for him to do this?

Explain your answer.

No, Ahmed would have to score 13 to do this.
**ACTIVITY SPLASH PAGE**

**POLYGON**

**Materials**
- A set of polyhedral dice
- A BINGO card

**Instructions**
Roll all of the polyhedral dice.

Use some (or all) of the numbers and the four operations to make numbers on the BINGO card.

The winner is the first player to make all of the numbers in a row, column or diagonal on their card. They need to record their calculations.

---

**NOGGLLE**

**Materials**
- 1 dice

**Instructions**
Noggle is a number game that works the same way as the word game with the similar name.

Roll the 9 dice and arrange them as a 3 x 3 array.

Players use some or all of the numbers and the four operations (i.e., +, -, x, and /) to get as close to an agreed target (e.g., 30) as possible.

The first player to reach the target number exactly scores 10 points. If neither player reaches the target, the player who is closest receives 10 points minus the number they are away from the target.

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**Chicken Nugget Problem**

The chicken nugget problem caused mathematicians a real stomach ache and they wanted out that there is a maximum number of nuggets that cannot be purchased in a single transaction.

A box of nuggets can only be bought in packs of 4 and/or 7.

What is the largest number that is impossible to buy?

---

**DISCARD**

**Equipment**
- A 6-sided die
- A deck of cards

**Instructions**
Each player is dealt 8 cards. The remaining cards are placed on the table in the stock pile. Players take it in turns to roll two six-sided dice and try to match cards from the top of the deck to the numbers rolled in one of the following ways:
1. A single card may be matched to the sum of the two numbers rolled.
2. Two cards may be matched to the two numbers rolled on the dice.
3. If the player has just one card remaining, they need only match it with one of the dice. E.g., if 1 and 6 are rolled, the player may discard either 1 or 6.

The winner of the game is the first player to discard all of their cards.

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**Number Thief!**

**The notorious number that has struck again!**

Three of the digits appear to have been stolen.

So far it seems that the digits that the digits taken have been selected at random.

**Instructions**
Roll three six-sided dice to determine the three digits that have been stolen.

For example, the missing digits may be 2, 3 and 7.

If two or more dice show the same digit, then roll again.

Mathematicians are worried that other digits might be missing and are hoping to be able to use the remaining digits to replace all of the numbers from 1 to 20 in case there's a national number shortage.

---

**UnPrime**

**Equipment**
- 1 counter for each player
- A 6-sided die

**Instructions**
Players take it in turns to roll the dice, adding or multiplying the two numbers.

They must then move their counter forward by that number of spaces.

If they land on a prime number, they must move their counter back to the START.

---

Example:

Since 2 and 3 are missing, we can't do $3 - 2 = 1$ or $3 	imes 2 = 6$.

Fortunately, we can calculate $5 - 4 = 1$ and $6 - 1 = 5$.  
POLYNGO

Materials
A set of polyhedral dice
A BINGO card

Instructions
Roll all of the polyhedral dice.

Use some (or all) of the numbers and the four operations to make numbers on the BINGO card.

The winner is the first player to make all of the numbers in a row, column or diagonal of their card. They need to record their calculations.
# POLYNGO

## Materials
A set of polyhedral dice  
A BINGO card

## Instructions
Roll all of the polyhedral dice.

Use some (or all) of the numbers and the four operations to make numbers on the BINGO card.

The winner is the first player to make all of the numbers in a row, column or diagonal of their card. They need to record their calculations.

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<td>45</td>
<td>17</td>
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<td>14</td>
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<td>26</td>
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<td>41</td>
<td>29</td>
<td>6</td>
<td>20</td>
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- $7 - 1 = 6$
- $8 + 8 + 7 - 1 = 22$
- $8 + 2 + 1 = 11$
- $(8 + 8) \times 2 - 1 = 31$
NOGGLE

Materials
9 dice

Instructions
Noggle is a number game that works the same way as the word game with the similar name. 😊

Roll the 9 dice and arrange them as a 3 x 3 array.

Players use some or all of the numbers and the four operations (i.e. +, -, x and ÷) to get as close to an agreed target (e.g. 50) as possible.

The first player to reach the target number exactly scores 10 points. If neither player reaches the target, the player who is closest receives 10 points minus the number they are away from the target.
**POWERBALL NOGGLE**

**Materials**
9 dice

**Instructions**
Noggle is a number game that works the same way as the word game with the similar name. 😊

Roll the 9 dice and arrange them as a 3 x 3 array.

Players use some or all of the numbers and the four operations (i.e. $+,-,\times$ and $\div$) to get as close to an agreed target (e.g. 50) as possible.

In this variation, players **must** use the number on the central die. **Hint:** Use a different colour die so players cannot simply move any number to the centre.
Chicken Nugget Problem

The chicken nugget problem caused mathematicians a real stomach ache until they worked out that there is a maximum number of nuggets that cannot be purchased in a single transaction!

Say nuggets can only be bought in packs of 4 and/or 7.

What is the largest number it is impossible to buy?
The chicken nugget problem caused mathematicians a real stomach ache until they worked out that there is a maximum number of nuggets that cannot be purchased in a single transaction!

Say nuggets can only be bought in packs of 4 and/or 7.

What is the largest number it is impossible to buy?

Clearly it is not possible to purchase 1, 2 or 3 nuggets. It is also not possible to purchase 5 or 6. It is possible to purchase 8 nuggets but not 9 or 10. It is possible to purchase 11 or 12 nuggets, but not 13. It is possible to purchase 14 nuggets, but not 15. It is possible to purchase 16 nuggets, but not 17. It is possible to purchase 18, 19, 20 or 21 nuggets…
DISCARD

Equipment
• 2 x 6-sided dice
• A deck of cards (1s – 12s / A – 9, J, Q, K)

Instructions
Each player is dealt 8 cards. The remaining cards are placed on the table as the stock pile. Players take it in turns to roll two six-sided dice and to match cards from their hand to the numbers rolled in one of the following ways:
1. A single card may be matched to the sum of the two numbers rolled
   E.g., if a 6 and a 2 are rolled, then the player can discard an 8.
2. Two cards may be matched to the two numbers rolled on the dice.
   E.g., if a 1 and 4 are rolled, the player discards a 1 and a 4.
3. If the player has just one card remaining, they need only match it with one of the dice. E.g., if a 1 and a 6 are rolled, the player may discard either a 1 or a 6.

If a player is unable to make a match during their turn, they must draw a card from the stock pile.

The winner of the game is the first player to discard all of their cards.
Number Thief!

The notorious number thief has struck again!

Three of the digits appear to have been stolen.

So far it seems that the digits that the digits taken have been selected at random.

Instructions
Roll three ten-sided dice to determine the three digits that have been stolen.

For example, the missing digits may be 2, 3 and 7.

If two or more dice show the same digit, then roll again.

Mathematicians are worried that other digits might go missing and so are hoping to be able to use the remaining digits to replace all of the numbers from 1 to 20 in case there’s a national number shortage.

Example
Since 2 and 3 are missing, we can’t do 3 – 2 = 1 or 3 + 2 = 5.

Fortunately, we can calculate 5 – 4 = 1 and 6 – 1 = 5.
UnPrime

Equipment
• One counter for each player
• 2 x 6-sided dice

Instructions
Players take it in turns to roll the dice, adding or multiplying the two numbers.

They must then move their counter forward that number of spaces.

If they land on a prime number, they must move their counter back to the START!