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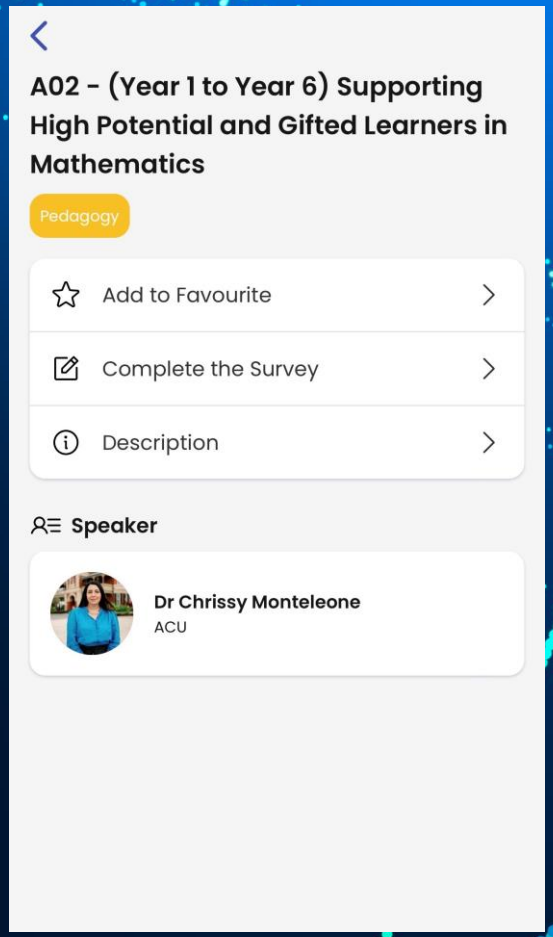

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An exploration of teaching mathematics through problem-solving in primary classrooms

Donna Guise

Margo’s classroom

“In Margo’s Grade 3 class, small groups of students create different solutions to a lesson problem and then present their solutions to their classmates. Although the first group’s solution includes colourful pictures and a lengthy description, it doesn’t explain the strategy they’ve used. The second group’s solution is difficult to follow. As group after group shares, attention begins to fade. As the sixth group presents, Margo sees only a few students listening. As the students go out for recess, Margo wonders, “What are students really learning by sharing? How can I help my students become more effective mathematical communicators?” (Ontario Ministry for Education, 2010, p.1)

What’s your best problem-solving advice, and how has it impacted your mathematics classrooms?

Background

Although problem-solving has been advocated in mathematics curriculum documents and supporting materials for decades, this vision has failed to be realised in the classroom (R. K. Anderson et al., 2018; Schoenfeld, 2013).

Teaching for problem-solving

- Teaching for problem-solving typically begins with an explicit teaching approach and is commonly found in traditional classrooms.
- Usually, the content is demonstrated by the teacher, and then the students complete related exercises.
- It is anticipated that students are provided with opportunities to apply their learning to problems.

Teaching about problem-solving

- Teaching about problem-solving is concerned with the process of problem-solving.
- In the classroom this may look like learning about different problem-solving strategies and skills.
- Exploring Polya's (1945) four-steps of problem-solving may be included in teaching about problem-solving (Understand the problem, Devise a plan, Carry out the plan, Look back).

Teaching through problem-solving

- Teaching through problem-solving involves students starting with a rich problem.
- Students actively learn through being immersed in the problem, as is the case with inquiry-based learning.
- Strong pedagogical content knowledge is needed for teaching through problem-solving.

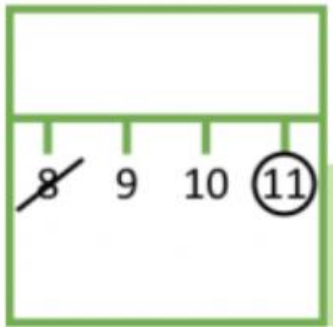
Strike it Out

This game starts with a 0 to 20 number line.

Player 1 picks two numbers, crosses them out and circles either their sum or their difference. The crossed out numbers can't be used again.

Player 2 crosses out the circled number and another number, and again circles either their sum or their difference.

The winner is the person who stops their opponent from being able to take a turn!



Instead of playing against each other, you could work together to use as many numbers as possible. Can you use all the numbers from 0-20? Why or why not?

nrich.maths.org

https://nrich.maths.org/problems/strike-it-out-poster

Activity

Please share through post-it notes and table discussions the **facilitators and barriers to problem-solving** implementation in the mathematics classroom.

Facilitators to problem-solving	Barriers to problem-solving
	

Teacher	▶ **Content first beliefs may lead teachers to think that problem-solving is not for all students in a classroom and that a level of readiness is required** (Sullivan et al., 2020) ▶ **Experience, knowledge, and self-efficacy** (Takahashi, 2021) ▶ **Beliefs about mathematics and mathematics pedagogy** (Schoenfeld, 2016) ▶ **Lack of understanding of the terms associated with problem-solving** (J. Anderson, 2000) **and the associated classroom roles** (Kroll & Miller, 1993) ▶ **Reluctance to allow students to struggle** (Russo et al., 2019)
Setting	▶ **School social environment** (Takahashi, 2021) ▶ **Assessments with outcomes linked to teacher accountability and parental expectations to teach predominately procedural knowledge** (Burns, 1992)
Student	▶ **Beliefs about mathematics and mathematical learning** (Corkin et al., 2019; Minas, 2019)

Key factors influencing the implementation of problem-solving

Activity

Please share some open and closed mathematical tasks which could be used as part of a mathematics trail.

https://www.uni-play.co.uk/wp-content/uploads/2020/01/PMSHAPES1-20-3-scaled.jpg

Research

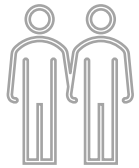
Research questions

- What **rationales** are given by the primary teachers for teaching mathematics through problem-solving?

- What **outcomes** are perceived as flowing from student mathematics learning?

- **How** do the primary teachers **plan** to teach mathematics through problem-solving and to what extent are the plans enacted? How is mathematics **taught** through problem-solving in the primary classroom?

Methodology



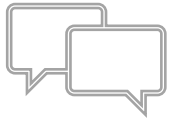
- Participants

- Duration

Data sources

- Classroom observations

- Interviews



- Informal conversations with classroom teachers

- Documentation

Teacher rationale

- Development of problem-solving skills and strategies
- Problem-solving is needed for high school and beyond
- Perceived student outcomes of confidence and engagement

Outcomes from student mathematics learning

- Engagement (teacher identified)
- Confidence (teacher identified)
- Enjoyment (identified by both student and teacher)

How is mathematics planned and taught through problem-solving in the primary classroom?

- Student choice (autonomy)
- Cooperative learning (relatedness)
- Maintaining cognitive challenge through teacher dialogue and growth mindset messages (competence)
- Task design (autonomy, relatedness, competence)

Main themes derived from the research findings

- **Lesson structure** which allows student exploration of mathematical concepts provides opportunity for problem-solving.

- A focus on mathematical **process outcomes** as well as mathematical content outcomes provides opportunity for problem-solving.

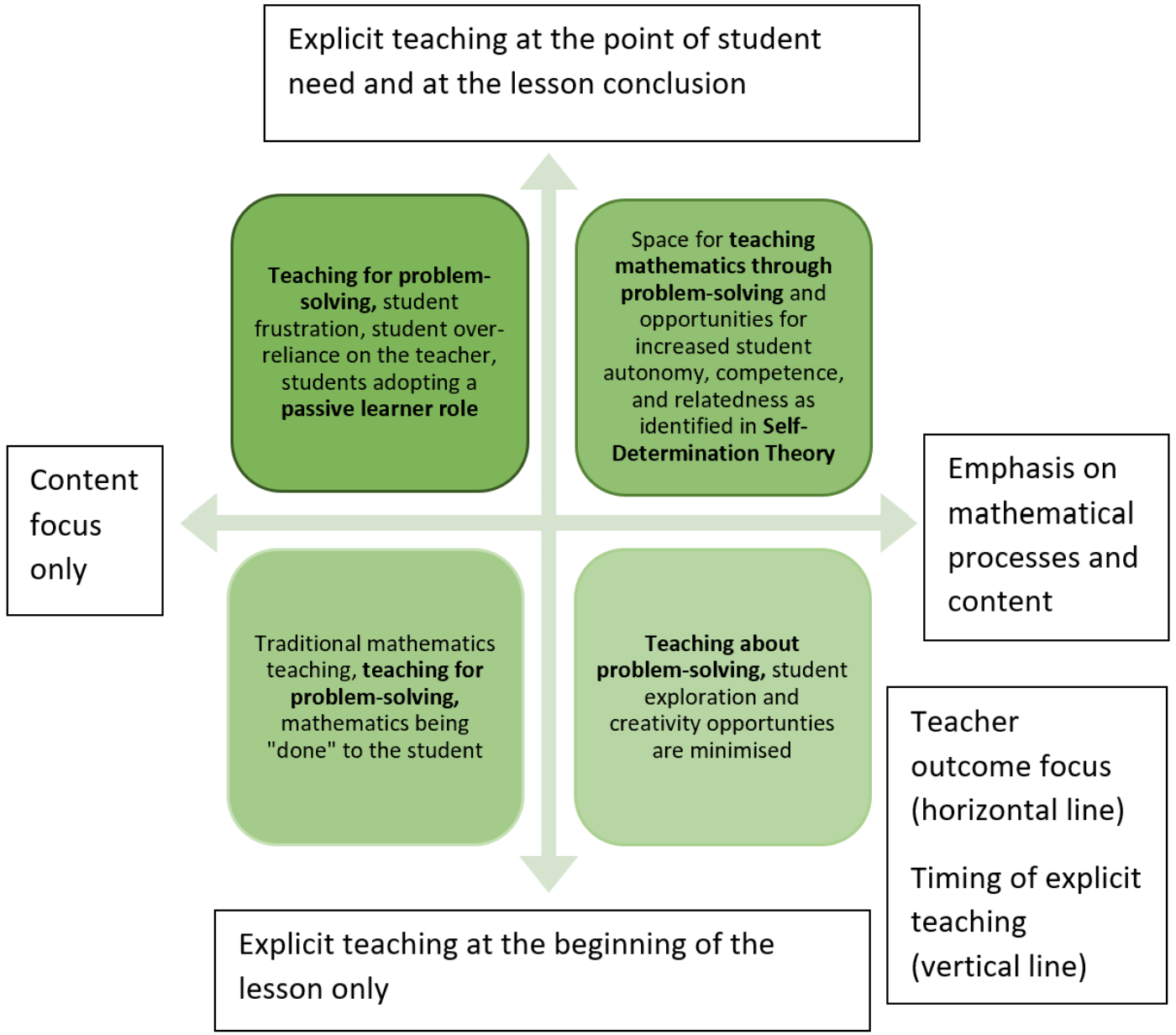
Discussion and Implications

- Teaching mathematics **for** and **about** problem-solving occurs frequently, however there is a significant lack of teaching mathematics **through** problem-solving in the observed classrooms.

- A strictly traditional mathematics lesson structure, which begins with teacher telling, and a focus on content outcomes were found to negatively impact opportunities for the implementation of teaching mathematics through problem-solving.

- When the more explicit teaching occurs later within a mathematical lesson structure and the more there is an increased focus on mathematical process outcomes, the more space is created for teaching mathematics through problem-solving and for further student autonomy, competence, and relatedness opportunities.

A conceptual teaching mathematics through problem-solving implementation



This study has highlighted three consideration for teachers:

- Provide opportunities for student independent learning and independent practice
- Focus on process outcomes to reduce the gap between the intended and implemented curriculum
- Plan and teach to allow for student-centred learning

In what ways do traditional mathematics tasks differ from rich tasks in supporting deeper mathematical thinking in students?

Comparison of Traditional and Rich Tasks (Flewelling & Higginson, 2001, as cited in Sousa, 2008, p.177)

Traditional Tasks	Rich Tasks
Prepare for **success in school**	Prepare for **success outside of school**
Address learning **outcomes in mathematics**	Address learning **outcomes in mathematics and other subject areas**
Focus on the use of relatively **few skills**	Provide an opportunity to use a **broad range of skills in an integrated and creative fashion**
Are more **artificial and out of context**	Are **authentic and in context**
Encourage **recollection and practice**	Encourage **thinking, reflection, and imagination**
Allow for demonstration of a **narrow range of performance**	Allow for demonstration of a **wide range of performance**
Usually require enrichment to be added after the task	Provide enrichment within the task
Permit the use of **fewer teaching and learning strategies**	Encourage the use of a **wide variety of teaching and learning strategies**
Keep students and teachers **distanced from the task**	Encourage greater **engagement of students and teachers in the task**

Questions and Statements

• **Good**
- ? + ? + ? = 13. What might the missing numbers be?

• **Not-so-good**
- ? + ? + ? = 13. Which numbers am I missing?

•**Good**
-How many different ways can you make 20 cents?

•**Not-so-good**
-What can you do with these coins to make 20 cents?

• **Good**
- Write down everything you can about the number 12.

• **Not-so-good**
- Tell me something about 12?

•**Good**
-I am thinking of a number between 10 and 100. My number has a single 9 in it. What might my number be?

•**Not-so-good**
-I am thinking of a number between 10 and 100, but my number is only allowed to have nines in it. What is my number?

•**Good**
- What is something we could do that takes exactly one minute?

•**Not-so-good**
- Do something for one whole minute!

• **Good**
- What can you find that is lighter than a pen?

• **Not-so-good**
- Is this lighter than a pen?

•**Good**
- I took two steps and finished near the desk. Where might I have started?

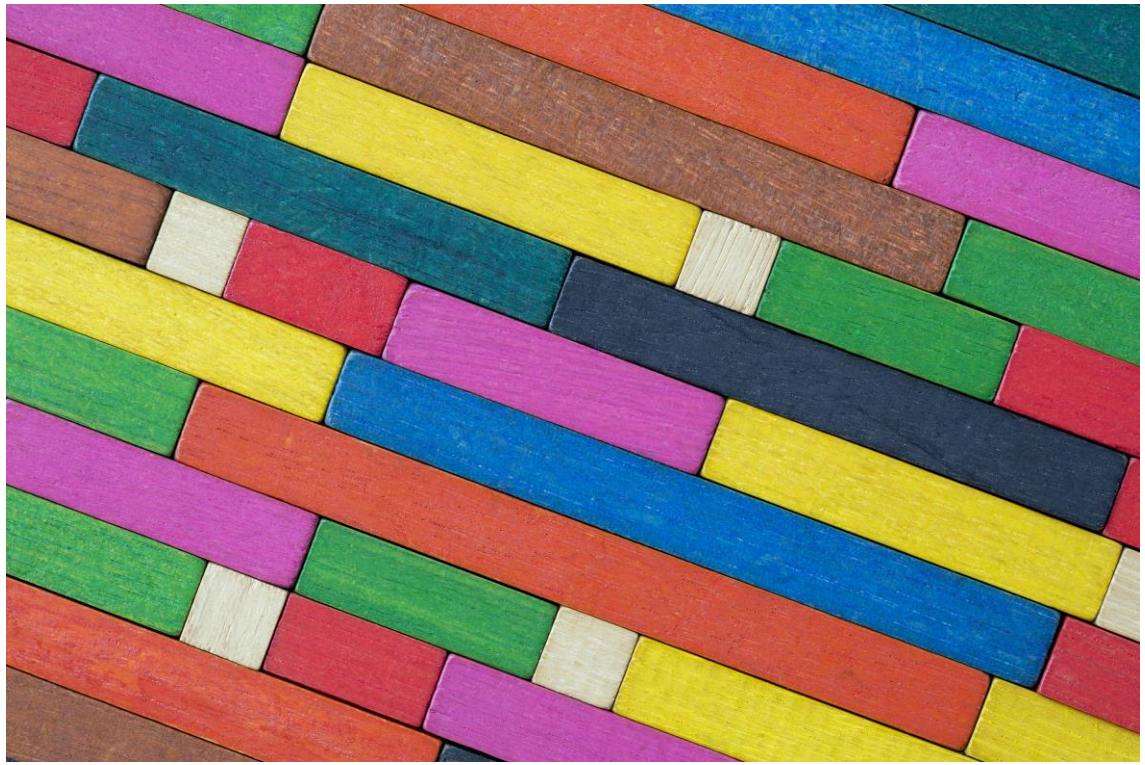
•**Not-so-good**
- I took two steps. Did I start from the table?

•**Good**
- I drew a shape with four sides. Draw what my shape might look like
.

•**Not-so-good**
- I drew a shape with four sides. Can you draw a square?

(Sullivan & Lilburn, 2002)

Resources I have used when thinking about implementing problem-solving



Four different ways of teaching through problem solving

Stacey, K. (2018). *Teaching mathematics through problem solving*.

Wayside stop (a few minutes)

Teachers who approach mathematics with a spirit of inquiry will often see opportunities to open even routine exercises to a problem-solving approach.

Students’ own observations and questions frequently provide prompts.

A day trip (one lesson)

Problems can be used to introduce or consolidate concepts, to develop fluency, and to develop strategic thinking, as well as to deepen knowledge.

Students need a supportive classroom environment, problems that are accessible at some level to all students, and structured reflection so that they learn from the experience.

Climbing the mountains (a unit of work)

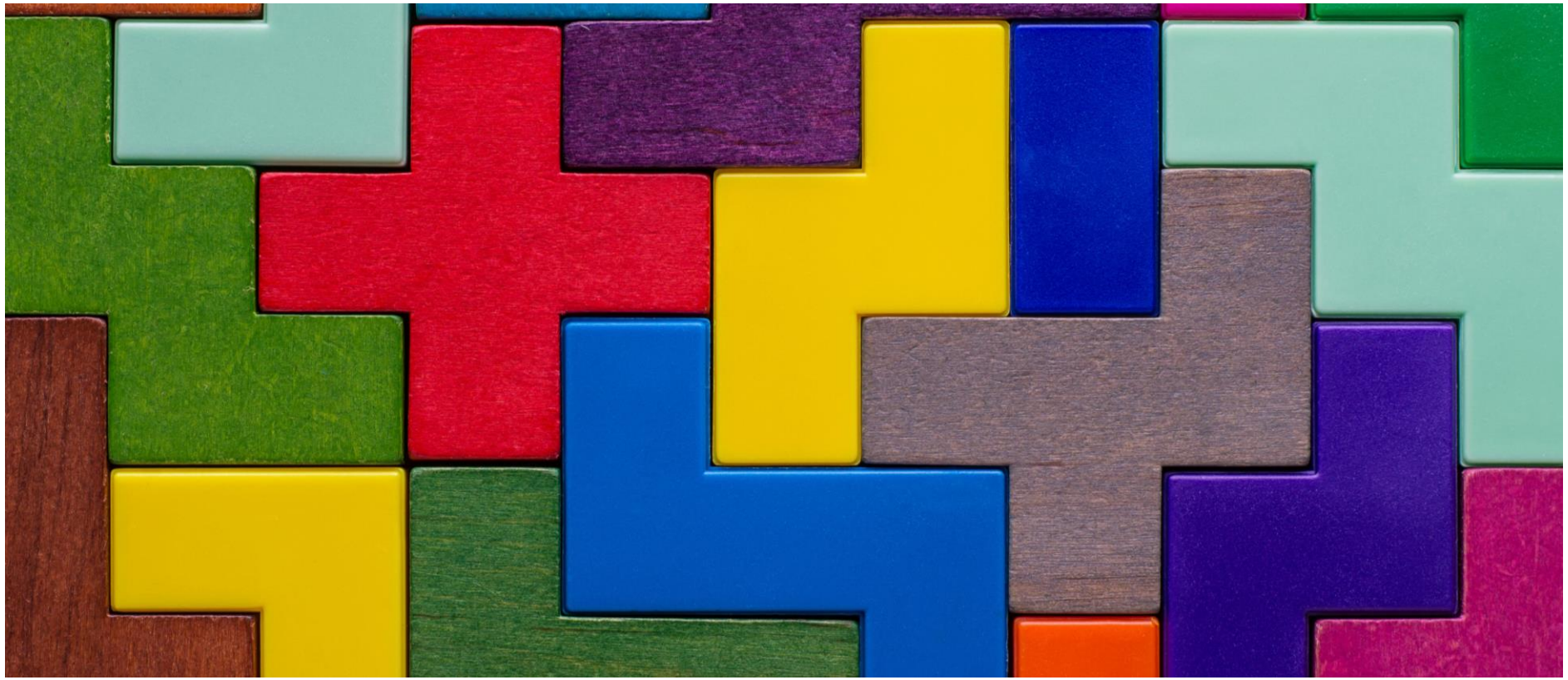
Tasks need to be selected to build a connected body of concepts, facts, and skills.

The teacher usually presents a problem and ensures that students understand what is required. Students then try to solve the problem either individually or in groups. During this time, the teacher moves around the classroom, looking for students whose work demonstrates some important learning points. In the following class discussion, selected students show their work and the teacher formalises and consolidates the main points of the lesson.

Crossing the plains (a unit of work)

A situation or problem (usually a real-world question) is posed for students to investigate. The problem is open and there is opportunity for students to go in various directions, to get a broader view of the uses of mathematics, and to use different parts of mathematics together to find a solution.

This unit provides a context and a purpose for students to apply old and new mathematical ideas in an authentic way.



Developing a Classroom Culture That Supports a Problem-solving Approach to Mathematics

Pennant, J. (2021). ***Developing a classroom culture that supports a problem-solving approach to mathematics*****. NRICH.**
https://nrich.maths.org/10341

1. **Who does most of the talking in whole-class parts of the lesson?**

Generally, in a strong problem-solving environment the teacher needs to be doing around 30% of the talking and the students 70%.

What do you notice about the balance in your classroom?

What type of things are you saying when you are talking?

Explaining how to do something?

Asking questions?

2. **What questions do I ask?**

Do you ask closed questions such as, 'can you see how the system works?' or open questions such as, 'what system can you see emerging in this problem?'.

3. **Who answers the questions?**

Is it the mostly the same students?

Is it the more articulate ones?

Is it more often boys or girls?

4. How well do I listen to the students' answers and seek to understand what they are saying?

Do I respond by telling the whole class what I think a particular student said without checking with them?

Do I slightly adjust what they said to make better sense or fit a 'better/right answer'?

Do I ask the student a 'clarification' question, such as 'can I just check what I think you said was ...'?

5. **What do I do with the students' answers?**

Do I praise them for a fabulous answer?

Do I simply evaluate their answers with comments such as 'Good', 'Well done', 'Right', 'OK', 'No', 'Think again’?

Do I carry on with the next thing I was going to say?

Do I ask other students to comment on what was said?

Do I ask another follow-up question such as 'are you sure?' or 'how do you know that?'?

6. How do I facilitate the learning?

Do I explain how it needs to be done and make sure they understand it as fully as possible before working on their own?

Do I give them key pointers/hints/clues to help them?

Do I pull out the learning from the students' thinking and use that to develop the journey of the lesson?

7. **How confident are the students to take a risk, to try out ideas, to make mistakes?**

What evidence is there of the students taking a risk in what they offer to the discussion or ideas that they try out?

What evidence is there that the students are trying out their ideas rather than replicating mine?

When is it helpful for them to replicate mine?

What do I do when a student makes a mistake or follows a 'dead end' line of thought?

8. **What does my body language communicate?**

Do I communicate interest/acceptance/frustration/disapproval ...?

How does my body language change through the lesson?

Make 37

Four bags contain a large number of 1s, 3s, 5s and 7s.

Can you pick ten numbers from the bags that add up to 37?

Resources I have used when implementing problem-solving

Website resources to assist with problem-solving

maths 300

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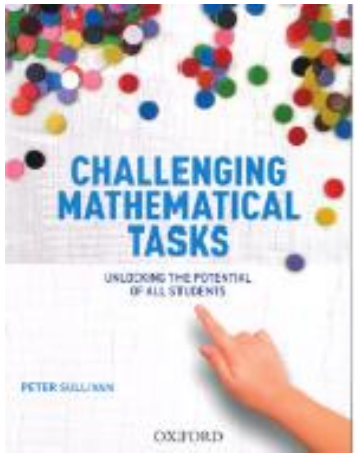
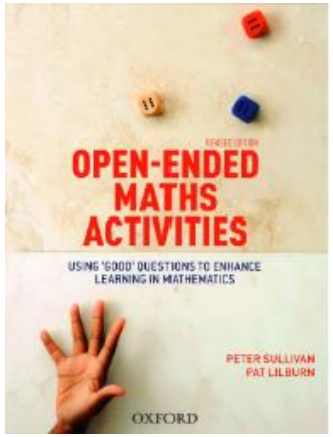
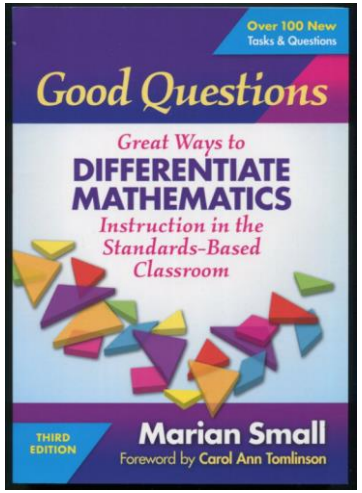
resources for teachers of mathematics

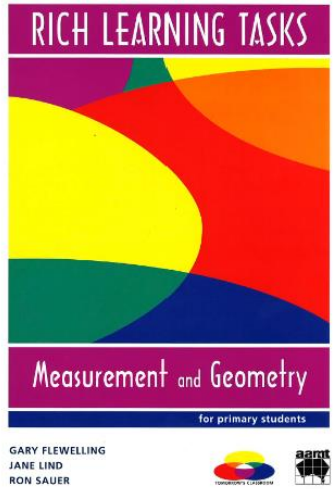
Numeracy Guide
The Numeracy Guide presents dynamic approaches to developing student numeracy.

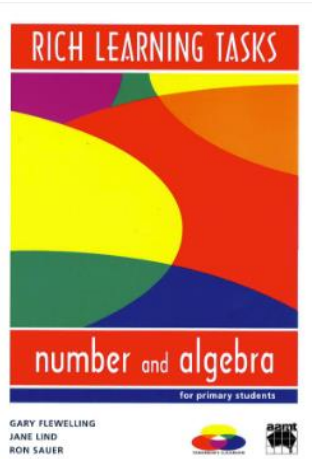
Book resources to assist with problem-solving

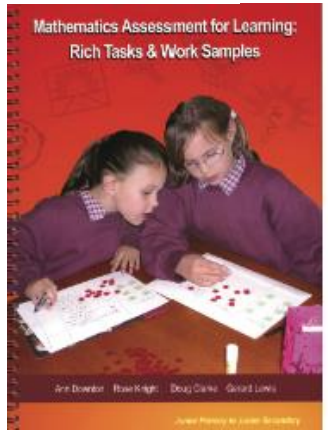


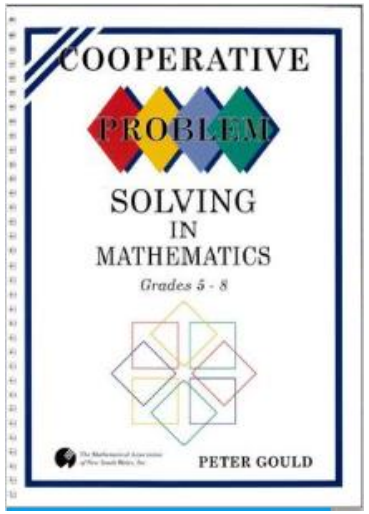












What is a new idea you and/or your colleagues could try to further support teaching mathematics through problem-solving in the classroom?

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