Design-based research in education: Getting it published

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DESIGN RESEARCH

Design research is an emerging paradigm which aims to ***develop a sequence of activities*** and to ***grasp an empirically grounded understanding of how learning works***. (Brown, 1992; Collins, 1992; Research Advisory Committee, 1996; Gravemeijer, 1994; Cobb, Stephan, McClain, & Gravemeijer, 2001)

DESIGN RESEARCH

Design research in education involves ***engineering*** particular forms of learning in a natural environment such as classroom and **systematically studying** how learning takes place in iterative cycles of learning.

(Cobb, Confrey, diSessa, Lehrer, &Schauble, 2003; Collins, Joseph, & Bielaczyc, 2004; Kelly, 2003; d Lamberg & Middleton, 2009)

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Reflexive relation between theory and experiments

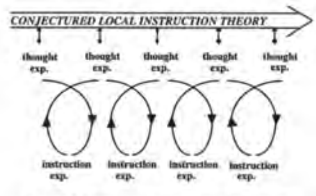

FIGURE 2 Reflexive relation between theory and experiments

Gravemeijer (2004) Vol 6 no 2, p. 112

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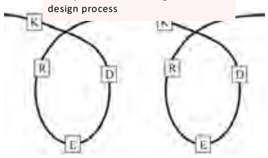
DESIGN RESEARCH phases

KNOWLEDGE (K)
Begin with knowledge of mathematics, students, students' anticipated solutions to guide the design process



Phases of knowledge, design, experiment and retrospective analysis in *Design Research cycles* (Dolk, Widjaja, Zonneveld, & Fauzan, 2010, p. 177)

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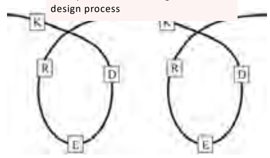

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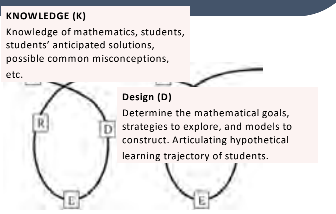

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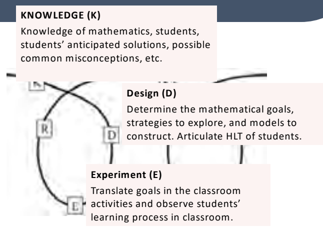

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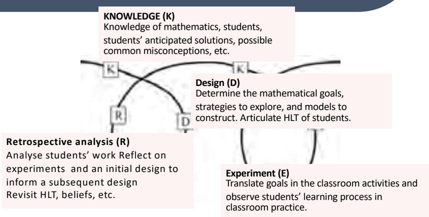

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Analyses in design research (1)

Analyses will have to be cases of a more general phenomenon that can inform design or teaching in other situations. One of the primary aims of a design research experiment is to support the constitution of an empirically grounded local instruction theory. (Gravemeijer & Cobb, 2013, p. 79)

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Analyses in design research (2)

The objective of design experiment is not to try and demonstrate that the initial design or initial local instruction theory works. The overall goal is not even to assess whether it works… Instead the purpose of the design experiment is both to test and to improve the conjectured LIT that was developed in the preliminary phase, and to develop an understanding of how it works. (Gravemeijer & Cobb, 2013, p. 81)

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Reeves (2006) depicts the design research approach as follows:

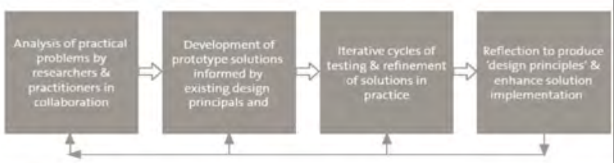

Figure 2: Refinement of problems, solutions, methods, and design principles (Reeves, 2000, 2006)

van den Akker, Bannan, Kelly, Nieveen & Plomp, T. (2013, p. 8, p.18).

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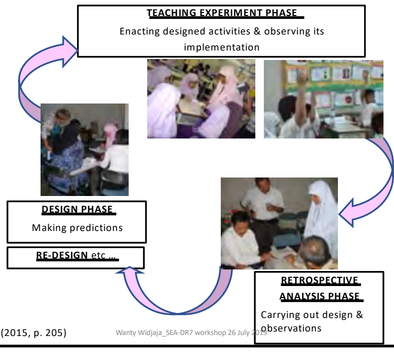
Teacher DESIGN RESEARCH

Teacher design research (TDR), whose goal is to promote the ***growth of teachers*** as ***adaptive experts***… the instructional aspects of TDR comes not from outside experts, but, rather from the teachers' ***cognitive dissonance experiences*** as designers in design cycles.

(Bannan-Ritland, 2008, p. 247)



Widjaja, W., & Dolk, M. (2015, p. 205)

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Why design research?

- Developing appropriate activities that support learning to take place
- Examining the complexity of classroom learning practices
- Gathering *a systematic evidence* from classroom practice by research
- Encouraging researchers-teachers collaboration
- Developing a new instruction or learning theory

van den Akker, Bannan, Kelly, Nieveen & Plomp, T. (2013, p. 8, p.11)

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Theoretical intent in design research

A primary aim when conducting a retrospective analysis is to place the design experiment in a broader theoretical context, thereby framing it as a paradigm case of the more encompassing phenomena specified at the outset.

(Cobb, Confrey, diSessa, Lehrer & Schauble 2003, p. 13)

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The power of context in DBR

The strength of design studies lie in *testing the theories* in crucible of practice; in *working collegially with practitioners, co-constructing knowledge*; in *confronting everyday classroom, school, and community problems* that influence teaching and learning, and *adapting instruction to these conditions*; in *recognizing the limits of theory*; and in capturing the specifics of practice and the potential advantages of *iteratively adopting and sharpening theory in its context*.

(d. Lamberg & Middleton, 2009, p. 233)

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A Local Instruction Theory

Encompasses both the overall process of learning and the instructional activities that are designed to foster the mental activities that constitute the long-term process. So… a process of conjecturing and revising can happen at two levels, on the level of individual classroom sessions, and on the level of the instructional sequence as a whole.

(Gravemeijer& Cobb, 2013, p. 85)

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…On replicability and validity

…feedback from teachers on how the instructional sequence was adjusted to accommodate various classrooms can strengthen the ecological validity significantly.

(Gravemeijer& Cobb, 2013, p. 103)

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Design research to design and develop an intervention

Such as programs:

- teaching-learning strategies and materials, products and
- systems) as a solution to a complex educational problem as well
- as to advance our knowledge about the characteristics of these
- interventions and the processes to design and develop them, or
- alternatively to design and develop educational interventions
- (about for example, learning processes, learning

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Contributions of Design research to theory and practice

Theory

- teaching-learning strategies and materials, products and
- systems) as a solution to a complex educational problem as well
- as to advance our knowledge about the characteristics of these
- interventions and the processes to design and develop them, or
- alternatively to design and develop educational interventions
- (about for example, learning processes, learning environments

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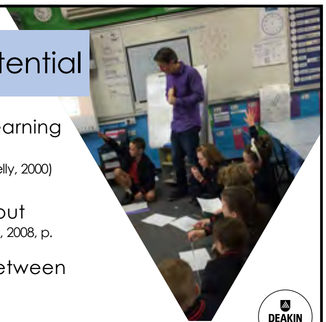
Methodological potential



- Multitiered, multidirectional learning by researchers, teachers and students (Bannan-Ritland, 2008; Lesh & Kelly, 2000)
- Provokes articulation and reconsideration of beliefs about teaching practice (Bannan-Ritland, 2008, p. 259)
- Strengthens collaborations between practitioners and researchers

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The strength of DESIGN RESEARCH

The strength of design studies lie in *the testing the theories in the crucible of practice*; in *working collegially with practitioners, co-constructing knowledge*; in confronting everyday classroom, school, and community problems that influence teaching and learning and adapting instruction to these conditions; *in recognizing the limits of theory*; and *in capturing the specifics of practice* and the potential advantages from *iteratively adopting and sharpening theory in its context.*

(Shavelson, Phillips, Towne, & Feuer, 2003, p. 25)

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Methodological issues and challenges

- Collecting large amount of data creates an issue of data reduction
- Tracking changes in classroom practice
- Establishing classroom mathematical norms
- Ensuring credible and trustworthy assertions

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Questions?

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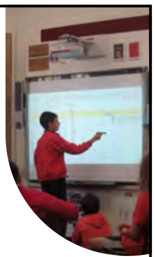
My journey in using design research and getting the research published

Theoretical underpinning

- Lesson Study
- Realistic Mathematics Education (Pendidikan Matematika Realistik Indonesia)

Design-based research methodolog



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Teacher-researcher collaboration in forming communities of inquiry

Acknowledgement: *The Implementing structured problem-solving mathematics lessons through lesson study project* by Susie Groves, Brian Doig, Colleen Vale and Wanty Widjaja

Teachers' and researchers' roles

- Teachers and coaches are taken a full authority to plan the research lesson
- The roles of Deakin research team:
  - sourcing potential mathematical tasks
  - modelling a problem solving lesson
  - providing resources e.g., research articles on Lesson Study, samples of lesson plans

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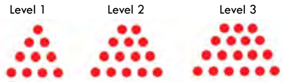
Lesson plans

- Offer insights for observers into the planning team's knowledge of curriculum, of mathematics, of teaching resources and of students' mathematical development.
- To be followed closely by the teacher during the public research lesson.

- Lesson study research theme
- About the curriculum
- Unit goals and research lesson goals
- Sequence of lessons in the unit
- Documents students anticipated solutions, strategies and reasoning.
- Flow of the lesson.
- Evaluation

Super Snooker

Super Snooker is a new snooker game that can
be played at different levels with different numbers of red balls



Children can play at Level 1, while experienced people can play at higher levels

I want to set up a snooker parlour for Super Snooker and am wondering how many red balls I will need to buy for Level 7

Can you help me to work this out?

Can you explain your answer with a diagram?

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Super snooker

Rationale of the Unit

Fit in Problem solving proficiency strand in the Australian Curriculum in mathematics

Jump-in lessons (not as curriculum dependent)

Objective of the lesson

- Find ***multiple solutions*** to the Super Snooker problem
- Use ***diagram to justify*** their mathematical sentences.
- See the ***relationship between different solutions.***
- Understand the importance of being able to ***link diagrams to the mathematical sentences.***

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Engaging in Problem solving

PROFESSIONAL LEARNING DAY, JUNE 2012

Sharing and justifying multiple strategies

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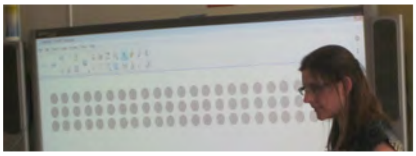
The array problem



- Here are some dots on a page. Use the diagram to show your thinking to work out how many dots there are altogether.

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Sharing your ideas

- Determine the goals and the year level
- Anticipate possible strategies using diagrams how students will solve the problem
- Identify relevant resources/teaching materials

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Engaging in Problem Solving

Teachers start with varying views and practice on problem solving

Planning starts by solving the mathematical problem

"If teachers are to encourage mathematical thinking in students, they need to engage in mathematical thinking throughout the lesson themselves." (Stacey, 2006)

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Collaborative planning

it would be easy to knowing the strategies beforehand and the progression because …so if you got the strategies set out of the natural progression that's going to make whoever's job that is teaching a whole lot easier when they need to share.

[Lynn, Planning meeting 3 Bobbies team]

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Anticipating students' solutions

Possible Solutions:

A. Doesn't make a start	B. Count all dots	C. Repeated Addition: 23 + 23 + 23 = 69 3 + 3 + 3…=69	D. Skip Counting: 3, 6, 9, 12….69	E. (Double23) + 23	F. 3, 6, 9, 12……69 (saw 23 columns of 3)
G. 34 groups of 2 (+ 1)		H. Groups of 6 (11 x 6) + Group of 3 (3)	I. 23 X 3 Vertical Multiplication. Knowing that 3x3=9and 20x3=60.		J. 23 x 3 = 69 (20 x 3, 3 x 3)

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Public research lessons

- A proving ground for planning team and teachers to test their ideas
- Not aiming to produce a perfect lesson
- Insights into students' mathematical strategies
- Insights into teachers' pedagogical decisions
- Reflective practice

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Recording students' ideas

To document evidence of students' learning
To facilitate the whole-class discussion by ***pulling different ideas together***

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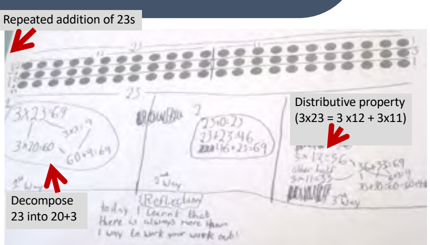
Students' multiple strategies



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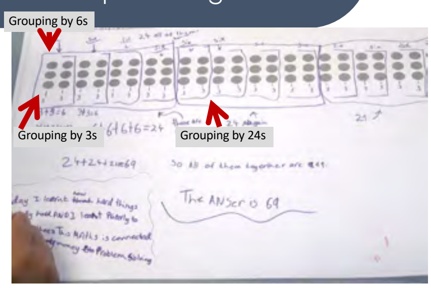

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Role of observers

"One hundred pairs of eyes"

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Teachers' perspective

- Opportunity to develop teacher knowledge
  - Sharing of resources
  - Unpacking student thinking and misconceptions (anticipated responses)
  - Developing content knowledge:
    "Teach yourself before we teach the students"
- Opportunity for Reflection
  - Giving and receiving effective feedback
- Challenging each other as professionals
  - Different perspective on teaching and learning

Source: Lesson Study presentation with teachers –MAV 2012 ppt

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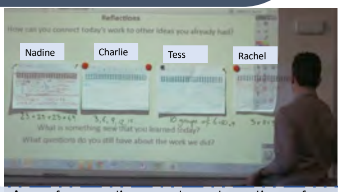
Planning whole-class discussion



Sequencing of recording and explanation of responses ***correspond with levels of generalisation*** that was indicated ***in the planning***

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Post-lesson discussion

Starts with the teacher and the planning team sharing their reflection of their learning
Focuses on students' learning and evidence of their works
Gains insights from observers and the knowledgeable other

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Shared ownership of the lesson

You know if you said well that it went really well or if you said that if this could have done better or that could have done better … You've done it together, it's all yours – it's not Trevor's lesson. It's our lesson that Trevor presented.

[Camilla, planning meeting 5, 18/10/2012]

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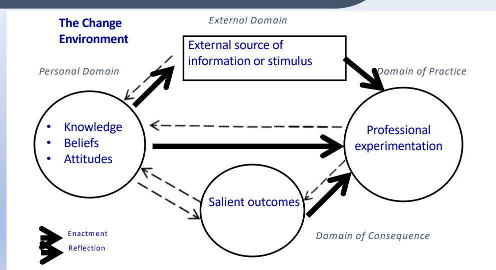
Clarke & Hollingsworth's (2002) *Interconnected Model of Professional Growth (p. 951)*



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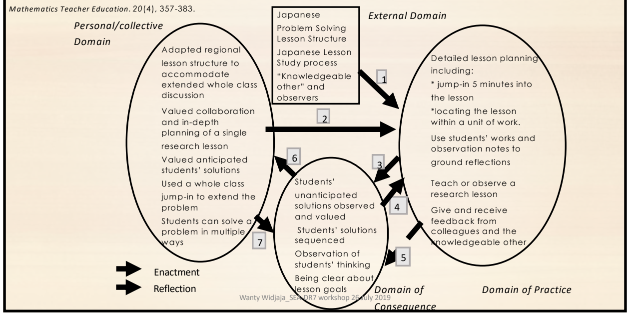
Map of Bobbies PT professional learning journey through planning, observing, and participating in cycle 2 research lessons (Widjaja, Vale, Groves, Doig, (2017). Teachers' professional growth through engagement with Lesson Study. *Journal of Mathematics Teacher Education*. 20(4), 357-383.



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Communities of inquiry

- Expectation that researchers would lead the way → ownership of the planning teams
- Collective effort by everyone in the planning teams
- A strong sense of mutual trust
- Value benefits of in-depth planning
- Planning teams working as communities of inquiry

(Groves, Doig, & Splitter, 2000; Jaworski, 2008)

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Getting your work published

- By invitations in a Special issue (ZDM) or books
- Planning ahead which parts of the study fits best and you can tell a compelling narrative that is different than the others
- Meeting the timelines set by the editors – very critical if you want to get another invitation
- Present findings from your publications to increase their impact and citations

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Publish in a journal with 'the right fit' preferably a high quality journal (Scimago Q1 or Q2)

WANTY WIDJAJA, COLLEEN VALE, BRIAN DOIG

NOTHING LIKE PLANNING AND REFLECTING TOGETHER TO BUILD TRUST

Studies on teams of practicing mathematics teachers' and coaches' collaboration

INTRODUCTION

To date, there has been extensive research on mathematics teachers' collaboration and its role in advancing their professional learning (Darling-Hammond & Richardson, 2009; ...

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Preface

Section 1. Mathematics Teachers in Collaboration

Chapter 5: Nothing Like Planning and Reflecting Together to Build Trust
Wanty Widjaja, Colleen Vale, and Brian Doig

Section 2. Collaborations Among Diverse Participants

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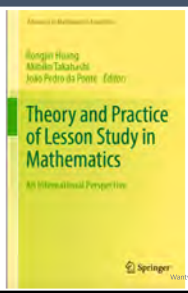
Invited book chapter arising from *'Implementing Structured Problem-solving in mathematics'* project



Theorizing Professional Learning through Lesson Study Using the Interconnected Model of Professional Growth

Wanty Widjaja, Colleen Vale, Susie Groves, and Brian Doig

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Using a conference paper as a starting point for a chapter or a journal article

To be submitted by 31 July 2019
http://icmistudy25.ie.ulisboa.pt/discussion-document/

ICMI Study 25
TEACHERS OF MATHEMATICS WORKING AND LEARNING IN COLLABORATIVE GROUPS
Theme C
Lisbon, Portugal, 3-7 February 2020

NEGOTIATING DUAL ROLES IN TEACHER COLLABORATION THROUGH LESSON STUDY: LEAD TEACHERS' PERSPECTIVE

Wanty Widjaja, Deakin University, Australia, w.widjaja@deakin.edu.au
Colleen Vale, Monash University, Australia, colleen.vale@monash.edu

Lead teachers play a vital role in supporting a successful teacher collaboration. Yet, relatively little is understood about the way in which leading teachers negotiate their roles and tensions or challenges they faced to support teacher collaboration. This paper seeks to examine the dual role of lead teachers as a numeracy coach or curriculum coordinator and a member of a planning team and explore the extent to which the diversity of the different teachers' experience and knowledge contribute to teacher collaboration in the context of Lesson Study. The analysis is based on interviews carried out after the first and the second Lesson Study research cycles.

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Recent publications arising from this research

Widjaja, W. & Vale, C. (by invitation, to be submitted by 31 July). Negoitiating dual roles ihn teacher collaboration through Lesson Study: Lead teachers' perspective. *ICMI Study 25. Teachers of Mathematics Working and Learning Together in Collaborative Groups. Theme C*, Lisbon, Portugal 3-7 Feb 2020.

Widjaja, W., Vale, C., Doig, B. (in press). Nothing like planning and reflecting together to build trust: studies on teams of practicing mathematics teachers and numeracy coaches' collaboration. To be published In G. Llyod (Ed). *The International Handbook of Mathematics Teacher Education. (2nd edition) Volume 3: Participants in mathematics teacher education.* Sense Publisher. Acceptance date: 15 June 2018.

Widjaja, W., Vale, C., Groves, S., Doig, B. (2019). Theorising Professional Learning through Lesson Study using the Interconnected Model of Professional Growth. In R. Huang, A. Takahashi, J. P. de Pedro. *Theory and practices of lesson study in mathematics: An International perspective'.* Singapore: Springer. (pp. 103-133) Online preview of the book https://www.springer.com/gp/book/9783030040307

Vale, C., **Widjaja, W.**, Doig, B., Groves, S. (2019). Anticipating students' reasoning and planning prompts in structured problem-solving lessons *Mathematics Education Research Journal.* 31(1), 1-25.

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Building Teachers' Capacity in Primary Mathematics School-Based Assessment

Ng, K. E. D., Chan, C. M. E., Widjaja, W.

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Modeling design principles

1. The task warranted sense-making and extension of prior knowledge (reality principle)
2. The situation created the need to develop (or refine, modify, or extend) a mathematically significant construct (model construction principle)
3. The situation required self-assessment (self-evaluation principle)
4. The situation required modellers to reveal their thinking about the situation (construct documentation principle)
5. the elicited model would be generalisable to other similar situations (construct generalisable principle)
6. The problem-solving situation would be simple to carry out (the simplicity principle)

(Lesh & Kelly, 2003)

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Multi-tiered teaching experiment

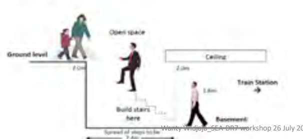
Tier 1 - **Researchers**	Development of conceptual framework (model) Researchers collaborate with teachers to test and review modeling task Reflect on their own evolving knowledge of the participants' learning	Video and audio transcript on teacher learning Written artifacts of teachers' solutions
Tier 2 - **Teachers**	Collaborate with researchers to test and review modeling task Review feedback for designing their own task Reflect on their evolving knowledge of students' learning	Video and audio transcript on teacher-reflection Written artifacts of teacher's solution
Tier 3 – **Students**	Engage in model-eliciting tasks in small groups Describe, represent, explain, justify and document their mathematical constructions	Video and audio transcript on student learning Written artifacts of students' solutions

Adapted and modified from Lesh &Kelly (2000, p. 198) in Chan, Ng, Widjaja, & Seto (2015, p. 8)

The design phase: Task design

In a shopping centre, there is a basement that will lead to a train station. However, a flight of stairs is to be constructed to link the basement to the ground floor. In this activity, you will refer to the diagram and help design a flight of stairs between the Ground level and the Basement.
Think about some considerations that you will take to ensure that a person of average height of 1.6 m can go up the stairs from the Basement to Ground level comfortably. There are two conditions to note:
(1) There needs to be a safe vertical height space of at least 15 cm between the ceiling and an adult when he is only on the first step (at the basement).
(2) Each step must be of the same height and each step-space must be of the same width.

Source: Chan, Ng, Widjaja, & Seto (2015, p. 31)



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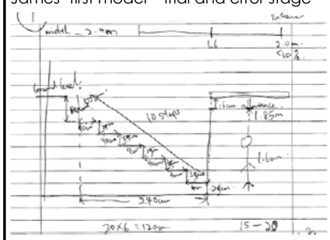
The teaching experiment

James' first model – trial and error stage



Assumptions:
- step-space to be 40 cm (based on his foot size) and step height to be 20 cm (out of convenience as an initial trial.
- extreme height of a person to be 1.85 m to allow for 15 cm gap to meet condition of not hitting the partial ceiling.

Source: Chan, Ng, Widjaja, & Seto (2015, p. 15)

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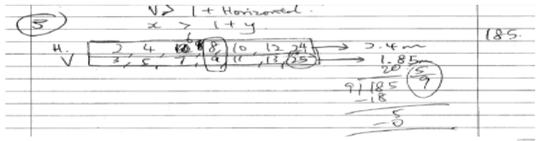
The teaching experiment

James' revision of the second model



- Made more realistic range in the dimensions of the step-space based on shoe-size. Measured his shoe size and found it to be 30.24 cm.
- Provided a more realistic range for the step height "I feel it has to be between 15 to 23 cm maximum I think to be comfortable", "20, I think still okay… 20 you lift up a foot is not too bad. If you elevate it further, it will be difficult".

Source: Chan, Ng, Widjaja, & Seto (2015, pp. 16, 18)

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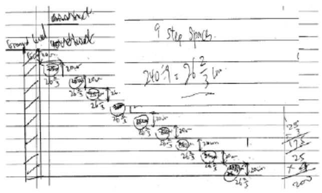
The teaching experiment

James' revision of the second model



"So I only need 9 steps, 9 steps spaces

"Because the vertical steps is always one more than the horizontal steps because the height is always more than. So vertical steps is always one plus the horizontal".

"Yah, 27.66666666,6. So 26 and 3 thirds"

Source: Chan, Ng, Widjaja, & Seto (2015, p. 18)

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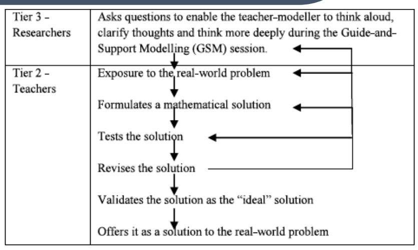
Interaction between teachers and researchers



Source: Chan, Ng, Widjaja, & Seto (2015, p. 24)

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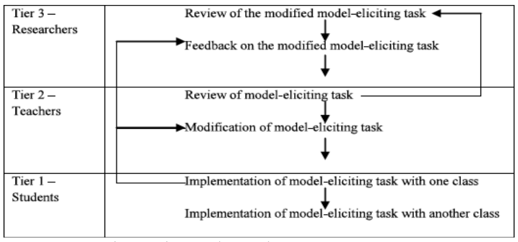
Express-test-revise cycle from a macro perspective of mathematical modelling



Source: Chan, Ng, Widjaja, & Seto (2015, p. 25)

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The Retrospective analysis:
Teachers' perception of mathematical modelling

James: I think it's like a real world situation in that sense. An authentic situation where actually the pupils need to come out with reasons and assumptions to actually solve that task. So it's a problem. And then the children need to actually use their prior knowledge to actually solve the problem. Yah and then explain the problem with of course the right reasoning adequately.

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The Retrospective analysis:
Researchers' reflection

- Evoke the guiding role of the teacher in designing and facilitating mathematical modelling with his students
- Aware of the level of explicitness of the guidance a facilitator
- Design questions to invoke mathematical inquiry for model development
- Extend and capture dynamic interactions between the researcher and the teacher between Tier 2-3 to be tested in Tier 1

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Chan, C. M. E., **Widjaja, W.**, & Ng, K. E. D. (2011, p. 129)

Data are collected as part of the research project by Ng, K. E. D., Chan, C. M. E., Widjaja, W. (2011). *Building Teachers' Capacity in Primary Mathematics School-Based Assessment.* Non-funded research. Singapore: National Institute of Education.

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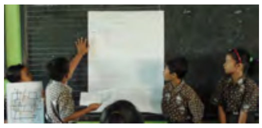

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Publications arising from this research

Chan, C. M. E., Ng, K. D., Widjaja, W., & Seto, C. (2015). A case study on developing a teacher's capacity in mathematical modelling. *The Mathematics Educator 16*(1), 1-31.

Ng, K. E. D., Widjaja, W., Chan, C. M. E., & Seto, C. (2015). Activating teacher critical moments through videos for facilitating student mathematisation processes during modelling tasks In S. F. Ng (Ed.), *Cases of mathematics professional development in East Asian countries, Mathematics Teacher Education.* (pp. 15-38). Singapore: Springer

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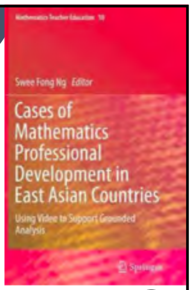

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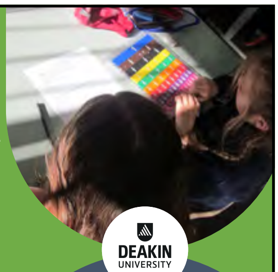
Assessing reasoning

Funded by Australian Academy of Science through reSolve Mathematics by Inquiry ($122K)

Mathematical Reasoning Research Group (MaRRG)
Assoc. Prof. Colleen Vale
Dr. Sandra Herbert
Dr. Leicha Bragg
Dr. Esther Loong
Dr. Wanty Widjaja



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Background

re(Solve)

- Teachers' capacity to notice and use students' reasoning
- A suite of reasoning assessment materials

Aim

- Greater insights into their students' reasoning and its relationship to mathematical learning

The materials will be used by teachers as part of their everyday planning, teaching and assessment practices

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Painted cube lesson

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Introducing the task to students

Allow time for students to explore and notice the pattern using concrete materials
Establish the expectation to communicate and justify their reasoning to one another

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Generalising and Conjecturing Prompt Cards

What is the pattern here?	**Is that … (pattern) always going to work?**
What happens in general?	**What is the rule?**
Are there other examples that fit the rule?	**How can you explain the rule to someone else?**

Produced by Mathematical Reasoning Research Group, Deakin University (2017) for ReSolve, AAMT

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Reasoning Level	Anticipated Student Reasoning – what the student might say.	Reasoning Rubric Action Analysing (A) Forming Conjectures and Generalising (FCG) Justifying and Logical argument (JL)	Additional notes	Sample teacher prompts to support and/or extend student thinking.
Not evident	They will always be painted because they are dipped in paint.	• Attends to non-mathematical aspects of the examples or cases. (A) • Does not communicate a common property or rule for pattern. (FCG)		Offer MAB and/or Multi-link cubes
Beginning	For 1 by 1 by 1 cube there is 1 cube altogether. For 2 by 2 by 2 cube, there are 8 cubes altogether. For 3 by 3 by 3, there are 27 cubes altogether. For 4 by 4 by 4, there are 64 cubes altogether.	• Notices similarities across examples (A) • Recalls random known facts related to the examples. (A)	Describing what they see	*Where are the cubes with no faces painted?*
Beginning	*A 1x1x1 cube will have all 6 sides painted because you dip the whole cube in the paint*	• Describing what they did and why it may or may not be correct.(JL) • Recognises what is correct or incorrect using materials, objects, or words. (JL)	Describing not analysing – what the student can 'see'	*Where are the cubes with 1 2 3 faces painted?*

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Developing	To find the total number of small cubes is n x n x n. For example, in a 3 side cube, you just times 3 by 3 by 3 to get the total number of cubes.	• Communicates a rule about a ***property*** using words, diagrams or number sentences. (FCG) • Checks the truth of statements using materials and informal methods. (JL) • Uses known facts to verify that the statement, common property, or rule for a pattern holds for each case. (JL)	• Identifying a 'rule' for calculating volume.	
Consolidating	***1-side painted:*** Inside a 5x5x5 is actually a 3x3x3 cube, so you only count those cubes (3+3+3+3) which will be painted on 1-side. So if it's a 6x6x6 cube, you have to take away 2, which will make it a 4x4x4 on the inside, therefore only 16	• Repeats and extends patterns using both the numerical and spatial structure. (A) • Notices more than one common property. (A)		

DRAFT produced by Mathematical Reasoning Research Group, Deakin University (2017) for ReSolve, AAMT

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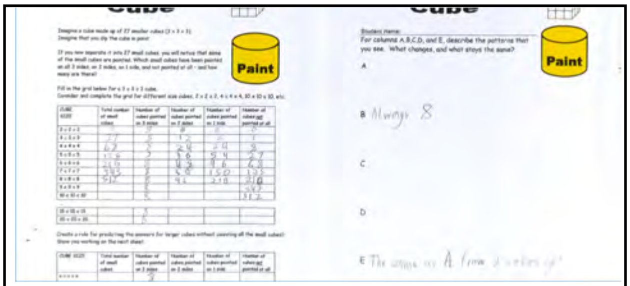

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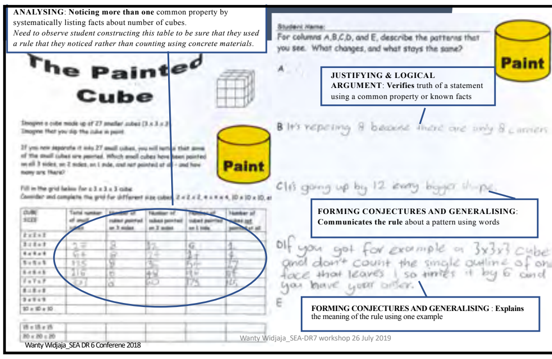

ANALYSING: Consolidating
FORMING CONJECTURES & GENERALISING Developing
JUSTIFYING & LOGICAL ARGUMENT: Developing
Teacher Prompt
Can you write a rule to find the number of cubes painted on two sides for any size cube? Can you describe the pattern for the number of cubes with one pained side?

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Communicating reasoning

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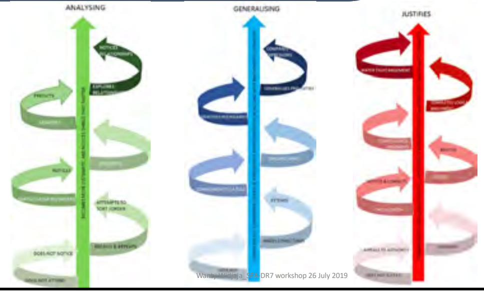
Reasoning Trajectories



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	Analysing	Forming Conjectures and Generalising	Justifying and Logical argument
Not evident	• **Does not notice** numerical or spatial structure of examples or cases. • Attends to **non-mathematical** aspects of the examples or cases.	• **Does not communicate** a common property or rule for pattern. • **Non-systematic** recording of cases or pattern. • **Random** facts about cases, relationships or patterns.	• **Does not justify**. • **Appeals** to teacher or others.
Beginning	• **Notices** similarities across examples • **Recalls** random known facts related to the examples. • Recalls and **repeats patterns** displayed visually or through use of materials. • Attempts to **sort** cases based on a common property.	• Uses body language, drawing, counting and oral language to **draw attention** to and **communicate**: ○ a single common property ○ repeated components in patterns. • **Adds** to patterns displayed verbally and/or visually using diagrams or through use of materials.	• **Describes** what they did and why it may or may not be correct. • **Recognises** what is correct or incorrect using materials, objects, or words. • Makes **judgements** based on simple criteria such as known facts. • The **argument may not be coherent** or include all steps in the reasoning process.
Developing	• **Notices** a common numerical or spatial property. • **Recalls, repeats and extends** patterns using numerical structure or spatial structure. • **Sorts and classifies** cases according to a common property. • **Orders** cases to show what is the same or stays the same and what is different or changes. • **Describes** the case or pattern by labelling the category or sequence.	• **Communicates** a rule about a: ○ *property* using words, diagrams or number sentences. ○ *pattern* using words, diagrams to show recursion or number sentences to communicate the pattern as repeated addition. • **Explains** the meaning of the rule using one example.	• **Verifies** truth of statements by using a common property, rule or known facts that confirms each case. May also use materials and informal methods. • **Refutes** a claim by using a counter example. • Starting statements in a **logical argument** are correct and accepted by the classroom. • **Detecting and correcting errors** and inconsistencies using materials, diagrams and informal written methods.

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Consolidating	• **Notices more than one** common property by systematically generating further cases and/or listing and considering a range of known facts or properties. • **Repeats and extends patterns** using both the numerical and spatial structure. • Makes a **prediction** about other cases: • with the same property • included in the pattern.	• **Identifies** the boundary or limits for the rule (generalisation) about a common property. • **Explains** the rule for finding one term in the pattern using a number sentence • **Extends** the number of cases or pattern using another example to explain how the rule works.	• Uses a correct **logical argument** that has a complete chain of reasoning to it and uses words such as 'because', 'if...then...', 'therefore', 'and so', 'that leads to' ... • **Extends the generalisation** using logical argument.
Extending	• **Notices and explores** relationships between: ○ common properties ○ numerical structures of patterns. • **Generates examples**: ○ using tools, technology and modelling ○ to form a conjecture.	• **Communicates** the rule for any case using words or symbols, including algebraic symbols. • **Applies** the rule to find further examples or cases. • **Generalises** properties by forming a statement about the relationship between common properties. • **Compares** different symbolic expressions used to define the same pattern.	• Uses a **watertight logical argument** that is mathematically sound and leaves nothing unexplained. • **Verifies** that the statement is true or the generalisation holds for *all* cases using logical argument.

Evidence of student's reasoning

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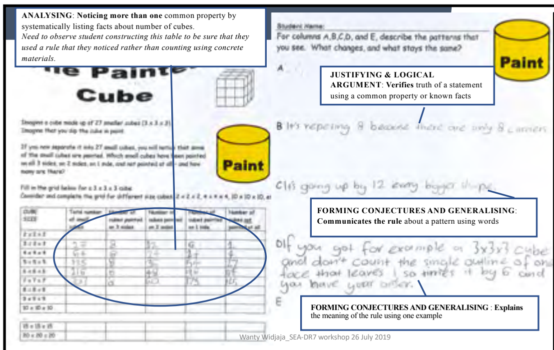

ANALYSING: **Noticing more than one** common property by systematically listing facts about number of cubes.
Need to observe student constructing this table to be sure that they used a rule that they noticed rather than counting using concrete materials.

JUSTIFYING & LOGICAL ARGUMENT: **Verifies** truth of a statement using a common property or known facts

FORMING CONJECTURES AND GENERALISING: **Communicates the rule** about a pattern using words

FORMING CONJECTURES AND GENERALISING : **Explains** the meaning of the rule using one example

ANALYSING: Consolidating

FORMING CONJECTURES & GENERALISING Developing

JUSTIFYING & LOGICAL ARGUMENT: Developing

Teacher Prompt

Can you write a rule to find the number of cubes painted on two sides for any size cube? Can you describe the pattern for the number of cubes with one pained side?

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Challenges and issues

- The absence of discussion of epistemological issues (Walker, 2011)
- How do we know that the effects observed are casually related to the design? How do we know they are not related to any of the other elements of the context, or what the specific combination of design and context was?

.... *only when we know what makes a design work can we make suggestions regarding its applicability in other instructional settings*. (Reimann, 2011, p. 43)

- *Data deluge*: complexities of planning and documenting the multi-cyclical process of design and theory revision. (Reimann, 2011, p. 47)

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Final remark

Educational innovations should not be a net addition to what teachers do. For teachers *innovations* have sometimes become synonymous with centre-led, top-down *initiatives*, which have indeed often been an addition to what teachers do rather than a replacement and this explains in part why some of them have been resisted and treated as a burden.

(Hargreaves, 2004, p. 66)

THANK YOU

Acknowledgement
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