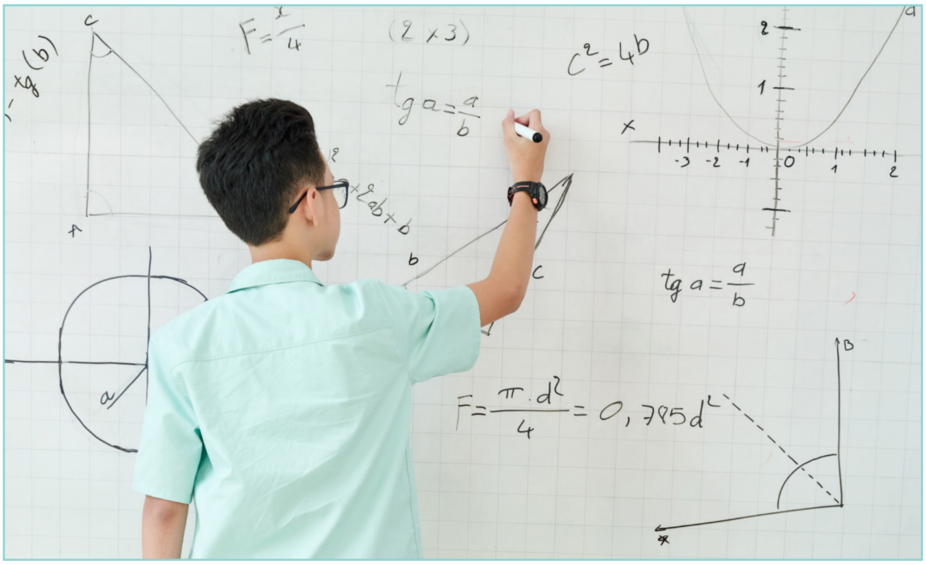
Fulfilling Inquiry-Based Learning in Singapore Mathematics Classrooms

By *Lee Ngan Hoe*

Lee Ngan Hoe is Associate Professor with the Mathematics & Mathematics Education Academic Group at the National Institute of Education, Singapore. His research interests include the teaching and learning of mathematics at all levels.



Introduction

To prepare students to be future-ready, Singapore mathematics educators have been encouraged to consider inquiry-based learning (IBL) as an instructional strategy in their practice (Ministry of Education, 2020a) and include it as a key area of practice in their professional development roadmap (Ministry of Education, 2020b). Identified as a practice that can nurture students' voices in learning while getting them to ask meaningful questions and use evidence to address complex problems (Ministry of Education, 2020b), IBL has the potential to create deeper understanding of concepts in the problem-solving tradition in mathematics.

In search for tractable and effective pedagogical learning designs that could fulfil IBL in the mathematics classrooms, a Curriculum Specialist from the Curriculum Planning and Development Division (CPDD) and a few Master Teachers from the Academy of Singapore Teachers (AST) have partnered with the National Institute of Education (NIE) in developing and validating suitable learning designs for mathematics teachers to leverage.

The Constructive Learning Design's Potential in Supporting IBL in Mathematics

In IBL, teachers are required to shift their practices to be more student-centred, make constructive use of students' prior knowledge structures, use probing questions to challenge students, encourage discussions of alternative viewpoints, and allow for students to make connections between their ideas and mathematics concepts (Cheng et al., 2021). These practices harmonise with constructivist principles of learning, which propose that new knowledge is constructed based on current knowledge structures, and hence it is important for teachers to build upon these and facilitate students to see the viability of the new knowledge via social negotiation. Current direct instructional (DI) approaches, where the exposition of mathematical concepts is structured by the teacher, may not be adequate in supporting the aspirations of IBL.

Recognising that fulfilling IBL may be challenging for teachers, a learning design was developed to afford the engagement of inquiry processes when learning new mathematical ideas and concepts. Coined the "Constructivist Learning Design" (CLD), this two-phased learning design comprises a (i) problem solving phase where students first work collaboratively to solve a complex problem targeting a math concept that they have yet to learn, before (ii) being engaged in instruction that builds upon their solutions in the teaching of the concept, and practices that reinforce these ideas (see Figure 1 below for more details).

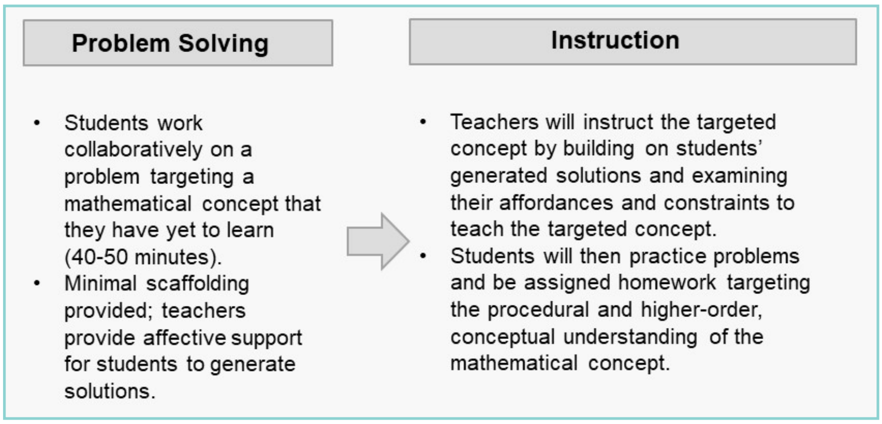
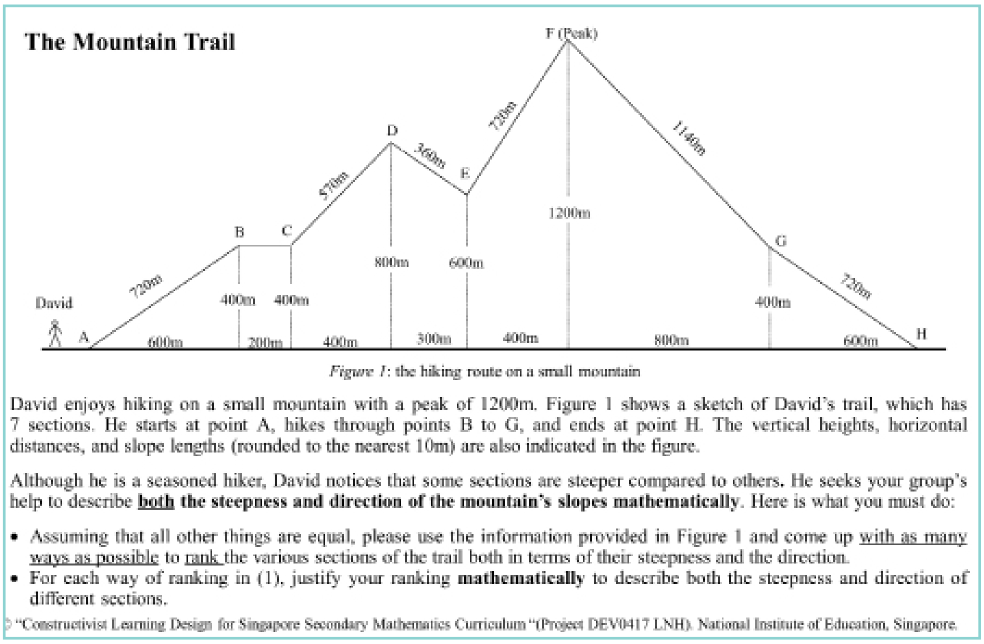


Figure 1. The Constructivist Learning Design.



The Mountain Trail

Figure 1: the hiking route on a small mountain

David enjoys hiking on a small mountain with a peak of 1200m. Figure 1 shows a sketch of David's trail, which has 7 sections. He starts at point A, hikes through points B to G, and ends at point H. The vertical heights, horizontal distances, and slope lengths (rounded to the nearest 10m) are also indicated in the figure.

Although he is a seasoned hiker, David notices that some sections are steeper compared to others. He seeks your group's help to describe **both the steepness and direction of the mountain's slopes mathematically**. Here is what you must do:

- Assuming that all other things are equal, please use the information provided in Figure 1 and come up with as many ways as possible to rank the various sections of the trail both in terms of their steepness and the direction.
- For each way of ranking in (1), justify your ranking **mathematically** to describe both the steepness and direction of different sections.

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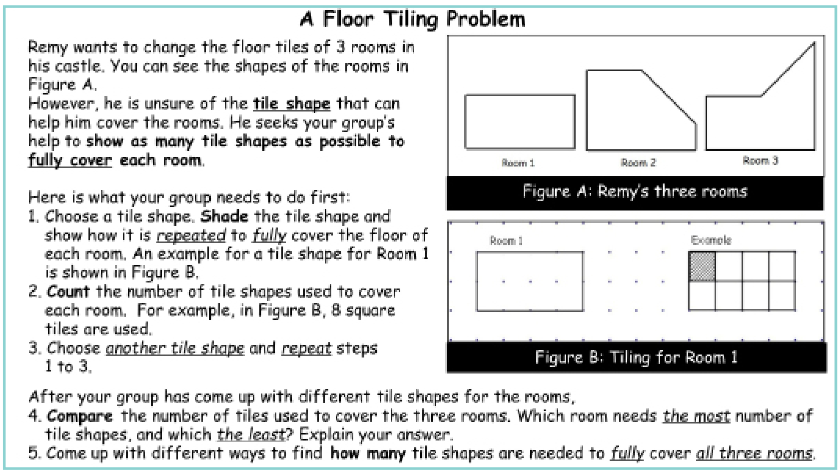
Figure 2. An example of CLD problem for secondary level.

We subject the CLD in the design of a mathematical unit on "gradient of linear graphs", a concept that is taught at Secondary 1 level (see Figure 2 above for the example problem). Although most students did not know how to solve the problem in the problem-solving phase, they were able to produce solutions that teachers could build upon to teach the targeted gradient concept in the teacher-led instruction phase. Comparing the implementation of the unit in a mainstream school in a CLD class to its DI counterpart, where students were instructed the concept prior to problem solving, results indicate that the CLD class surpassed the DI class in terms of their performance on post-test items testing for students' procedural fluency, conceptual understanding, and transfer related to the concept of gradient.

Insights from CLD for Better Practice

The positive indications from the validation of the CLD unit in a mainstream school suggests that it can be effective and tractable in engendering the deeper learning of concepts, and may have the potential to support IBL. This has also paved the way for the development of more curricular units that cover the major strands in the secondary mathematical syllabus (see Ng et. al., 2020 for examples) and a unit at primary level (see Figure 3 below). The AST, with inputs from NIE, has also employed the CLD to develop a framework—"The Mathematics Framework for Inquiry based learning in Mathematics"—as a guide to the process of inquiry in Singapore Mathematics classrooms (see Figure 4 on the following page). Findings from a CLD research project have also shed light on other important mechanisms regarding productive learning, such as cognitive load, in planning better direct instruction lessons.

Taken together, the CLD demonstrates that IBL is possible in the mathematics



A Floor Tiling Problem

Remy wants to change the floor tiles of 3 rooms in his castle. You can see the shapes of the rooms in Figure A.
However, he is unsure of the **tile shape** that can help him cover the rooms. He seeks your group's help to **show as many tile shapes as possible to fully cover each room.**

Here is what your group needs to do first:
1. Choose a tile shape. **Shade** the tile shape and show how it is *repeated* to *fully* cover the floor of each room. An example for a tile shape for Room 1 is shown in Figure B.
2. **Count** the number of tile shapes used to cover each room. For example, in Figure B, 8 square tiles are used.
3. Choose *another tile shape* and *repeat* steps 1 to 3.

After your group has come up with different tile shapes for the rooms,
4. **Compare** the number of tiles used to cover the three rooms. Which room needs *the most* number of tile shapes, and which *the least*? Explain your answer.
5. Come up with different ways to find **how many** tile shapes are needed to *fully* cover *all three rooms*.

Figure 3. An example CLD problem for primary level.

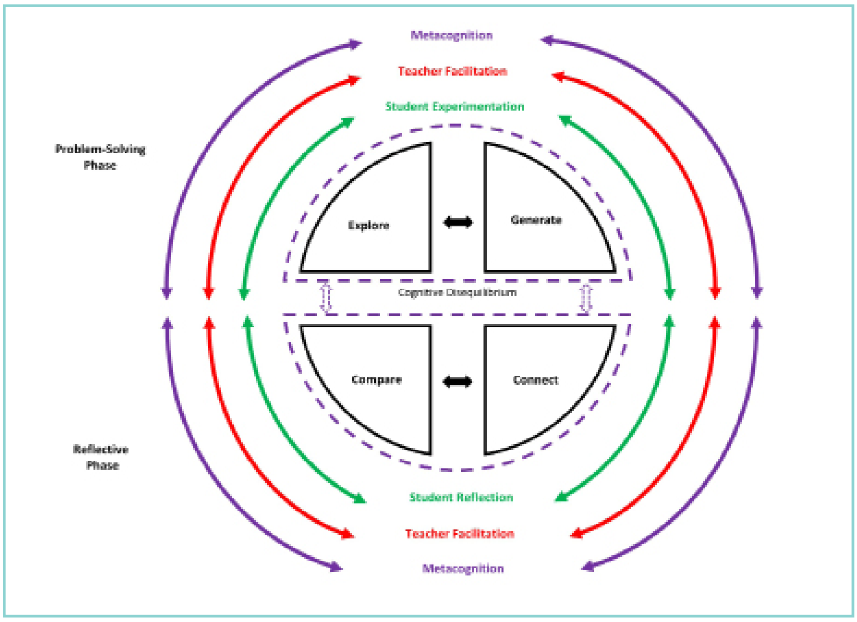


Figure 4. The "Mathematics Framework for Inquiry based learning in Mathematics" developed by AST.

classroom when the ***processes*** of problem solving to afford meaningful learning and the development of mathematical habits and dispositions in students are emphasised. The partnership between AST and NIE also illustrates a concerted effort for change from research and practice that could slowly help to sustain pedagogical approaches that have potential for deep learning.

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