Using design research to promote interdisciplinary secondary mathematics and science teaching

A cross-national study in Australia and Indonesia

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Acknowledgement: REDI Development Research Grant, Deakin University (2017-2018; $19,819) – Wanty Widjaja, Peter Hubber, George Aranda, Esther Loong with Tarsisius Sarkim, Hongki Julie, Albertus Panuluw Hariwangsa

RATIONALE

• Recent initiatives call for a greater emphasis on STEM integration in education
• Both Australia and Indonesia share a common concern to improve science and mathematics teaching quality using inquiry approach
• Increasing teacher capacity and STEM teaching quality are critical
• Enhancing secondary students’ scientific and mathematical literacy

100 Jobs of the Future
Russell Tytler et al


Gaps identified in the literature
• Inconclusive as to what effective STEM integration entails
• Different interpretations of STEM integration
• Different nature and scope of such integration
• Lack of balanced and transparent content representations in STEM

Barriers to STEM interdisciplinary
• Different pedagogical traditions in science and mathematics
• The pervading system of disciplinary silos in the school curriculum that is reflected in the teaching timetables

THEORETICAL FRAMEWORK
• Problem solving and modelling of mathematics enacted in the real world
• Multi-modal representational tools of science and mathematics to generate, coordinate and critique evidence
• Representation construction approach
THIS PROJECT

Commonalities and differences in practice that relate to different cultural-historical traditions of these countries will be explored in addition to building stronger international collaboration.

It uses:
- real-world tasks
- multiple theoretical frameworks
- multi-tiered design research
- contemporary video-capture

DESIGN RESEARCH

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


DESIGN-BASED RESEARCH

A research design to enable educators to solve problems while also creating design principles that may guide and inform future practice in that area.

(Kervin, Vialle, Herrington, & Okely, 2006, p. 72)

DESIGN-BASED APPROACHES TO RESEARCH

Analysis of practical problems by researchers and practitioners in collaboration

Development of solutions informed by existing design principles and technological innovations

Iterative cycles of testing and refinement of solutions in practice

Reflection to produce ‘design principles’ and enhance solution implementation

Reeves (2000)

A continuum of STEM approaches to curriculum integration (Vasquez, Snider, & Conner, 2013, p. 73)

In groups of 2 or 3. How much does a dripping tap cost per year?
Design considerations:
How to get students to collect data to answer the research problem?
How will the students analyze their data and report on their learning?
How does the STEM challenge address the curriculum goals in both science and mathematics?
How do we assess their learning?

TEACHERS’ EXPERIENCES & VIEWS

‘To find those touch points whether the curriculum intersects so you can say, this is going to be a meaningful point to do it. And but I think particularly the junior years, I, I think we’ve structured junior school so much to build up to VCE expectations where they’re going into the individual subject areas.’

‘If you look at the cost of that dripping tap or and, and just go into their, their water bill and seeing how little 200mls of water costs, how do you justify buying a 500ml bottle of Mount Franklin for $3.00? …So, so that consumed quite a lot of the discussion’

THE STEM TASK

• Designed by the teachers in collaboration with the researchers
• Interdisciplinary in nature
• Authentic real world context: the context of roller coasters or skateboard parks
• The science topic: Energy The mathematics topic: Percentages

2018 Data collection
One secondary school
2 teachers
1 Year 8 class

Exploring different types of energy
Energy skate park investigation
(Taken from http://phet.colorado.edu/en/simulation/energy-skate-park-basics).

The simulation shows energy changes of a skater in a skate park. It uses a graph representation (columns and bar graphs). The simulation allows the friction to be changed as well as the shape of the track.

Learning Objectives:
• Explain the relationship between total energy and kinetic, potential, and thermal energy.
• Explain how changing track friction affects kinetic, potential, and thermal energy.
• Design a skate park using the concepts of mechanical energy and energy conservation.

The investigation has three parts:
1. Energy skate park pre-lab.
2. Energy skate park.
3. Energy skate park post-lab.

Key assessment criteria

Students’ ability to:
• Demonstrate procedural fluency (e.g., being able to calculate a percentage increase given starting and ending points).
• Identify, describe, and apply scientific concepts related to energy (e.g., being able to identify and describe the differences between kinetic and potential energy).
• Demonstrate skills associated with undertaking an open inquiry (e.g., being able to develop questions about energy to be investigated).
• Demonstrate the 21st century skills (e.g., creativity, critical thinking, collaboration, and communication).
TEACHERS’ AND STUDENTS’ VIEWS AND EXPERIENCES

To what extent does the use of real-world problems support student engagement in interdisciplinary learning of science and mathematics?

Marble run presentations
Potential of the real-world problems

It was a familiar enough idea that they weren’t going to get lost on the context, but it had enough complication and unfamiliarity with what was happening when a marble actually goes down whatever they decided to make it go down. (Mathematics teacher, MPI)

Some of the practical work that we did in terms of tennis balls and bouncing of balls… just to get the idea of kinetic gravitational potential… and then what that energy is turning into when it hits the ground… I think that went really well. (Science teacher, MPI)

Awareness of Science, Mathematics, and Technology/Engineering Embedded in the STEM Project

Our marble run sat on an angle and started at 80% and the marble went over a couple of bumps and reached higher than the start, reaching around 100%. Our marble was able to gain enough kinetic energy and friction to roll throughout the whole marble run and land straight in the cup. (SGR)

When the marble didn’t and did work, we had to find ways to fix or improve the marble run, we had to change our designs to better improve our success rate. (SGR)

Views on STEM Integration

They’ve got a subject now, design technology… and it’d almost be good to look at what other subjects are doing from that point of view with this in mind to see if there is some common language there so that we can share with each other and utilize in those sorts of processes even more widely than science and maths as part of the STEM. (Mathematics teacher, MPI)

If we were going to take that sort of stuff seriously with the critical thinking and all the rest of it, we probably do need a common set of tools that are regularly used so the students get familiar with them and start using them automatically themselves. (Science teacher, MPI)
THANK YOU

Acknowledgement: We thank the teachers and the students from for their work and contribution in this project.