

Using design-research to promote interdisciplinary secondary mathematics and science teaching

A cross-national study in Australia and Indonesia

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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




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100 Jobs of the Future

Russell Tytler et al

https://auhtv.com/watch/could-you-be-a-space-tourism-operator-or-a-cyborg-psychologist-nine-news-australia_gG2zGnQCSND9wOx.html



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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



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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



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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




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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




www.wipps.deakin.edu.au/learning/21July/2019

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.

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



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DESIGN-BASED RESEARCH

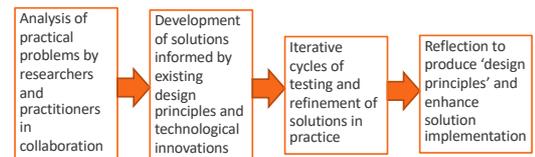
A research design to enable educators to solve problems while also creating design principles that may guide and inform future practice in that area.

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



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DESIGN-BASED APPROACHES TO RESEARCH



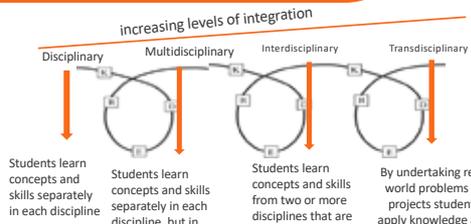
Reeves (2000)



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

increasing levels of integration



Disciplinary
Students learn concepts and skills separately in each discipline

Multidisciplinary
Students learn concepts and skills separately in each discipline, but in reference with a common theme

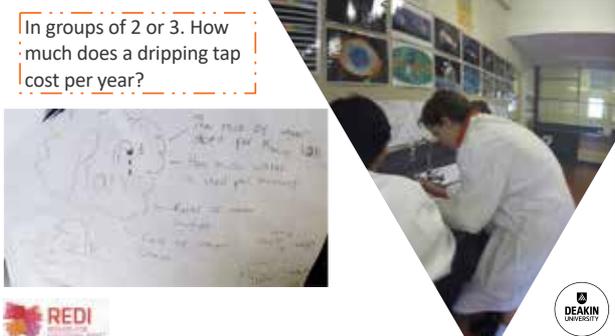
Interdisciplinary
Students learn concepts and skills from two or more disciplines that are tightly linked so as to deepen knowledge and skills

Transdisciplinary
By undertaking real-world problems or projects students apply knowledge and skills from two or more disciplines




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In groups of 2 or 3. How much does a dripping tap cost per year?





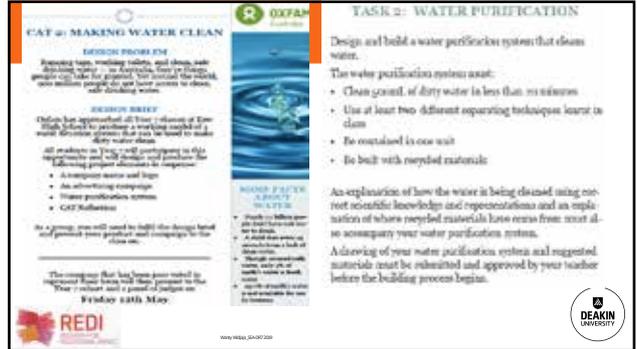
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Design considerations:
 How to get students to collect data to answer the research problem?
 How will they analyse their data and report on their learning?
 How does the STEM challenge address the curriculum goals in both science and mathematics?
 How do we assess their learning?

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TASK 2: WATER PURIFICATION
 Design and build a water purification system that cleans water.
 The water purification system must:
 • Clean ground or dirty water to less than 200 microns
 • Use at least two different separating techniques learnt to clean
 • Be contained in one unit
 • Be built with recycled materials

An explanation of how the water is being cleaned using correct scientific knowledge and expectations and an explanation of where recycled materials have come from must also accompany your water purification system.
 A drawing of your water purification system and suggested materials must be submitted and approved by your teacher before the building process begins.

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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'

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2018 Data collection

One secondary school
 2 teachers
 1 Year 8 class

	Science as a Human Endeavour	Science Inquiry Skills
Nature and Development	<ul style="list-style-type: none"> Have scientific evidence and knowledge developed through a range of practices and cultural contexts People's understanding of the world 	<ul style="list-style-type: none"> The Scientific Method Identify problems and can solve problems based on scientific knowledge Think as a team to collect data in and analyse the data in a systematic manner Range of ways to share conclusions and identify relationships based on evidence Available data using evidence to identify improvements Use scientific language to present change using evidence based representations
Use and Understanding	<ul style="list-style-type: none"> Social views and ethical considerations impact solutions to current issues Development of science in the technological revolution Development of practices in human activity 	
Risk and Space	<ul style="list-style-type: none"> How new ideas impact on society Physical Examine energy types including kinetic, heat and potential and the effects their transformations can cause 	

Achievement Standards: By the end of Year 8, students -
 Compares physical and chemical change using the particle model to explain substance behaviors. Students examine scientific knowledge used in occupations, and consider the implications this has on different groups in society. Identify forms of energy and how transformations can change in simple systems as well as the variables which can change, be measured and controlled to improve the quality of data. Analyse how cells function in the body's systems relative to their structure. Study processes

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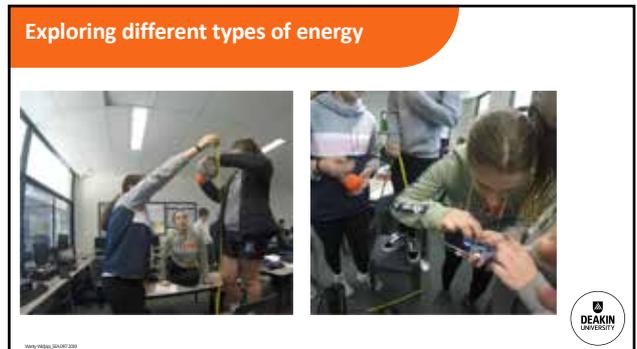
THE STEM TASK

- 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

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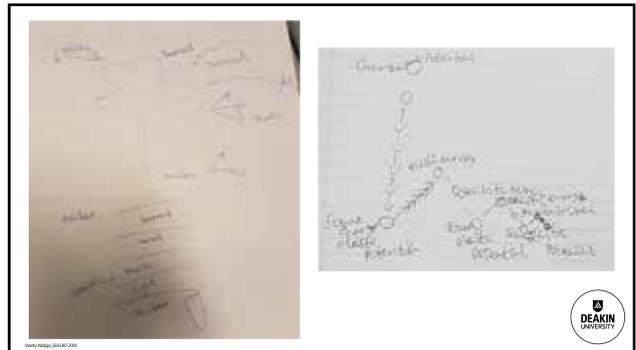
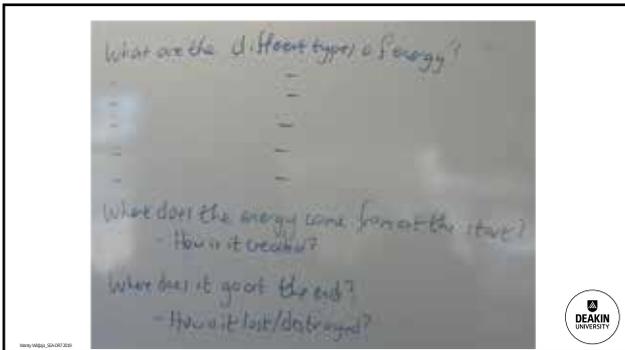
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Exploring different types of energy



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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 graphs 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.



You told me something about the energy transformation [pause] I am kind of interested in the degree of energy transformation though. It's great you have identified some of the things ... What about the design has to be 105% higher than the previous hump, does that design fulfil that do you think?

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).

Shows the basic ideas but needs to show deeper understanding	Has the basic understanding but needs more detail	Mastery – shows understanding
<p>Task</p> <ul style="list-style-type: none"> • Convert a fraction to a percentage • Convert a decimal to a percentage • Convert a percentage to a decimal 	<p>• The percentages were found in the design of the project</p> <p>• Calculations were done accurately, including an increase or decrease of an amount</p>	<p>• Conversion to and from percentages were used to compare related data in the project to relation to include representations of the data about energy</p> <p>• Single conversion of the data about energy design features of the project</p>
<p>Task</p> <ul style="list-style-type: none"> • Calculate an increase and decrease of an amount, given a percentage of an amount • Calculate a percentage increase and given a starting and final amount 	<p>• The increase or decrease of amounts using percentages about the changes and absolute values given in the design of the project</p> <p>• Calculations were done calculating percentages to and from the design elements of the project</p>	<p>• Relative changes in amounts were accurately calculated using percentages to show</p> <p>• Representations of the data about energy design elements of the project</p>

Maths concepts:
 - Percentages
 - Conversions

<p>Topic: Identify and describe the difference between kinetic and potential energy.</p> <p>Learning objectives: Explain knowledge of kinetic and potential energy and present to a group.</p>	<p>The description of the relationship between kinetic and potential energy is presented as follows:</p>	<p>The representation of the relationship between kinetic and potential energy is presented as follows:</p>	<p>The representation of the relationship between kinetic and potential energy is presented as follows:</p>	<p>The representation of the relationship between kinetic and potential energy is presented as follows:</p>
<p>Topic: Explain the relationship between kinetic and potential energy.</p>	<p>Relationship questions have been identified.</p>	<p>Students are able to construct a representation of data.</p>	<p>Students are able to construct a representation of data.</p>	<p>Students are able to construct a representation of data.</p>

Science concepts:

- Potential energy
- Kinetic Energy
- Representations
- Changes in energy

Science skills:

- Hypothesising
- Analyse patterns in data

<p>Topic: Explain the relationship between kinetic and potential energy.</p>	<p>Students are able to construct a representation of data.</p>	<p>Students are able to construct a representation of data.</p>	<p>Students are able to construct a representation of data.</p>	<p>Students are able to construct a representation of data.</p>
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Science skills:

- Analysing data
- Evaluating
- Explaining

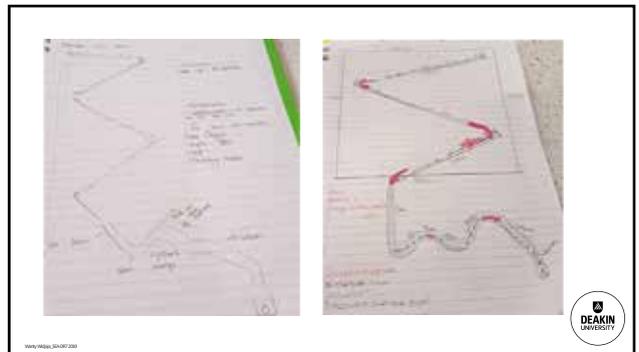
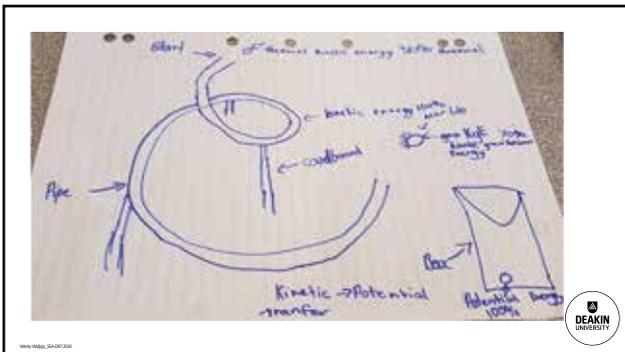
STEM skills:

- Demonstrate motivation, persistence
- Evaluate outcomes of group work
- Use strategies to evaluate and redirect thinking

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

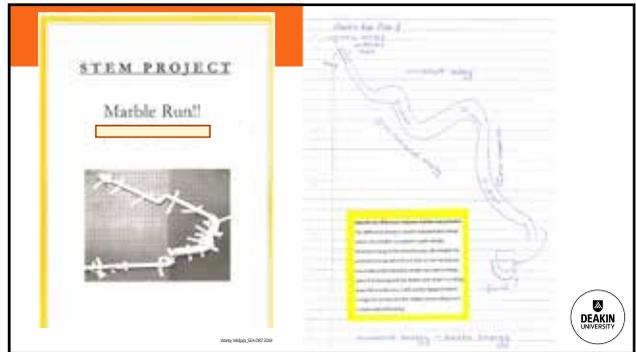


Potential of the real-world problems

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, MP)

Widjaja, W., Hubber, P., & Aranda, G. (in press). Potential and Challenges in Integrating Science and Mathematics in the Classroom through Real-world Problems: A case of implementing an interdisciplinary approach to STEM. In Y-S Hsu (Ed). *Asia-Pacific STEM Teaching Practices: from theoretical frameworks to practices.*

The image shows a poster titled "STEM PROJECT Marble Run!" with a photograph of a marble run structure. To the right is a student's handwritten work on lined paper, featuring a diagram of a marble run track and a yellow-highlighted text box. The Deakin University logo is in the bottom right corner.

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)

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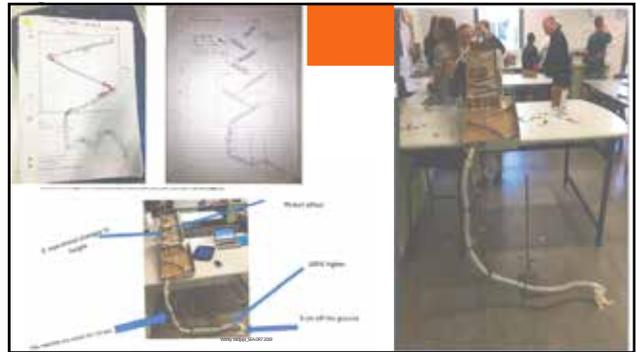



Views on STEM Integration

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)

Widjaja, W., Hubber, P., & Aranda, G. (in press). Potential and Challenges in Integrating Science and Mathematics in the Classroom through Real-world Problems: A case of implementing an interdisciplinary approach to STEM. In Y-S Hsu (Ed). *Asia-Pacific STEM Teaching Practices: from theoretical frameworks to practices.*

THANK YOU

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

